ONLINE ISSN 2255-923X
ISSN 1691-4031

Volume 37

Latvia University of Life Sciences and Technologies

Annual 28th International Scientific Conference
Research for Rural Development 2022

Latvia University of Life Sciences and Technologies

RESEARCH FOR RURAL DEVELOPMENT 2022

Annual 28th International Scientific Conference Proceedings

Volume 37

Jelgava 2022

LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

ONLINE ISSN 2255-923X
ISSN 1691-4031

RESEARCH FOR RURAL DEVELOPMENT 2022
http://www2.llu.lv/research_conf/proceedings.htm

May, 2022

The ethic statements of the conference 'Research for Rural Development 2022' are based on COPE's Best Practice Guidelines: http://www2.llu.lv/research_conf/proceedings.htm

DOI and similarity check: Crossref

Approved and indexed: The Proceedings of previous Annual International Scientific Conferences 'Research for Rural Development' published by Latvia University of Life Sciences and Technologies since 1994 and has been approved and indexed in to databases: AGRIS; CAB ABSTRACTS; CABI full text; EBSCO Academic Search Complete; Scopus; Web of Science ™, Clarivate Analytics /former Thomson Reuters; Primo Central (Exlibris)...

Editorial office: Latvia University of Life Sciences and Technologies, Lielā ielā 2, Jelgava, LV-3001, Latvia
Phone: + 371 630 05685; e-mail: natalija.sergejeva@lbtu.lv

LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

ONLINE ISSN 2255-923X
ISSN 1691-4031

RESEARCH FOR RURAL DEVELOPMENT 2022
http://www2.llu.lv/research_conf/proceedings.htm

Volume 37, 2022

FOREWORD

The International Scientific Conference „Research for Rural Development" is organized annually by Latvia University of Life Sciences and Technologies, this year, for the 28th time. Scientists from several countries of the world gather during the conference. During the conference 40 studies were presented via online presentations and 17 posters were posted on the conference website.

In these Proceedings 48 scientific articles have been selected after careful review. The authors of the articles are from 5 countries - Latvia, Lithuania, Estonia, Poland and Ukraine. The interdisciplinary papers contribute the latest scientific knowledge in crop production, animal breeding, forestry, wood processing, food sciences, agrarian and regional economics, veterinary medicine, water management, rural and environmental engineering, information and communication technologies, education.

We believe that these Proceedings will be an excellent reference volume for researchers worldwide and it will stimulate further research in all the areas mentioned above.

We would like to thank all authors and reviewers for their contribution in international scientific level.

Many thanks to the chairpersons of all conference sections G. Vitols, I. Grinfelde, M. Dobele, L. Ozola, T. Kondratovics, S. Eglite and S. Balina for organization and management of effective work of the sections.

We hope to see you at the Latvia University of Life Sciences and Technologies next year during the 29th International Scientific Conference "Research for Rural Development 2023".

.

Natalija Sergejeva
Chairperson
Annual 28th International Scientific Conference
"Research for Rural Development 2022"

CONTENTS

 DOI: 10.22616/rrd.28.2022.001

THE INFLUENCE OF CHANGING CONDITIONS FOR KEEPING AND COWS' MILKING ON THEIR BEHAVIOR, PRODUCTIVITY AND CONDITION

***Oleksandr O. Borshch[1,2], Oleksandr V. Borshch[1]**
[1]Bila Tserkva National Agrarian University, Ukraine
[2]National University of Life and Environmental Science of Ukraine, Ukraine
*Corresponding author's email: borshcha@outlook.com

Abstract
The aim of this work was to study the behavior, productivity and conditions of second lactation *Bos taurus* during the period of adaptation to new keeping and milking conditions. Thirty-four cows of the local black-and-white breed of the second lactation (24–47 days after calving) were transferred from a brick barn for 100 heads with tie-stall keeping in a newly low cost housing facility for 400 heads with free-stall keeping. Milking equipment also changed: before the changing conditions of keeping, cows were milked in the milk duct at UDM-100, and after changing the conditions in the milking parlor at Carousel, 32 cows were milked at the same time. We divided the first 30 days in the new conditions of keeping and milking into VI periods. The duration of the main behavioral reactions: lying down, drinking, and eating food in the first days after changing the conditions of keeping and milking decreased significantly – by 181; 13 and 89 min, respectively. Behavioral responses at the end of the adaptation period (30 days) was lower than on the last day before changing housing and milking conditions. During the first 5 days after the change of housing and milking conditions, the average productivity of cows decreased by 1.39 kg (or 6.01%), content of milk fat, protein and lactose by 0.03; 0.02 and 0.04%, respectively compared to the last day before the transfer of animals. As for the fat content, the level of the indicator of the last day before the cows transfer was reached in the IV period; protein and lactose in the III period (11–15 days).
Key words: dairy cows, tie-stall, free-stall, milking parlour, adaptation, behavior and productivity.

Introduction

The body of ruminants has the ability to regulate physiological processes independently, maintaining the internal environment within constant limits. The use of dairy cattle in an unusual environment (change of climatic zone or method of keeping) largely depends on the level of compliance of new housing conditions with hereditary traits of the organism and the level of adaptation to conditions (technologies) of keeping, feeding and milking (Webster *et al.*, 2008).

The efficiency of production activities of industrial dairy complexes largely depends on the extent to which the current technology meets the biological needs of animals. The adaptive capabilities of the body of dairy cattle are influenced by a set of environmental factors, which significantly affect the productivity of animals (Krawczel & Grant, 2009). Along with the level of feeding and genetic properties, the technology of keeping and milking of *Bos taurus* is important (Borshch, Ruban, & Borshch, 2021).

High productivity, reproductive traits, and feed efficiency are important indicators of successful adaptation of dairy cattle to changes in the environment and housing technology, milking equipment and level of feeding (O'Driscoll, Hanlon, & Boyle, 2008). The parameters of daily behavior of animals are also important, because during the first periods after changing the conditions of keeping and milking cows have a significant stress load, which affects productivity, milk quality and duration of economic use of animals. It is advisable to assess the adaptive traits of dairy cattle after a certain period (20–30 days), during which animals either acclimate to the new conditions of keeping and milking, restoring the former productive traits, or do not restore their productive potential (Cook, 2007; Pavlenko *et al*., 2018). Behavior is considered to be the most important indicator of the detection of all abnormalities in animal health and productivity. It finds expression in all elements of production technology, forming in combination with climatic, mechanical and organizational factors, a complex system (Ruban *et al.*, 2020; Sitkowska *et al*., 2015).

One of the current trends in the development of dairy farming is the use of intensive technologies of milk production. At the same time, the requirements for the dairy herd as the main means of production are growing. Cows suitable for use in a high-tech complex must have high productivity, sound constitution and high reproductive qualities (Borshch *et al*., 2020). Changes in housing conditions are accompanied by deviations from the established method, rhythm and schedule of existence of animals and loss of productivity, condition and problems with limbs (lameness). This is especially noticeable when changing not only the conditions of keeping, but also milking, because during increasing the milk yield the neuroreceptor system of cows begins to experience regular periodic irritation by the vacuum of the milking machine. These actions negatively affect both the productivity and the health of the cows' udder.

The aim of this work was to study the behavior, productivity and conditions of second lactation cows during the period of adaptation to new keeping and milking conditions.

Materials and Methods

The research was conducted on a commercial farm located (49°48′45"N30°18′56E) in Kyiv region (Ukraine). Thirty-four cows of the local black-and-white breed of the second lactation (24–47 days after calving) were transferred from a brick barn for 100 heads (Length × Width × Height: 76×12×6 m) with tie-stall keeping in a newly low cost housing facility for 400 heads (Length × Width × Height: 138×36×9.54 m) with free-stall keeping. All animals were not pregnant. Milking equipment also changed: before the changing conditions of keeping, cows were milked in the milk duct at UDM-100, and after changing the conditions in the milking parlor at Carousel, 32 cows were milked at the same time (GEA Farm Technologies, Germany). Daily milking frequency before and after the change of keeping conditions was three times. The change in housing conditions took place during May–June 2020; the average daily temperature was, according to West, (2003) thermoneutral for dairy cows (+15.8 °C). We divided the first 30 days under the new conditions of keeping and milking into six periods: the I period – 1–5 days; the II period – 6–10 days; the III period – 11–15 days; the IV period – 16–20 days; the V period – 21–25 days and the VI period – 26–30 days. During the study periods, the mean values of cows' behavior and behavioral indices, milk productivity and composition, fatness assessment, and assessment of walking were determined. During 5; 10; 15; 20; 25 and 30 days, direct visual observations of animals were performed, during which cases (and number of animals) of contact of cows with boxes (lying, standing, standing with forelimbs) were recorded.

Cow's behavior was determined by using internal surveillance cameras (8 Hikvision cameras Full HD). Filming in all barns takes place around the clock. Placing cameras in the barns allows you to record a recreation area, feeding passage and drinking bowls area and cows moving. Every 10 min, 32 cows involved in the experiment were observed: the number of cows, which during the observation consumed food, rested by standing or lying, moved and drank water were recorded.

Optimal duration of cows behavioral reactions was determined according to Cook, 2020. The effect of free-stall housing on stall comfort, welfare, and natural behavior of cows is used by practical indices including cow comfort index (CCI): number of cows lying in stalls per number of cows in contact with stalls: (Nelson, 1996); stall standing index (SSI): number of cows standing in stalls per number of cows in contact with stalls (Cook, Bennett, & Nordlund, 2005); stall perching index (SPI): number of cows standing with 2 front feet in the stall and the rear feet in the alley per number of cows in contact with stalls (Tucker, Weary, & Fraser, 2005), and stall use index (SUI): number of cows lying in stalls per number of cows not actively feeding (Overton *et al*., 2002).

Daily milk fat, protein, and lactose concentrations were determined on three consecutive (morning, midday and evening) milk samples (Milkotester Lactomat Rapid S, Bulgaria).

Fat-corrected milk (3.5% FCM) was calculated using the equation (NRC, 2001):

FCM = [0.432 × milk yield (kg day^{-1}) + 16.23 × milk fat yield (kg day^{-1})] (1)

Energy-corrected milk (ECM) yield was calculated as by Tyrrell & Reid, (1965):

ECM = [0.327 × milk yield (kg day^{-1}) + 12.95 × milk fat yield (kg day^{-1}) + 7.2 × milk protein yield (kg day^{-1})] (2)

The study locomotion scoring system was compared with criteria of Sprecher, Hosteler, & Kaneene, (1997), where 1 point – normal and 5 point – severely lame. Body condition score was determined according to 5-point scale (Edmondson *et al*., 1989).

The obtained data were statistically processed using STATISTICA (Version 11.0, 2012) software. The Student's *t*-test was used to estimate the statistical significance of the obtained values. Data were considered significant at $p<0.05$, $p<0.01$, $p<0.001$.

Results and Discussion

Research results have shown that changes in housing and milking conditions have become a significant stressor for cows. The duration of the main behavioral reactions: lying down, drinking, and eating food in the first days after changing the conditions of keeping and milking decreased significantly – by 181; 13 and 89 min, respectively (Table 1). At the same time, the duration of standing on the contrary increased by 48 min. During the adaptation period (30 days) to the new conditions of keeping and milking, the duration of lying cows increased from the second period (6–10 days) of observations. The difference in the duration of lying cows between periods I and VI was 114 min day^{-1}. The duration of feed consumption increased from the second period (by 9 min), and the largest increase occurred during the third period – by 18 min compared to the second period. In general, the duration of feed consumption during the observation period increased by 71 min. The most significant increase in the duration of lying down occurred during the third period: 73 min. The value of standing duration, on the contrary, decreased with each subsequent period. It was especially significant during the second period (48 min compared to the first period). In total, the difference between periods I and VI was 79 min. The duration of walking also decreased during the study period (by 45 min compared to the I period). The duration of watering during the adaptation period increased by 10 min compared to the I period.

Table 1

Duration of behavioral reactions of cows during the adaptation period, min per day

Behavioral reactions	Last day before milking parlor and housing system change	Periods, their start and end days					
		I 1–5	II 6–10	III 11–15	IV 16–20	V 21–25	VI 26–30
Lying	809±19.4	628± 11.1	654± 10.4	701± 12.7***	717± 14.9***	738± 14.2***	742± 15.9***
Feeding	296±15.8	207± 8.4	216± 9.4	234± 8.2*	242± 11.1*	257± 12.8**	263± 14.5**
Moving	–	93± 2.8	74± 2.3***	68± 2.1***	62± 2.0***	54± 1.8***	48± 1.2***
Standing	188±5.1	236± 8.3	188± 6.7***	173± 6.2***	167± 5.9***	165± 5.8***	157± 5.3***
Water drinking	47±0.8	34± 0.4	34± 0.3***	37± 0.6***	39± 0.7***	41± 0.9***	44± 1.1***

Note: *p<0.05; **p<0.01; ***p<0.0.001 as compared with I period.

The lack of restraint in the movement with free-stall keeping affected the change in the ratio of daily behavioral responses. Animals had to cross-distances for eating, drinking, and milking compared to tie-stall housing, so the duration of behavioral responses at the end of the adaptation period (30 days) was lower than on the last day before changing housing and milking conditions. Behavior and productivity of cows after changes in housing conditions were mostly studied when transferring animals from stall keeping indoors (winter) to grazing (summer) (Schnier, Hielm, & Saloniemi, 2003; Zähner *et al*., 2004). The results of our research coincide with the data obtained by Slovak scientists, who indicated a decrease in the duration of lying in Holstein breed cows after transferring them from tie-stall keeping to free-stall keeping (Broucek *et al*., 2017).

During the first 5 days after the change of housing and milking conditions, the average productivity of cows decreased by 1.39 kg day^{-1} (or 6.01%) compared to the last day before the transfer of animals to free-stall housing (Table 2). At the same time, the indicators of the content of fat, protein and lactose in milk decreased: by 0.03; 0.02 and 0.04%, respectively, as well as the value of the energy-corrected milk by 1.57 kg day^{-1} (or 6.51%) and fat-corrected milk by 1.55 kg day^{-1} (or 6.44%). The productivity of cows during the 30 days of adaptation gradually increased (by 0.13–0.65 kg) with each subsequent period and in the V period reached the level of the last day before transfer to new housing conditions. As for the fat content, its value increased by 0.01% during the II period and was at a stable level until the end of the III period (11–15 days), and in the IV period reached the level of the last day before the transfer. The total difference in fat content in milk at the end of the study was 0.04% (compared with I period). The content of milk protein during the period of monthly observations increased by 0.05% achieving the level of the last day before the transfer took place in the III period (11–15 days). The largest increase in protein content was observed in the IV period (16–20 days) – by 0.04% (compared to the I period). During the research period, the content of lactose increased most among the components of milk: by 0.06% (in the VI period compared to the I period), and reached the level of the last day before the transfer took place in the III period. In accordance with the increase in the main components of milk (fat, protein, lactose) during the study period, the values of the energy-corrected milk increased by 1.87 kg day^{-1} (in VI period) and fat-corrected milk per 1.79 kg day^{-1}, respectively. Our data are partially in line with the data from a team of scientists at the University of Wisconsin-Madison (USA) who indicate that after changes in housing conditions, which included moving cows to new premises with free-stall keeping, productivity recovered faster than when animals were housed into renovated premises (Bewley *et al*., 2001). Broucek *et al*. (2013) reported about decrease in productivity in cows (by 23.28%) on the first day after changing housing and milking conditions. The results of these studies coincide with our results.

One of the fundamental indicators of the state of the dairy cow's bodies in the period of changing housing and milking conditions, as well as in the period of maximum productivity (1–3 months of lactation) is the body condition and locomotion scores (Wang *et al*., 2016). It was found that body condition in cows during the adaptation period gradually decreased starting from the II and ending with the VI period. In general, body condition during the study period decreased by 0.44 points (Table 3). Regarding the cows' locomotion score, its values during the

Table 2

Milk yield and composition during adaptation period

Indicators	Last day before milking parlor and housing system change	Periods, their start and end days					
		I 1–5	II 6–10	III 11–15	IV 16–20	V 21–25	VI 26–30
Milk yield, kg day^{-1}	23.16± 0.48	21.77± 0.33	22.08± 0.40	22.38± 0.44	23.03± 0.48*	23.21± 0.50*	23.34± 0.51*
Fat, %	3.75± 0.02	3.72± 0.01	3.73± 0.01	3.73± 0.01	3.75± 0.02	3.75± 0.02	3.76± 0.02
Protein, %	3.18± 0.03	3.16± 0.02	3.16± 0.02	3,19± 0,03	3.20± 0.03	3.20± 0.03	3.21± 0.03
Lactose, %	4.10± 0.02	4.06± 0.02	4.07± 0.02	4.10± 0.02	4.10± 0.02	4.11± 0.03	4.12± 0.02*
FCM, kg day^{-1}	24.10± 0.55	22.53± 0.26	22.89± 0.28	23.20± 0.31	23.96± 0.39**	24.05± 0.40**	24.32± 0.40**
ECM, kg day^{-1}	24.06± 0.27	22.51± 0.21	22.89± 0.23	23.26± 0.29*	24.01± 0.32***	24.20± 0.30***	24.38± 0.33***

Note: *p<0.05; **p<0.01; ***p<0.001 as compared with I period.

Table 3

Body condition score and locomotion score change during adaptation period

Indicators	Last day before milking parlor and housing system change	Periods, their start and end days					
		I 1–5	II 6–10	III 11–15	IV 16–20	V 21–25	VI 26–30
Body condition score	3.21±0.35	3.21± 0.35	3.09± 0.16	3.03± 0.19	2.92± 0.22	2.86± 0.15	2.77± 0.19
Locomotion score	-	1.33± 0.06	1.33± 0.06	1.33± 0.06	1.68± 0.12*	1.68± 0.12*	1.68± 0.12*

Note: *p<0.05 as compared with I period

Table 4

Values of indices that characterize cow comfort during adaptation period, %

Comfort indices	Periods, their start and end days					
	I 1–5	II 6–10	III 11–15	IV 16–20	V 21–25	VI 26–30
CCI	70.24± 1.16	73.82± 2.84	78.33± 2.63**	86.64± 4.19***	88.26± 4.81***	90.54± 5.06***
SSI	18.68± 0.29	16.53± 0.24***	15.45± 0.23***	9.12± 0.12***	7.53± 0.10***	6.78± 0.08***
SPI	11.08± 0.17	9.65± 0.13***	6.22± 0.08***	4.24± 0.07***	4.21± 0.07***	2.68± 0.05***
SUI	54.19± 2.08	59.07± 2.77	66.38± 3.19**	71.66± 3.41***	78.43± 3.96***	82.26± 4.20***

Note: *p<0.05; **p<0.01; ***p<0.001 as compared with I period.
CCI – cow comfort index; SSI – stall standing index; SPI – stall perching index; SUI – stall use index.

I–III periods were equal: 1.33 points with a slight increase in IV to 1.68 points. These values of locomotion score are acceptable for dairy cattle, which indicates good adaptation of animals to changes in housing technology.

The data obtained by us coincide with the data of various groups of scientists who also indicate a decrease in the body condition score in cows in the first months after calving (Rafia *et al*., 2012; Roche *et al*., 2013; 2009).

To more fully study of the influence of changes in housing conditions and milking on the behavior of cows, we studied the values of four comfort indices for boxing, which depend on the indicators of daily behavior. The values of cow comfort index (CCI) and stall use index (SUI), which depend on the daily duration of rest lying down, increased with each subsequent period and in the VI period increased by 20.30 and 28.07%, respectively (Table 4). At the same time, the stall standing index decreased by 11.90% during the 30-day adaptation period, and the stall perching index decreased by 8.40%.

Conclusions

Changes in housing and milking conditions at the beginning of the adaptation period during 14–21 days became a significant stress factor for dairy lactating cows, which led to reduced productivity, worsening of milk quality and reduced basic behavioral responses (lying down, feed consumption, watering, and led to increase of motor activity). During the 30 days of adaptation, the productivity of cows, milk quality exceeded the level reached before the transition to new conditions, and behavioral responses were slightly lower, but met the recommended values for dairy cows.

The results of the research can be used in the reconstruction and modernization of existing dairy farms with tie-stall keeping and their transfer to free-stall keeping and milking in milking parlors, as well at the construction of new farms using cows which were kept under other technological conditions.

For reduction of the adaptation period and decreasing the negative impact of changes in housing and milking conditions on the productivity and comfort of second lactation cows, it is necessary to transfer to other housing conditions no later than one month after calving. It is desirable to change the housing conditions for lactating cows during the thermo-neutral temperature period (up to +25 °C). At the same time, it is necessary to ensure full feeding, comfort of housing conditions and to follow the rules of automated milking during the adaptation period under the new housing conditions.

References

Bewley, J., Palmer, R.W., & Jackson-Smit, D.B. (2001). A Comparison of Free Stall Barns Used by Modernized Wisconsin Dairies. *Journal of Dairy Science*, 84, (2), 528–541. DOI: 10.3168/jds.S0022-0302(01)74504-3.

Borshch, O.O., Gutyj, B.V., Sobolev, O.I., Borshch, O.V., Ruban, S.Yu., Bilkevich, V.V., … Nahirniak, T. (2020). Adaptation strategy of different cow genotypes to the voluntary milking system. *Ukrainian Journal of Ecology*, 10(1), 145–150. DOI: 10.15421/2020_23.

Borshch, O.O., Ruban, S.Yu., & Borshch, O.V. (2021). The influence of genotypic and phenotypic factors on the comfort and welfare rates of cows during the period of global climate changes. *Agraarteadus*, 1, 25–34. DOI: 10.15159/jas.21.12.

Broucek, J., Uhrincat, M., Mihina, S., Soch, M., Mrekajova, A., & Hanus, A. (2017). Dairy Cows Produce Less Milk and Modify Their Behaviour during the Transition between Tie-Stall to Free-Stall. *Animals*, 7 (16). DOI: 10.3390/ani7030016.

Broucek, J., Uhrincat, M., Palkovicova, Z., Tancin, V., & Hanus, A. (2013). Effect of relocation and sire lineage on behaviour and milk yield of dairy cows. *Archiv Tierzucht*, 56 (20), 208–215. DOI: 10.7482/0003-9438-56-020.

Cook, N.B. (2020). Symposium review: The impact of management and facilities on cow culling rates. *Journal of Dairy Science*, 103, 3846–3855. DOI: 10.3168/jds.2019-17140.

Cook, N.B. (2007). The Dual Roles of Cow Comfort in the 'Get Lame – Stay Lame' Hypothesis. Sixth International Dairy Housing Conference Proceeding, 16-18 June (701P0507e). Minneapolis, Minnesota, USA: ASABE. DOI: 10.13031/2013.22819.

Cook, N.B., Bennett, T.B., & Nordlund, K.V. (2005). Monitoring indices of cow comfort in free-stall-housed dairy herds. *Journal of Dairy Science*, 88, 3876–3885. DOI: 10.3168/jds.S0022-0302(05)73073-3.

Edmonson, A.J., Lean, I.J., Weaver, L.D., Farver, T., & Webster, G. (1989). A body condition scoring chart for Holstein dairy cows. *Journal of Dairy Science*. Vol. 72 (1), 68–78.

Krawczel, P., & Grant, R. (2009). Effects of cow comfort on milk quality, productivity and behavior. In Proceedings of the NMC Annual Meeting, 25–28 January (pp. 15–24). Charlotte, North Carolina, USA.

Nelson, A.J. (1996). On-farm nutrition diagnostics. Proceedings 29th Annual Conference. American Association of Bovine Practitioners, September 12-14 (pp. 76–85). San Diego, California, USA: Frontier Printers, Inc. DOI: 10.21423/aabppro19965940.

NRC. (2001). Nutrient Requirements of Dairy Cattle. 7th rev. ed. Washington, DC: National Acad. Press.

O'Driscoll, K., Hanlon, A., & Boyle, L. (2008). The Effect of Out-Wintering Pad Design on the Synchrony of Dairy Cow Behavior. *Journal of Dairy Science*, 91, 4651–4660. DOI: 10.3168/jds.2007-0741.

Overton, M.W., Sischo, W.M., Temple, G.H., & Moore, D.A. (2002). Using time-lapse video photography to assess dairy cattle lying behavior in a free-stall barn. *Journal of Dairy Science*, 85, 2407–2413. DOI: 10.3168/jds.S0022-0302(02)74323-3.

Pavlenko, A., Lidfors, L., Arney, D.R., Kaart, T., & Aland, A. (2018). Behavior and Performance of Dairy Cows After Transfer from Tied to Cubicle Housing. *Journal of Applied Animal Welfare Science*, 21 (1), 82–92. DOI: 10.1080/10888705.2017.1376204.

Rafia, S., Taghipour-Bazargani, T., Khaki, Z., Bokaie, S., & Tabrizi, S.S. (2012). Effect of body condition score on dynamics of he-mogram in periparturient Holstein cows. *Comparative Clinical Pathology*, 21, 933–943. DOI: 10.1007/s00580-011-1204-9.

Roche, J.R., Macdonald, K.A., Schütz, K.E., Matthews, L.R., Verkerk, G.A., Meier, S., … Webster, J.R. (2013). Calving body condition score affects indicators of health in grazing dairy cows. *Journal of Dairy Science*, 96 (9), 5811–5825. DOI: 10.3168/jds.2013-6600.

Roche, J.R., Friggens, N.C., Kay, J.K., Fisher, M.W., Stafford, K.J., & Berry, P.D. (2009). Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. *Journal of Dairy Science*, 92, 5769–5801. DOI: 10.3168/jds.2009-2431.

Ruban, S., Borshch, O.O., Borshch, O.V., Orischuk, O., Balatskiy, Y., Fedorchenko, M., … Zlochevskiy, M. (2020). The impact of high temperatures on respiration rate, breathing condition and productivity of dairy cows in different production systems. *Animal Science Papers and Reports*, 38(l), 61–72.

Schnier, C., Hielm, S., & Saloniemi, H.S. (2003). Comparison of milk production of dairy cows kept in cold and warm loose-housing systems. *Preventive Veterinary Medicine*, 61 (4), 295–307. DOI: 10.1016/j.prevetmed.2003.08.008.

Sitkowska, B., Piwczyński, D., Aerts, J., & Waśkowicz, M. (2015). Changes in milking parameters with robotic milking. *Archive Animal Breeding*, 58, 137–143. DOI: 10.5194/aab-58-137-2015.

Sprecher, D.J., Hosteler, D.E., & Kaneene, J.B. (1997). A lameness scoring system that uses posture and locomotion to predict dairy cattle reproductive performance. *Theriogenology*, 47, 1179–1187. DOI: 10.1016/s0093-691x(97)00098-8.

Tucker, C.B., Weary, D.M., & Fraser, D. (2005). Influence of neck-rail placement on free-stall preference, use, and cleanliness. *Journal of Dairy Science*, 88, 2730–2737. DOI: 10.3168/jds.S0022-0302(05)72952-0.

Tyrrell, H.F., & Reid, J.T. (1965). Prediction of the energy value of cow's milk. *Journal of Dairy Science*, 48, 1215–1223.

Wang, F.X., Shao, D.F., Li, S.L., Wang, Y.J., Azarfar, A., Cao, Z.J. (2016). Effects of stocking density on behavior, productivity, and comfort indices of lactating dairy cows. *Journal of Dairy Science*, 99, 3709–3717. DOI: 10.3168/jds.2015-10098.

Webster, J.R., Stewart, M., Rogers, A.R., & Verkerk, G.A. (2008). Assessment of welfare from physiological and behavioural responses of New Zealand dairy cows exposed to cold and wet conditions. *Animal Welfare*, 17, 19–26.

West, J. (2003). Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science*, 86, 2131–2144. DOI: 10.3168/jds.S0022-0302(03)73803-X.

Zähner, M., Schrader, L., Hauser, R., Keck, M., Langhans, W., & Wechsler, B. (2004). The influence of climatic conditions on physiological and behavioural parameters in dairy cows kept in open stables. *Animal Science*, 78 (1), 139–147. DOI: 10.1017/S1357729800053923.

 DOI: 10.22616/rrd.28.2022.002

FORMATION OF YIELD AND QUALITY OF WINTER DURUM WHEAT GRAIN DEPENDING ON LONG-TERM FERTILIZATION

Hryhorii Hospodarenko, ***Vitalii Liubych**
Uman National University of Horticulture, Ukraine
*Corresponding author's email: LyubichV@gmail.com

Abstract
Durum wheat (*Triticum durum* Desf.) grain is the main raw material for the production of high-quality pasta and cereal products. The research was conducted at Uman National University of Horticulture (Ukraine) in a long-term stationary experiment, founded in 2011. The aim of the work was to study the impact of long-term use of various fertilization systems (with incomplete return of nitrogen, phosphorus and potash fertilizers) on the yield and quality of durum winter wheat grain. The long-term application of nitrogen, nitrogen-potassium, nitrogen-phosphorus and nitrogen-phosphorus-potassium systems in the field crop rotation has a strong impact on the formation of durum winter wheat yield. Long-term use of $N_{150}P_{60}K_{80}$ increases it from 3.6 t ha^{-1} up to 4.9 t ha^{-1} ($p \leq 0.05$). The use of half a dose of complete mineral fertilizer provides 4.5 t ha^{-1} ($p \leq 0.05$). Variants with incomplete return of phosphorus-potassium fertilizers, as well as paired combinations with a nitrogen component, provide the formation of 4.6–4.8 t ha^{-1} grains. Nitrogen fertilization systems increase grain yield to 4.2–4.5 t ha^{-1} depending on the fertilizer dose. It should be noted that durum winter wheat responds well to the use of nitrogen fertilizers, as the protein content increases from 13.3 to 14.8–15.9 % ($p \leq 0.05$), and the gluten content from 28.0 to 31.1–33.4% ($p \leq 0.05$) depending on the fertilization system. The protein content was most affected by the application of nitrogen component from complete mineral fertilizer.
Key words: durum wheat, long-term fertilization, yield, protein content, gluten content.

Introduction

According to Eurostat (FAOSTAT data, 2021 June, available at: http://www.fao.org/faostat/en/#data/QC), the world's gross common wheat grain production is about 765 million tonnes, of which durum wheat (*Triticum durum* Desf.) makes up almost 5%. Durum wheat grain is the main raw material for the production of high-quality pasta and cereal products (Panayotova *et al*., 2021). The production of valuable grain products from wheat is possible due to the use of high-protein grain in their production technology (Osokina *et al*., 2020). High-quality pasta requires durum wheat flour, which forms a strong dough with high tear and deformation resistance during cooking. Such flour performance is achieved with high-protein durum wheat grain (Mefleh *et al*., 2018). However, durum wheat is more demanding in terms of growing conditions than common wheat. Therefore, the development of an effective fertilization system ensuring the formation of a heavy yield of grain high in protein is relevant.

Crop productivity is the most variable and integral indicator of their vitality, which accumulates their genetic potential, soil fertility, weather conditions and elements of the cultivation technology (Kiseleva *et al*., 2016). One of the strongest factors leading to the increase in yield and grain quality is application of fertilizers under favourable weather conditions (Novak *et al*., 2019).

Nitrogen, phosphorus, potassium fertilizers (Hospodarenko *et al*., 2019), microfertilizers and a range of organic and organomineral fertilizers are usually used in winter wheat fertilization system (Bezuglova *et al*., 2017). However, the use of nitrogen fertilizers has the greatest impact on wheat crop capacity formation (Litke, Gaile, & Ruža, 2017). Thus, application of N_{60} was found to increase the yield of durum winter wheat grain from 3.77 t ha^{-1} up to 4.19 t ha^{-1}, in case of adding N_{120} – up to 4.80 t ha^{-1}, while application of N_{180} reduced it to 4.62 t ha^{-1}. The effectiveness of nitrogen fertilizers varied depending on the weather conditions of the growing season. Adding N_{60} ensured wheat yield from 3.36 to 4.71 t ha^{-1} depending on the year of the study (Panayotova, Almaliev, & Kostadinova, 2017). In other studies (Pačuta *et al*., 2021) the yield of durum winter wheat grain varied from 2.10 t ha^{-1} in a less favorable year to 5.51 t ha^{-1} in a more favourable year. Initiating a mineral fertilization program increased the yield of durum winter wheat from 2.88-4.61 to 3.46-5.67 t ha^{-1} depending on the weather conditions of the study year (Slamka & Hanáčková, 2014). In these studies, however, the effectiveness of nitrogen fertilizers was explored without phosphorus-potassium fertilizers. In addition, nitrogen is a biogenic element whose content in soil is determined by the activity of its microorganisms and rhizosphere (Karpenko *et al*., 2021).

In the studies (Almaliev, Kostadinova, & Panayotova, 2014) when $N_{120}P_{80}$ was applied, the grain yield increase varied from 21.3 to 40.4 kg depending on the year of a study. However, these studies did not explore the effectiveness of potash fertilizers at all, and the doses of phosphorous and potash fertilizers were high. Moreover, it was a short-term application of a fertiliser, much different from a long-term application in the field crop rotation.

Durum wheat needs nitrogen throughout the entire growth period. Nitrogen nutrition must be balanced

with the content of mobile phosphorus and potassium compounds in the soil. Modern durum wheat varieties have a high yield potential yet realize it in conditions of a high agricultural background (Panayotova, Almaliev, & Kostadinova, 2017).

One should point out that long-term use of fertilizers has an advantage over short-term use. With long-term use of fertilizers in low doses, it can be effective at the level of short-term application of high doses. This phenomenon is caused by the aftereffect of fertilizers applied for previous crops in the rotation (Šimansky, 2016).

Usage of mineral fertilizers not only has a positive effect on increasing wheat yield, but also significantly improves grain quality (Hospodarenko & Liubych, 2021). Different elements of plant nutrition have different effects on grain protein content. The mineral fertilization system, which included a nitrogen component, had the greatest impact on the formation of protein content in durum winter wheat grains. Thus, the studies (Slamka & Hanáčková, 2014) found that the protein content increased from 11.1% in the non-fertilized variant to 11.7% after application of a complete mineral fertilizer. Scientists indicate a significant variation in protein content in different weather conditions – from 10.5 to 12.4%.

The analysis of scientific literature confirms the essential role of nitrogen fertilizer use in the agricultural technology of durum winter wheat. A large variation of their effectiveness depending on weather conditions was established. However, studies usually involve the application of nitrogen fertilizers only, which negatively affects the balance of mobile phosphorus and potassium compounds in the soil. In addition, the studies were conducted in short-term experiments, which do not allow us to establish the real yield capacity of durum winter wheat under different soil fertility conditions. Therefore, the analysis of data obtained in stationary experiments on the regularities of the influence of fertilization systems with different return of nutrition elements will allow to develop and put into practice the system of fertilizer application based on protection of soil resources, strengthening of self-regulation processes, restoration of sustainable functioning of agro-ecosystems. In the currently widespread short rotation systems with a significant saturation with grain crops, there has been insufficient research on the impact of predecessors and fertilization systems on the yield and grain quality of durum winter wheat.

The aim of the work was to study the impact of long-term use of various fertilization systems (with incomplete return of nitrogen, phosphorus and potash fertilizers) on the yield and quality of durum winter wheat grain.

Materials and Methods

The studies were carried out during 2020-2021. The stationary field experiment was carried out at the Uman National University of Horticulture (certificate of the National Academy of Agricultural Sciences No. 87) (Stationary field experiments of Ukraine, 2014) in the Right-Bank Forest Steppe of Ukraine with Greenwich geographical coordinates 48° 46' of northern latitude and 30° 14' of eastern longitude. The experiment was launched in 2011. The following crops were cultivated in the four-field crop rotation: winter wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), spring barley (*Hordeum vulgare* L.) and soya (*Glycine max* Moench.). The aim of the field experiment is to establish the efficiency of the action of different types, rates and proportions of mineral fertilizers on the yielding capacity and quality of grain and seeds of field crops, and fertility of the black soil. The scheme of the experiment includes 11 variants of combinations and separate applications of mineral fertilizers including the control variant without fertilizers (Table 1).

In the variant of the experiment with an average rate of nutrients in the crop rotation per hectare $N_{110}P_{60}K_{80}$, the total (100%) compensation with fertilizers of average annual removal of the nutrients by the crops in the crop rotation is planned. The scheme of the experiment was developed in such a way that it could be possible to determine the opportunity to decrease the rates of certain types of mineral fertilizers. The placement of the variants in the experiment is successive. Performance of the experiment simultaneously on four fields provides annual data about yielding capacity of all crops in the four-field crop rotation. The experiment was repeated three times. The total area of the experimental plot is 110 m^2, the accounting area is 72 m^2. Phosphorus (granulated superphosphate) and potassium (potassium chloride) fertilizers were applied during fall tillage, nitrogenous fertilizers (ammonium nitrate) during pre-sowing cultivation and fertilizing of winter wheat.

The soil on the experimental plot is the podzolized chernozem heavy loamy soil on loess with 3.8% of humus content, the content of nitrogenous hydrolyzed compounds (by Cornfield method) is low (105 mg kg^{-1}), the content of mobile compounds of phosphorus and potassium (by Chirikov method, extraction 0.5 m CH_3COOH) is increased (106 mg kg^{-1}) and high (132 mg kg^{-1}) correspondingly, pH KCl – 5.7.

The grain was harvested by combined harvesters. The protein content and gluten content were determined by the method of infrared spectroscopy using Infratec 1241 (FOSS Analytical, Sweden). The accounting of the harvest of non-marketable produce was conducted with the method of the trial sheaf. Non-marketable part of the harvest of the crop rotation plants (straw, stems) was left in the field for fertilizing.

Table 1

The design of application of fertilizers in the experiment

Variant of the experiment: average rates of nutrients in the crop rotation (kg active substance ha^{-1} per year)	Application of fertilizers under crops in the crop rotation			
	Winter wheat	Maize	Spring barley	Soya
Without fertilizers (control)	–	–	–	–
N_{55}	N_{75}	N_{80}	N_{35}	N_{30}
N_{110}	N_{150}	N_{160}	N_{70}	N_{60}
$P_{60}K_{80}$*	$P_{60}K_{80}$	$P_{60}K_{110}$	$P_{60}K_{70}$	$P_{60}K_{60}$
$N_{110}K_{80}$	$N_{150}K_{80}$	$N_{160}K_{110}$	$N_{70}K_{70}$	$N_{60}K_{60}$
$N_{110}P_{60}$	$N_{150}P_{60}$	$N_{160}P_{60}$	$N_{70}P_{60}$	$N_{60}P_{60}$
$N_{55}P_{30}K_{40}$	$N_{75}P_{30}K_{40}$	$N_{80}P_{30}K_{55}$	$N_{35}P_{30}K_{35}$	$N_{30}P_{30}K_{30}$
$N_{110}P_{60}K_{80}$	$N_{150}P_{60}K_{80}$	$N_{160}P_{60}K_{110}$	$N_{70}P_{60}K_{70}$	$N_{60}P_{60}K_{60}$
$N_{110}P_{30}K_{40}$	$N_{150}P_{30}K_{40}$	$N_{160}P_{30}K_{55}$	$N_{70}P_{30}K_{35}$	$N_{60}P_{30}K_{30}$
$N_{110}P_{60}K_{40}$	$N_{150}P_{60}K_{40}$	$N_{160}P_{60}K_{55}$	$N_{70}P_{60}K_{35}$	$N_{60}P_{60}K_{30}$
$N_{110}P_{30}K_{80}$	$N_{150}P_{30}K_{80}$	$N_{160}P_{30}K_{110}$	$N_{70}P_{30}K_{70}$	$N_{60}P_{30}K_{60}$

Note. * P – P_2O_5, K – K_2O.

Statistical data processing was performed using STATISTICA 10. The null hypothesis was confirmed or refuted during the performing of variance analysis. The p-value was determined for this purpose, which showed the probability of the corresponding hypothesis. In cases, where $p<0.05$, 'the null hypothesis' was refuted and the influence of the factor was significant.

Weather conditions during the years of the study differed from the annual average (see Table 2). The amount of precipitation in 2020 was lower compared to the annual average and 2021. There was not enough precipitation to produce sprouts in October 2019. In 2021, there was sufficient precipitation during the growing season to produce a high grain yield. Temperatures in 2020 were higher than the annual average, except for BBCH-stage 10 and BBCH-stage 50.

As a result of the moisture deficit in the fall of 2019, winter durum wheat sprouted in January 2020, which affected the formation of fewer productive stems (Table 3). In addition, the negative impact of frost during the phase BBCH 30 caused the formation of lower grain yield capacity compared with 2021.

Characteristics of 'Andromeda', a durum winter wheat variety. Originator: Institute of Irrigated Agriculture (Ukraine). Type of development: winter, early ripening. Plant height: 75-100 cm. It is recommended for growing in forest-steppe and steppe zones. The potential yield is 3.6-6.0 t ha^{-1}. Resistance to lodging – 5 points, to shedding – 7, to root rot – 5, to septoria – 9, to fusarium – 7, to brown rust – 8, to

Table 2

Weather conditions at the experimental site

Indicators	Year of research				1991–2020	
	2019/2020		2020/2021			
	Precipitation (mm)	Temperature (°C)	Precipitation (mm)	Temperature (°C)	Precipitation (mm)	Temperature (°C)
Sowing time	10.3	10.0	81.5	12.7	49	8.3
BBCH 10	78.9	-2.1	109.7	-0.2	72	-5.0
BBCH 20	38.7	7.1	44.9	9.5	77	6.1
BBCH 30	35.6	17.0	59.1	14.3	52	15.4
BBCH 50	34.3	20.4	68.0	18.7	81	20.9
BBCH 73	35.8	21.9	58.7	23.0	49	20.1

Table 3

Winter durum wheat sowing, date of the development phase of plants beginning and harvesting time date during trial years

Indicators	Year of research	
	2019/2020	2020/2021
Sowing time	October 17th, 2019	October 30th, 2020
BBCH 10	January 25th	November 20th
BBCH 20	February 25th	April 13th
BBCH 30	May 01th	May 10th
BBCH 50	June 05th	June 06th
BBCH 73	June 20th	June 20th
Harvesting time	July 15th	July 22th

powdery mildew – 6 points. Pasta-making properties are high – 7.4 points (9 is the best, 1 is the worse).

Results and Discussion

It was established that the yield of durum winter wheat grain with long-term use of $N_{150}P_{60}K_{80}$ increased by 1.4 times (4.9 t ha^{-1}) compared to the non-fertilized variant (3.6 t ha^{-1}) (Figure 1B). In the variants with incomplete return of phosphorus-potassium fertilizer this indicator was lower by only 2-6% compared to the complete mineral fertilizer, but reliable. Application of $N_{75}P_{30}K_{40}$ increased the yield by 1.3 times (4.5 t ha^{-1}) compared to non-fertilized areas. Under this fertilization scenario, the yield was only 9% lower compared to long-term application of $N_{150}P_{60}K_{80}$.

The efficiency of nitrogen-phosphorus and nitrogen-potassium fertilizer systems was at the level of variants with incomplete return of phosphorus-potassium fertilizers. However, the yield was significantly lower compared to the complete mineral fertilizer. Long-term use of 75 kg ha^{-1} of nitrogen fertilizers increased grain yield by 1.2 times compared to non-fertilized areas. This indicator was significantly lower compared to variant $N_{75}P_{30}K_{40}$. The

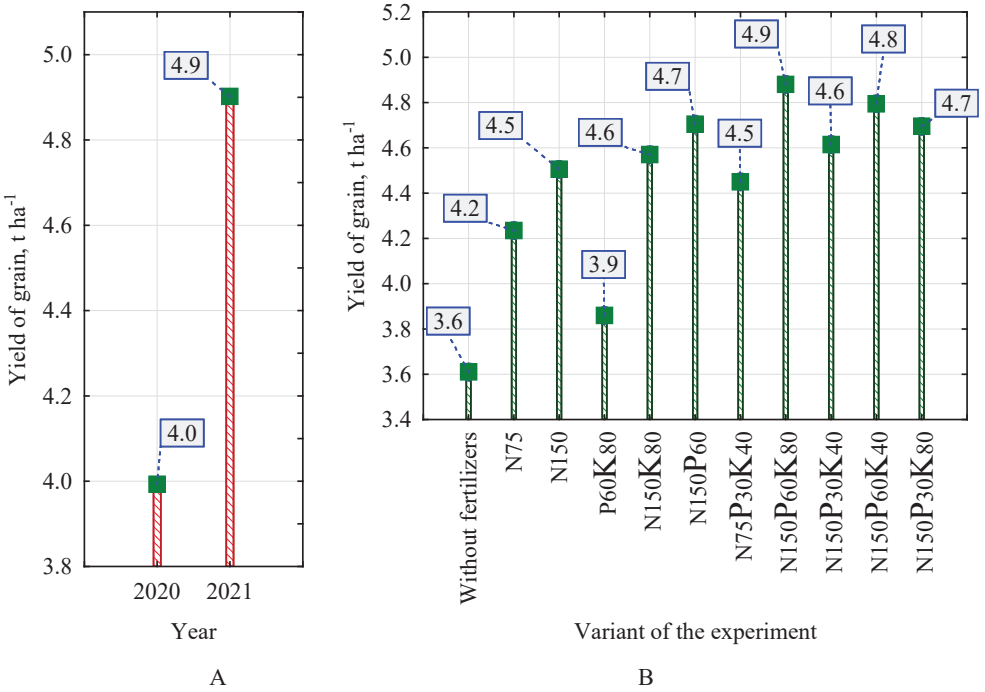

Figure 1. Durum winter wheat grain yields under different fertilisation systems (B) and on average per trial year (A), t ha^{-1}

use of 150 kg ha^{-1} of nitrogen fertilizers increased the yield by 1.3 times compared to the test sample. The effectiveness of this fertilizer system was at the level of $N_{75}P_{30}K_{40}$. However, the yield was significantly lower compared with the variants where nitrogen-phosphorus-potassium fertilizers were used.

The yield of durum winter wheat was least affected by the use of phosphorus-potassium fertilizers. With this fertilization system, it increased only by 8% compared to the variant without fertilizers and was significantly less compared to the variants, which included a nitrogen component.

The results of statistical analysis confirm a strong effect of weather conditions on the formation of durum winter wheat yield. Thus, more favourable weather conditions in 2021 ensure a 23% higher grain yield compared to less favourable conditions in 2020 (Figure 1A).

Weather conditions in 2021 were typical for the Right-Bank Forest-Steppe of Ukraine. In 2020, only 187.5 mm of precipitation fell during the growing season, which is 1.5 times less than in 2021 (281.7 mm). This means that durum winter wheat plants in 2020 were under moisture stress conditions, which affected the formation of a smaller grain yield. It has been proved that the reduction in grain yield of durum winter wheat under stress conditions is due to the formation of fewer productive stems, grain mass and grain number per ear (Ruiz *et al.*, 2019). In other studies (Shehab-Eldeen, Khedr, & Genedy, 2021) application of N_{25-75} in a more favourable year, the yield of winter wheat grain increased from 5.97 t ha^{-1} up to 9.62 t ha^{-1}. In a less favourable year from 4.52 t ha^{-1} up to 6.89 t ha^{-1}. These results confirmed the role of the amount and distribution of precipitation during the growing season for the formation of wheat yields in the conditions of the Right-Bank Forest-Steppe of Ukraine. The efficiency of fertilization systems depended on the nitrogen component of mineral fertilizers, as wheat is a nitrogen-philic crop (Panayotova, Almaliev, & Kostadinova, 2017). Therefore, there was no significant decrease in the yield of durum winter wheat grain from incomplete return of phosphorus-potash fertilizers. Long-term use (since 2011) of $N_{75}P_{30}K_{40}$ was at the level of long-term application of N_{150} in terms of efficiency. This confirmed the conclusions about the high efficiency of low doses of fertilizers when applied for a long time (Šimansky, 2016).

The results of the analysis show that the application of all fertilization programs containing the nitrogen component significantly increased the protein content in grain compared with the test sample (Figure 2 B). The only exception was the phosphorus-potassium fertilizer system, which did not substantially affect the protein content. Long-term use of N_{75} increased protein content by 11% compared to non-fertilized areas. The application of a double dose of nitrogen fertiliser increased it by 18% compared to the test sample and by 6% compared to N_{75}. It is worth

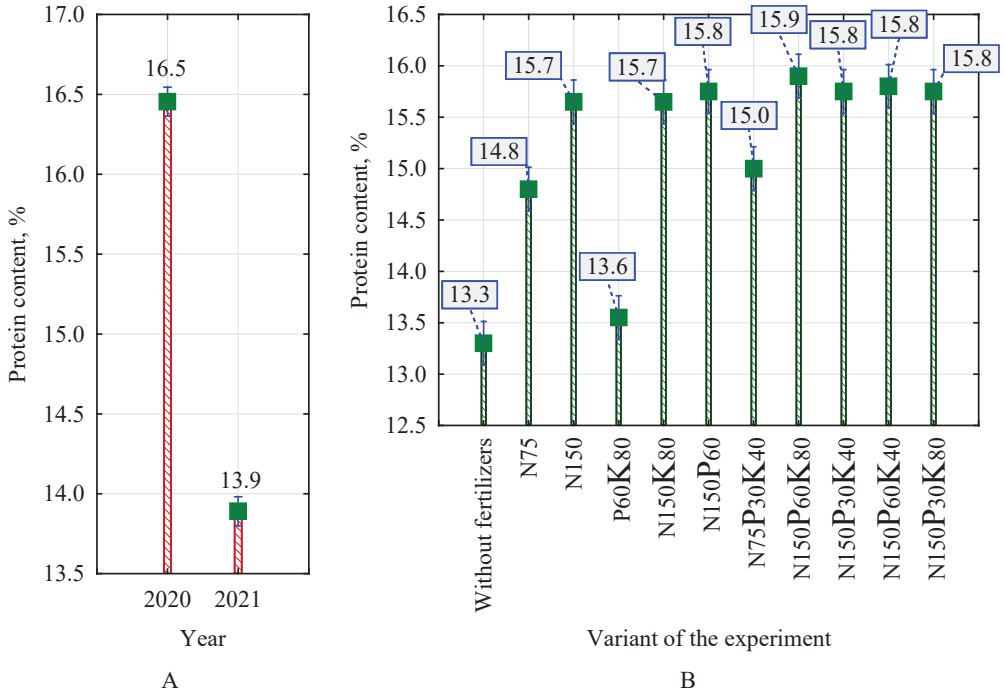

Figure 2. Protein content of durum winter wheat grains under different fertilization systems (B) and on average per trial year (A).

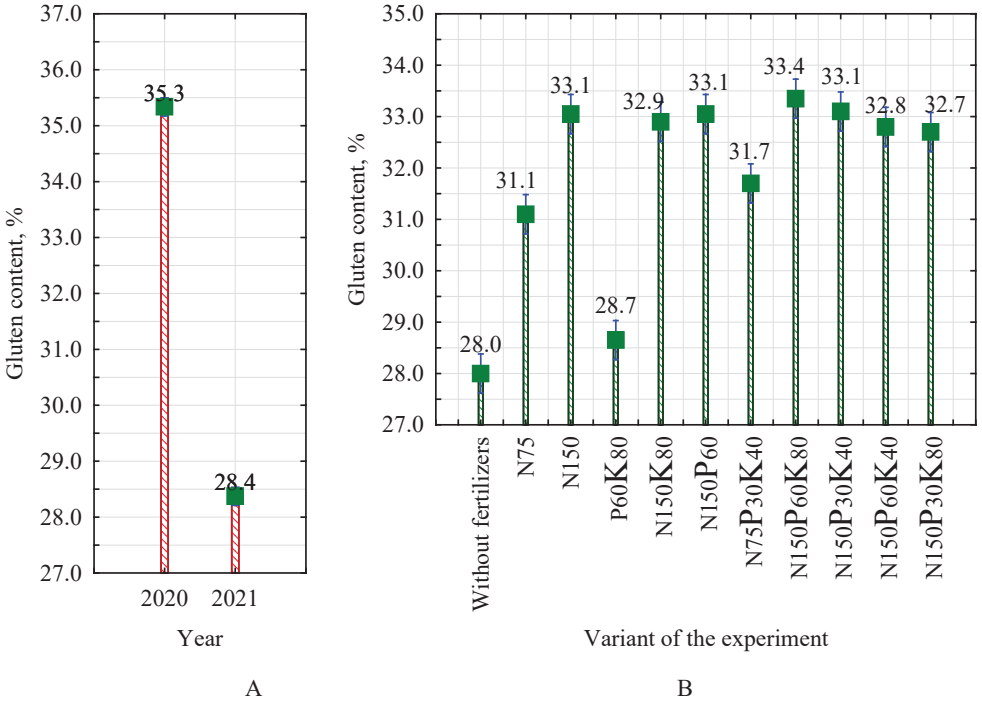

Figure 3. Gluten content of durum winter wheat grains under different fertilization systems (B) and on average per trial year (A).

noting that the use of nitrogen-phosphorus-potassium fertilizers did not significantly increase the protein content compared to nitrogen systems. The impact of weather conditions was also high, as protein content ranged from 13.9% in 2021 to 16.5% in 2020. The protein content in durum winter wheat grain in 2020 was 1.2 times higher compared to the protein content in 2021 (Figure 2A).

The gluten content in durum winter wheat grain with prolonged use of 75 kg ha^{-1} of nitrogen fertilizers increased by 11% compared to the test sample (Figure 3B). Long-term use of N_{150} increased its content by 18% compared to non-fertilized areas and by 6% compared to variant N_{75}. Nitrogen-phosphorus-potash fertilization systems had no advantages over the use of nitrogen fertilizers alone. It stands to mention that long-term use of phosphorus-potassium fertilizers did not significantly increase the gluten content. The gluten content of durum winter wheat grain ranged from 28.4 to 35.3%, depending on weather conditions (Figure 3A).

Durum winter wheat grain quality is shaped by the combined effect of abiotic and biotic factors. The protein and gluten content are most dependent on weather conditions during grain maturation and the use of nitrogen fertilizers (Pačuta *et al*., 2021).

Studies (Ruiz *et al*., 2019) confirmed a significant effect of weather conditions on the formation of protein content, which varied from 7.5 to 12.7%. It is noteworthy that in these studies at a yield of 3.60 t ha^{-1} the protein content in durum winter wheat grain was at the level of 9.7%, 3.11 t ha^{-1} – 7.5%, and for 1.37 t ha^{-1} – 12.7%. A decrease in grain yield contributes to an increase in grain protein content. Apparently, this is due to the ability of plants to reutilize nitrogen from the vegetative mass for protein synthesis in grain. In our research, moisture deficiency and high temperature during the BBCH-stage 73 in 2020 contributed to 1.2 times higher protein and gluten content in grain compared to the year 2021.

The factors studied (fertiliser system, year) had a statistically significant ($p \leq 0.05$) effect on yield formation and grain quality of durum winter wheat. The strength of influence was high for both factors. The effects of these factors on yield, protein content and gluten content were almost identical. This indicates that the fertilisation efficiency of durum winter wheat depends on the weather conditions of the growing season and fertilisation. It should be noted that this conclusion applies only to two years of research (2020-2021) or for years with similar weather parameters.

The results obtained can be used for the durum winter wheat variety 'Andromeda' or varieties of this type. In addition, the results obtained can be used for four-field crop rotation, where durum winter wheat is grown after soybeans. In other agricultural technology scenarios, further research is required.

Conclusions

The long-term application of nitrogen, nitrogen-potassium, nitrogen-phosphorus and nitrogen-

phosphorus-potassium systems in the field crop rotation has a strong impact on the formation of durum winter wheat yield. Long-term use of $N_{150}P_{60}K_{80}$ increases it from 3.6 t ha^{-1} up to 4.9 t ha^{-1} ($p \leq 0.05$). The use of half a dose of complete mineral fertilizer provides 4.5 t ha^{-1} ($p \leq 0.05$). Variants with incomplete return of phosphorus-potassium fertilizers, as well as paired combinations with a nitrogen component, provide the formation of 4.6-4.8 t ha^{-1} grains. Nitrogen fertilization systems increase grain yield to 4.2-4.5 t ha^{-1}depending on the fertilizer dose. It should be noted that durum winter wheat responds well to the use of nitrogen fertilizers, as the protein content increases from 13.3 to 14.8-15.9% ($p \leq 0.05$), and the gluten content from 28.0 to 31.1-33.4% ($p \leq 0.05$) depending on the fertilization system. The protein content was most affected by the application of nitrogen component from complete mineral fertilizer. A high influence of the factors of the fertilization system and the year on the yield, protein content and gluten content in durum winter wheat grain was established.

References

Ali, S.A., Tedone, L., Verdini, L., Cazzato, E., & De Mastro, G. (2019). Wheat Response to No-Tillage and Nitrogen Fertilization in a Long-Term Faba Bean-Based Rotation. *Agronomy*. 9, 50. DOI: 10.3390/ agronomy9020050.

Almaliev, M., Kostadinova, S., & Panayotova, G. (2014). Effect of fertilizing systems on the phosphorus efficiency indicators at durum wheat. *Agriculture & Forestry*. 60(4), 127–134. DOI: 10.15547/ast.2021.01.010.

Bezuglova, O.S., Polienko, E.A., Gorovtsov, A.V., Lyhman, V.A., & Pavlov, P.D. (2017). The effect of humic substances on winter wheat yield and fertility of ordinary chernozem. *Ann. Agrar. Sci*. 15, 239–242. DOI: 10.1016/j.aasci.2017.05.006.

Hospodarenko, H.M., & Liubych, V.V. (2021). Influence of long-term fertilization on yield and quality of spring triticale grain. In Annual 27th International Scientific Conference Research for Rural Development, 12-14 May 2021 (pp. 29–35), Vol. 36, Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/rrd.27.2021.004.

Hospodarenko, H., Prokopchuk, I., Nikitina, O., & Liubych, V. (2019). Assessment of the contamination level of a podzolized chernozem with nuclides in a long-term land use. *Agriculture*. 65(3), 128−135. DOI: 10.2478/AGRI-2019-0013.

Karpenko, V.P., Poltoretskyi, S.P., Liubych, V.V., Adamenko, D.M., Kravets, I.S., Prytuliak, R.M., Kravchenko, V.S., Patyka, N.I., & Patyka V.P. (2021). Microbiota in the rhizosphere of cereal crops. *Mikrobiol. Z*., 83(1), 21–31. DOI: 10.15407/microbiolj83.01.021.

Kiseleva, M.I., Kolomiets, T.M., Pakholkova, E.V., Zhemchuzhina, N.S., & Lubich, V.V. (2016). The differentiation of winter wheat (*Triticum aestivum* L.) cultivars for resistance to the most harmful fungal pathogens. *Agricultural Biology*. 51 (3), 299–309. DOI: 10.15389/AGROBIOLOGY.2016.3.299RUS.

Litke, L., Gaile, Z., & Ruža, A. (2017) Nitrogen fertilizer influence on winter wheat yield and yield components depending on soil tillage and forecrop. In Annual 23th International Scientific Conference Research for Rural Development, 17-19 May 2017 (pp. 54–61), Vol. 2, Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/rrd.23.2017.049.

Mefleh, M., Conte, P., Fadda, C., Giunta, F., Piga, A., Hassoun, G., & Motzo, R. (2018). From ancient to old and modern durum wheat varieties: interaction among cultivar traits, management, and technological quality. *J. Sci. Food Agric*. 99, 2059–2067. DOI: 10.1002/jsfa.9388.

Novak, L., Liubych, V., Poltoretskyi, S., & Andrushchenko, M. (2019). Modern Development Paths of Agricultural Production: Trends and Innovations. In V. Nadykto (Eds.), *Technological indices of spring wheat grain depending on the nitrogen supply* (pp. 753–761). Melitopol, Tavria State Agrotechnological University. DOI: 10.31388/2220-8674-2019-1-55.

Osokina, N., Liubych, V., Novikov, V., Leshchenko, I., Petrenko, V., Khomenko, S., Zorunko, V., Balabak, O., Moskalets, V., & Moskalets, T. (2020). Effect of Electromagnetic Irradiation of Emmer Wheat Grain on the Yield of Flattened Wholegrain Cereal. *Eastern European Journal of Enterprise Technologies*. 5(108), 40–51. DOI: 10.15587/1729-4061.2020.217018.

Pačuta, V., Rašovský, M., Michalska-Klimczak, B., & Wyszyński, Z. (2021). Grain Yield and Quality Traits of Durum Wheat (*Triticum durum* Desf.) Treated with Seaweed and Humic Acid-Based Biostimulants. *Agronomy*. 11, 1270. DOI: 10.3390/ agronomy11071270.

Panayotova, G., Almaliev, M., & Kostadinova, S. (2017). Nitrogen uptake and expense in durum wheat depending on genotype and nitrogen fertilization. *Agricultural Science and Technology*. 9(1), 26–34. DOI: 10.15547/ast.2017.01.005.

Panayotova, G., Kostadinova, S., Stefanova-Dobreva, S., & Muhova, A. (2021). Influence of long-term fertilization and environments on test weight of durum wheat (*Triticum durum* Desf.) grain. *Agriculture and Environment*. 13(1), 52–56. DOI: 10.15547/ast.2021.01.010.

Ruiz, M., Zambrana, E., Fite, R., Sole, A., Tenorio, J.L., & Benavente, E. (2019). Yield and Quality Performance of Traditional and Improved Bread and Durum Wheat Varieties under Two Conservation Tillage Systems. *Sustainability*. 11(17), 4522. DOI: 10.3390/su11174522.

Shehab-Eldeen, M.T., Khedr, R.A., & Genedy, M.S. (2021). Studies on Morphophysiological Traits and their Relationships to Grain Yield and its Components of Six Bread Wheat Genotypes under Four Nitrogen Fertilization Levels. *J. of Plant Production*. 12(1), 11–17. DOI: 10.21608/jpp.2021.152011.

Šimanský, V. (2016). Changes in soil organic matter parameters during the period of 18 years under different soil management practices. *Agriculture*. 62, 149–154. DOI: 10.1515/agri-2016-0015.

Slamka, P., & Hanáčková, E. (2014). Effect of different fertilization on durum wheat (*Triticum durum* Desf.) yield and quality parameters. *Research Journal of Agricultural Science*. 46 (3), 68–78.

Stationary field experiments of Ukraine. (2014). Agrarian Science, Kyiv. 146 p.

 DOI: 10.22616/rrd.28.2022.003

APPLICATION OF GROUND-BASED HIGH-THROUGHPUT PHENOTYPING PLATFORMS IN CEREAL BREEDING – A REVIEW

***Zaiga Jansone[1,2], Mara Bleidere[2], Gundega Putniece[1]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]Institute of Agricultural Resources and Economics, Latvia
*Corresponding author's email: zaiga.jansone@arei.lv

Abstract
Cereals are the most widely grown crops in Europe, accounting for 53.8% of total crop area. Today's farmers are facing serious challenges – climate change, resource scarcity and population growth, which can have a negative impact on the quantity and cost of agricultural production. It is therefore important to focus on the development of cereal breeding programmes and the introduction of new technologies, including High-Throughput phenotyping methods. The aim of this paper was to analyse the recent scientific literature on the current use of ground-based sensors applied in High-Throughput Phenotyping Platforms (HTPPs) for the assessment and analysis of morphological and physiological traits in cereals and for the selection of high-yielding genotypes. This enables the breeder to asses and identify genotypes of interest more quickly and accurately at different stages of plant development and in larger field and laboratory trials than with traditional breeding methods. The paper also provides information on the potential of using ground-based HTPPs, the most important methodological principles in setting up trials and measuring traits to ensure the accuracy of the assessments and the processing and interpretation of the results.
Key words: sensors, morphological traits, physiological traits, yield, correlation.

Introduction

Cereals are among the most widely grown crops in Europe. Compared to other crops, cereals account for 53.8% of the EU's cereal area in 2020 (Eurostat, 2020), with wheat (*Triticum aestivum* L.) accounting for almost 45%, and barley (*Hordeum vulgare* L.*)* 20% of European cereal production (Eurostat, 2020). Wheat (498 800 ha) was also the largest cereal area in Latvia in 2020, followed by oats (*Avena sativa* L.) (98 900 ha) and barley (75 300 ha) (CSB database, 2021).

Agriculture faces several challenges at the same time: climate change, resource scarcity and rising costs, and population growth. Although it has been predicted in the past that global wheat production will increasingly expand to northern regions (Ortiz *et al*., 2008), climate change has tended to reduce cereal productivity and quality in recent years. In recent years, droughts and record-high temperatures have been observed across Europe (NOAA National Centers for Environmental Information, 2020), significantly reducing cereal yields, including the Baltic States (Eurostat, 2020).

Cereal variety breeding, which results in the development of new and high-yielding varieties, is one of the most important resources to meet the demand for cereal inputs to increase food production. Studies confirm the importance of breeding for yield gains, changes in productivity – related traits and disease resistance (Laidig *et al*., 2021). Therefore, in the context of climate change, as well as the political and social imperative to produce more environmentally friendly food commodities, the progress of cereal breeding is also receiving constant attention (Laidig *et al*., 2021). The greatest challenge in crop breeding research in the 21st century is the ability to predict yields that are as close as possible to the genetic potential of a variety. Although genotyping efficiency has improved considerably thanks to new advances in DNA sequencing, methods for assessing plant traits (phenotype) have evolved relatively slowly over the last 30 years, and factors affecting phenotyping efficiency limit the breeder's ability to assess the genetics of quantitative traits, particularly those related to yield and stress tolerance (White *et al*., 2012). Therefore, the introduction and use of innovative phenotype – based selection techniques for breeding of new varieties is a current research area to improve yield and tolerance to abiotic and biotic factors under changing climatic conditions (Rubiales *et al*., 2021).

In breeding programmes using traditional phenotyping methods, breeders rely mainly on the evaluation of the traits of interest using visual and manual phenotyping methods. This is time-consuming, labour-intensive and it requires large human resources to select genotypes of interest from large hybrid populations and breeding nurseries. In contrast, high-resolution phenotyping methods can greatly increase the ability to make observations and quantify traits in field trials and breeding nurseries on a much larger scale (Reynolds, Chapman, & Crespo-Herrera, 2020; Yang *et al*., 2020). Nowadays, plant phenotyping is seen as a new research direction that provides important information on genotype – environment interactions, focused on selecting productive plants suitable for given growing conditions. Moreover, these studies mostly use non-invasive and digital technologies (Costa *et al*., 2019). The use of High-Throughput plant phenotyping platforms (HTPPs) in cereal breeding programmes makes it possible to identify

superior genotypes and thus achieve better results in the breeding process (Würschum, 2019). Due to the advantage of such phenotyping technologies, it is possible to replace subjective trait evaluations quickly and efficiently, and their application in plant breeding to select the best genotypes is seen as an important prerequisite for continuous grain yield progress in the future (Deery & Jones, 2021).

HTPP's are facilities on which various sensors and data collection systems are deployed to allow the breeder to assess phenotypes for various traits in large-scale trials (Li *et al*., 2021). The range of available phenotyping platforms is very wide and can be applied in field, greenhouse or laboratory trials using stationary, vehicle-based, self-propelled, portable or aerial platforms. This review focuses on a summary of research on the use of ground-based high-resolution methods for the evaluation of morphological and physiological traits and grain yield, as it is important in breeding to obtain phenotypic data for different genotypes that are as close as possible to real field conditions.

The aim of this paper was to analyse the recent scientific literature on the current use of ground-based sensors applied in High-Throughput Phenotyping Platforms (HTPPs) for the assessment and analysis of morphological and physiological traits in cereals and for the selection of high-yielding genotypes.

Materials and Methods

The present study was carried out using the monographic method to review different precise phenotyping methods provided for identifying morphological and physiological traits. The scientific literature from different journals and monographs has been used from research in Australia, Sweden, Germany, Poland, USA, Spain, Canada, China, Korea and India.

Results and Discussion

Characterization of ground-based HTPP

High-Throughput phenotyping involves specific tools that enable complex assessment of plant morphological and physiological traits at the organ, plant, canopy and even population levels (Li, Quan, & Song, 2021). To assess these different traits, different ground-based HTPPs have been developed, equipped with one or most commonly several combined spectral sensors. The most widely used of which are visible spectrum or RGB (red, green, blue) cameras (Deery *et al*., 2021), light detection and ranging or LIDAR (Deery *et al*., 2021; Lin, 2015), multispectral or hyperspectral cameras and thermal cameras (Bai *et al*., 2016; Kim *et al*., 2021).

Depending on the light source used, sensors are divided into two groups – active and passive sensors. Active sensors can be used in different lighting conditions and this does not affect the accuracy of the data obtained, as they use different independent light sources such as LED lamps as the illumination source (Kim *et al.*, 2016). One of the active sensors frequently used in studies is the GreenSeeker® sensor (Trimble, Sunnyvale, California, USA) which can measure the Normalized Difference Vegetation Index (NDVI) (Deery *et al.*, 2021). Passive sensors (RGB cameras), on the other hand, are dependent on sunlight, which affects their usability (Barmeier & Schmidhalter, 2017).

One of the most widely used phenotyping tools in the breeding programmes of cereal varieties are RGB image-based phenotyping platforms (Zhang & Zhang, 2018), which are typically used as a base sensor in combination with other types of additional sensors (Kim *et al.*, 2021). The main advantages of using RGB cameras compared to spectral sensors are their relative ease of use, low acquisition and maintenance costs (Kim *et al.*, 2021; Prey, von Bloh, & Schmidhalter, 2018). Multispectral and hyperspectral cameras, on the other hand, can provide higher image resolution, but their costs are considerably higher than for RGB cameras (Morgounov *et al*., 2014). Hyperspectral cameras can detect various stress symptoms in plants, including early drought stress symptoms that cannot be assessed visually (Kim *et al.*, 2021).

The literature indicates that each type of sensor has its optimal application time depending on the stage of plant development, as the accuracy of the measurement results can be affected by light reflection from the soil. For cereals, RGB is recommended for traits' assessment at early stages of plant development, while spectral measurements are recommended for cameras at later stages (Prey, von Bloh & Schmidhalter, 2018). Sensor performance can also be affected by various environmental changes such as sunlight, temperature, humidity and wind. To ensure the accuracy of the data obtained, it is recommended that measurements with RGB cameras are taken at a certain height above the canopy vegetation between 10 am and 2 pm, as the low sunlight angle in the afternoon causes shadows to form on the canopy (Bai *et al.*, 2016; Fernandez-Gallego *et al*., 2018). For better interpretation of the data when measurements are made under changing environmental conditions, it is recommended to also collect data on solar radiation, air temperature and relative humidity (Bai *et al*., 2016).

The use of HTPPs requires the development of state-of-the-art information technologies, as phenotyping of plants with different sensors generates large amounts of data, and the processing of the resulting data is complex (Rosenqvist *et al*., 2019), requires higher-capacity computers for image pre-processing and interpretation of the results (Bai *et al*.,

2016). Precise data structure, definition of algorithms and experiments, and data sharing are crucial as well (Rosenqvist *et al*., 2019).

Morphological traits assessment

Studies on plant greenness traits are of current interest as aboveground biomass, surface transpiration, photosynthetic potential and light interception are closely related to all green parts of plant organs such as leaves, ears and stems (Pask *et al*., 2012). **Early vigour (EV)** is a physiological trait that is the ability of plants to rapidly build leaf area and aboveground biomass during the early stages of development, thereby reducing water evaporation from the soil (Mullan & Reynolds, 2010) and increasing water use efficiency and competitiveness with weeds (Pask *et al*., 2012). EV can be used in cereal breeding programmes as a selection criterion to estimate plant biomass and predict plant productivity (Kipp *et al*., 2013). In traditional methods, EV is assessed visually (in scores), which is strongly influenced by subjective evaluation. If a larger number of genotypes needs to be assessed quickly and accurately, RGB cameras can be used from HTPPs, and these images are analysed in dedicated computer programs (Khadka *et al*., 2020). Spectral camera measurements are recommended especially in large field trials; the calculated Spectral Plant Vigour Index (EPVI) showed a consistent positive correlation with EV at the plant emergence stage over the years (Kipp *et al*., 2013).

Canopy ground cover (CGC) is the proportion of soil covered by the plant canopy, a trait influenced by both the morphology of the plant canopy and the rapid growth capacity of the plant up to and during the tillering stage. In cereal crops, CGC reduces soil water evaporation, soil erosion and nitrogen leaching into groundwater (Prabhakaraa, Hively and McCartyc, 2015) and in wheat also increases competitiveness with weeds (Feledyn-Szewczyk, Jończyk, & Berbeć, 2013). Trait CGC in cereals at both early and late stages of plant development is assessed using visual and HTPP assessment methods (Deery *et al*., 2014; Jimenez-Berni *et al*., 2018) with a strong correlation between the two methods found in spring wheat (Walter *et al*., 2019). In a study by Deery *et al*. (2014), CGC and canopy colour with an RGB camera were evaluated, calculating a greenness index. Another study used a spectral camera to assess this trait in wheat, finding a close correlation (r=0.93) between NDVI and CGC (Prabhakaraa, Hively, & McCartyc, 2015). A study by Deery *et al*. (2021) measured NDVI with GreenSeeker® during the emergence and tillering phases of plants, showing the least variation between measurements, unaffected by differences in light conditions and the presence of dew. When measuring CGC, it should be taken into account that the result may be influenced by intensity of light reflection from canopy, which depends on the structural and optical characteristics of the plants, as well as on the structural parameters of canopy such as row spacing, plant density and seeding direction (Kuester & Spengler, 2018).

Aboveground biomass (AGB) is a trait that represents vegetative plant mass per unit area and can be used to predict grain yield in cereals, including under drought stress (Morgounov *et al*., 2014). The detection of this trait by traditional methods is destructive, time and resource consuming, limiting the evaluation of large number of genotypes. Literature suggests that in barley the NDVI correlates well with AGB during intensive plant growth (Calera, Gonzalez-Piqueras, & Melia, 2004). According to the available information in the literature, significant differences in the change of NDVI index from the tillering to the flowering phase in wheat were found for high and low yielding genotypes (Morgounov *et al*., 2014). Bai *et al*. (2016) used RGB images to detect AGB at early plant stage (before plant tillering) by determining the proportion of green pixel fraction (GPF).

Plant height (PH) is closely related to AGB, which can be influenced by air temperature and soil moisture regime, especially until flowering. Kronenberg *et al*. (2020) points out that at the tillering stage, under conditions of elevated temperature and moisture stress, the process of stem elongation may differ between different wheat genotypes with consequent effects on both AGB and plant productivity. In different studies the height of the cereal canopy was assessed using a soil laser scanner (Kronenberg *et al*., 2020), an ultrasonic sensor (Bai *et al*., 2016), and LIDAR (Jimenez-Berni *et al*., 2018).

The leaf area index (LAI) is a trait that shows the ratio of green leaf area per unit of land surface, and it strongly correlates with cereal AGB and grain yield (Hasan, Sawut, & Chen, 2019). The LAI can estimate how much of a plant's leaf surface area captures solar radiation (González-Sanpedro *et al*., 2008). More accurate LAI measurements can be obtained with optical hand-held instruments, but it is labour and time consuming (González-Sanpedro *et al*., 2008; Nie *et al*., 2016). Ground-based HTPPs such as RGB cameras (Kim *et al*., 2021) and LIDAR or spectral sensors for NDVI detection can be used (Deery *et al*., 2014).

Physiological traits assesment

Physiological-functional traits include various measures of plant functions, such as photosynthesis, respiration, stress tolerance and plant water relations (respiratory function and transpiration) (Zhang & Zhang, 2018), canopy temperature (Li *et al*., 2019) and leaf senescence (Fernandez-Gallego *et al*., 2019).

Chlorophyll fluorescence is a characteristic of **photosynthetic rate (PR)** and indicates the response

of plants under drought stress, usually detected by using fluorescence sensors. This method can measure photosynthetic rate, conductance and gas exchange in leaves of plants under drought stress (Kim *et al*., 2021). High-Throughput phenotyping techniques use change-coupled cameras (CCD) to assess changes in various physiological parameters. It has been noted in literature that using fluorescence analysis makes these studies cumbersome to conduct in the field, as preparatory steps such as adjusting darkness and ensuring constant lighting conditions are required (Tietz *et al*., 2017). In the field, HTPPs can determine the photosynthetic area of the canopy by calculating vegetative indices such as relative green area (GA) and relative greener green area (GGA) (Fernandez-Gallego *et al*., 2019).

Canopy temperature (CT) for cereal describes the water status of the plant and is also used in breeding programmes to assess the response of genotypes under drought stress (Mason & Singh, 2014). CT is influenced by the genotype of the variety, which is determined by factors such as shoot morphology, root depth and root biomass, and external environmental factors such as solar radiation, soil moisture, wind speed, temperature and relative humidity (Li *et al*., 2019; Reynolds, Pask, & Mullan, 2012). CT is traditionally determined with an infrared thermometer. However, the result of this method in large-scale field trials can be affected by weather fluctuations, and the method is labour and time consuming (Deery *et al*., 2016). With HTPPs measurements of CT for cereal crops is recommended to be measured with a thermal camera (between 12 am until 2 pm), a thermal infrared radiometer (Bai *et al*., 2016) or by calculating the NDVI of the canopy at the beginning of the grain filling period (Li *et al*., 2019).

Leaf senescence (LS) is a trait characterised by the yellowing of the green leaves of plants. In cereals, it can be used to assess the effect of biotic (diseases) and abiotic stress (temperature, moisture, nutrient supply) on plants (Distelfeld, Avni, & Fischer, 2014). When LS occurs prematurely in plants, it causes yield and grain quality losses (Gregersen *et al*., 2013). Therefore, in cereal breeding programmes, the trait 'stay-green' (de Souza Luche *et al*., 2015; Lopes & Reynolds, 2012) is used to compare varieties for LS, which is usually assessed visually in scores. In HTPPs measurements of LS for cereals are assessed using spectral sensors by calculating NDVI, which simultaneously provides information in the degree of greenness level of the canopy (Fernandez-Gallego *et al*., 2018) and RGB cameras by calculating vegetative indices – plant senescence reflectance index (Fernandez-Gallego *et al*., 2019).

Nitrogen use efficiency (NUE) is a trait that is receiving increasing attention in the breeding programmes of cereal varieties (Nehe *et al*., 2020; Nguyen *et al*., 2019). A positive aspect of nitrogen use efficient varieties is their ability to maintain grain yield and quality even at reduced nitrogen fertilizer rates. Accurate assessment of this trait is resource-intensive, so the use of HTPPs is an important alternative for comparing NUE between varieties. In N-use related studies, HTPPs digital imaging aims at automated measurements of plant growth, organ development, physiological parameters and biochemical components (Nguyen & Kant, 2018). The application of HTPP methods for the identification of NUE is still under investigation, at first adopting them under controlled cultivation conditions. Banerjee *et al*. (2020) used RGB and hyperspectral imaging methods to identify NUE, 47 vegetative indices described in the literature were tested of which the Transformed Chlorophyll Absorption Reflectance Index (TCARI), the Vogelmann Red Edge Indices (VOG), Miller Index (ZMI) showed the highest correlation with chlorophyll levels. In this study, an improved vegetative index, the normalized difference chlorophyll index in wheat ($NDCI_W$) was developed, which together with digital plant biomass measurements are recommended for use as biomarkers for the selection of N-responsive wheat genotypes during the vegetative stages of plant development.

Grain yield and its components

As grain yield is a complex trait, the use of ground-based HTPP for estimating yield components is also recommended in grain breeding studies (Fernandez-Gallego *et al*., 2018; Hasan *et al*., 2018). **Spike number (SN)** or spike density per unit area is a trait that is formed by the interaction between yield components such as the number of plants and their productive tillering. The rapid assessment of this trait in large-scale studies helps the breeder to predict grain yield early, and it is recommended as a selection criterion in breeding programmes to select high-yielding genotypes (Fernandez-Gallego *et al*., 2018). Fernandez-Gallego *et al*. (2018) used an RGB camera to count spikes in durum wheat (*Triticum turgidum* L. subsp. *durum*), taking one image for each plot at a height of 1 m above the canopy. Automatic image processing was then carried out with algorithms developed for different wheat varieties and plant development stages. In this study, the SN per unit area assessed at flowering correlated better with grain yield than when this trait was assessed at later stages of plant development. The result may be influenced by the senescence of canopy, which complicates the image processing. Also, Hasan *et al*. (2018) recommends using an RGB camera, but only in an oblique position relative to the field surface. It was concluded that in this way, images could be better analysed for various characteristics of spikes such as texture, colour and shape, productivity and disease resistance.

Grain yield (GY) is a performance trait that is commonly the focus in the cereal breeding programmes (Bai *et al*., 2016). Grain yield prediction is a complex task, so it is essential for the breeder to find an efficient method for its accurate and early estimation. Studies using HTPPs with different sensors measure grain yield in cereal crops and analyse whether there are positive correlations between vegetative indices and grain yield, with the aim of finding out which of them could be used for GY prediction. For grain yield estimation Normalised Difference Vegetative Index (NDVI) (Bai *et al*., 2016; Christopher *et al*., 2014; Morgounov *et al*., 2014; Naser *et al*., 2020; Sultana *et al*., 2014), Green Area (GA), Greener Green Area (GGA), Normalized Green-Red Difference Index (NGRDI), and Triangular Greenness Index (TGI) (Fernandez-Gallego *et al*., 2019) are more widely recommended vegetative indices.

Conclusions

Sensors used in ground-based High-Throughput phenotyping platforms (HTPPs), including visible spectral (RGB) and hyperspectral cameras, can be used to assess and analyse morphological and physiological traits and select high-yielding genotypes in cereal breeding programmes. HTPPs methods enable the breeder to evaluate and identify genotypes of interest more quickly and accurately at different stages of plant development, including early stages, and in larger field and laboratory trials than traditional breeding methods. When working with HTPPs methods, depending on the type of sensor used, it is important to follow certain methodological principles for setting up the experiments, taking the measurements, processing the data and interpreting the results. The HTPPs studies carried out so far have mainly focused on wheat, so it is relevant to test the application of these methods also to other cereal species. In cereal breeding programmes, especially under field conditions, further research is needed to identify accurate biomarkers for the identification of nitrogen-use efficient and high-yielding genotypes by HTPPs methods.

Acknowledgments

Paper is prepared in the frame of the EEA/N Baltic Research Programme grant project 'NOBALwheat – breeding toolbox for sustainable food system of the NOrdic BALtic region' (NOBALwheat), Project identification No S-BMT-21-3 (LT08-2-LMT-K-01-032).

References

Bai, G., Ge, Y., Hussain, W., Baenziger, P.S., & Graef, G. (2016). A multi-sensor system for high throughput field phenotyping in soybean and wheat breeding. *Computers and Electronics in Agriculture.* 128, 181–192. DOI: 10.1016/j.compag.2016.08.021.

Banerjee, B.P., Joshi, S., Thoday-Kennedy, E., Pasam, R.K., Tibbits, J., Hayden, M., … Kant, S. (2020). High-throughput phenotyping using digital and hyperspectral imaging-derived biomarkers for genotypic nitrogen response. *Journal of Experimental Botany.* 71(15), 4604–4615. DOI: 10.1093/jxb/eraa143.

Barmeier, G., & Schmidhalter, U. (2017). High-Throughput Field Phenotyping of Leaves, Leaf Sheaths, Culms and Ears of Spring Barley Cultivars at Anthesis and Dough Ripeness. *Front Plant Sci*. 8, 1920. DOI: 10.3389/fpls.2017.01920.

Calera, A., Gonzalez-Piqueras, J., & Melia, J. (2004). Monitoring barley and corn growth from remote sensing data at field scale. *International Journal of Remote Sensing.* 25(1), 97–109. DOI: 10.1080/0143116031000115319.

Christopher, J.T., Veyradier, M., Borrell, A.K., Harvey, G., Fletcher, S., & Chenu, K. (2014). Phenotyping novel stay-green traits to capture genetic variation in senescence dynamics. *Functional Plant Biology*. 41, 1035 – 1048. DOI: 10.1071/FP14052.

Costa, C., Schurr, U., Loreto, F., Menesatti, P., & Carpentier, S. (2019). Plant Phenotyping Research Trends, a Science Mapping Approach. *Front. Plant Sci*. 9, 1933. DOI: 10.3389/fpls.2018.01933.

Centrālās statistikas pārvaldes (CSB) databāze. (last update 31.03.2022). *Lauksaimniecības kultūraugu sējumu platība, kopraža un vidējā ražība 2000 – 2021*. (Sowing area, total and average yield of agricultural crops 2000 – 2021). Retrieved January 11, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__LA__LAG/LAG020/table/tableViewLayout1/. (in Latvian).

de Souza Luche, H., da Silva, J.A.G., da Maia, L.C., & de Oliveira, A.C. (2015). Stay-green: a potentiality in plant breeding. *Ciência Rural*. 45 (10), 1755–1760. DOI: 10.1590/0103-8478cr20140662.

Deery, D., Jimenez-Berni, J., Jones, H., Sirault, X., & Furbank, R. (2014). Review Proximal Remote Sensing Buggies and Potential Applications for Field-Based Phenotyping. *Agronomy.* 5, 349–379. DOI: 10.3390/agronomy4030349.

Deery, D., Smith, D.J., Davy, R., Jimenez-Berni, J.A., Rebetzke, G.J., & James, R.A. (2021). Impact of Varying Light and Dew on Ground Cover Estimates from Active NDVI, RGB, and LiDAR. *Plant Phenomics Volume*. Article ID 9842178, 14 pages. DOI: 10.34133/2021/9842178.

Deery, D.M., & Jones, H. (2021). Review Article. Field Phenomics: Will It Enable Crop Improvement? *Plant Phenomics.*, Article ID 9871989, 16 pages. DOI: 10.34133/2021/9871989.

Deery, D.M., Rebetzke, G.J., Jimenez-Berni, J.A., James, R.A., Condon, A.G., Bovill, W.D., … Furbank, R.T. (2016). Methodology for High-Throughput Field Phenotyping of Canopy Temperature Using Airborne Thermography. *Front. Plant Sci*. 7, 1808. DOI: 10.3389/fpls.2016.01808.

Distelfeld, A., Avni, R., & Fischer, A.M. (2014). Senescence, nutrient remobilization, and yield in wheat and barley. *J Exp Bot*. 65(14), 3783–98. DOI: 10.1093/jxb/ert477.

Eurostat. (2020). *Cereals for the production of grain (including seed) by area, production and humidity*. Retrieved January 11, 2022, from https://ec.europa.eu/eurostat/data/database.

Feledyn-Szewczyk, B., Jończyk, K., & Berbeć, A. (2013). The Morphological Features and Canopy Parameters as Factors Affecting the Competition Between Winter Wheat Varieties and Weeds. *Journal of Plant Protection Research.* 53(3), 203–209. DOI: 10.2478/jppr-2013-0031.

Fernandez-Gallego, J.A., Kefauver, S.C., Vatter, T., Gutiérrez, N.A., Nieto-Taladriz, M.T., & Araus, J.L. (2019). Low-cost assessment of grain yield in durum wheat using RGB images. *European Journal of Agronomy.* 105, 146–156. DOI: 10.1016/j.eja.2019.02.007.

Fernandez-Gallego, J.A., Kefauver, S.C., Gutiérrez, N.A., Nieto-Taladriz, M.T., & Araus, J.L. (2018). Wheat ear counting in-field conditions: high throughput and low-cost approach using RGB images. *Plant Methods.* 14 (22). 1–12. DOI: 10.1186/s13007-018-0289-4.

NOAA National Centers for Environmental Information. (2020). *Global Climate Report*. Retrieved January 11, 2022, from https://www.ncdc.noaa.gov/sotc/global/202013.

González-Sanpedro, M.C., Le Toana, T., Morenob, J., Kergoata, L., & Rubio, E. (2008). Seasonal variations of leaf area index of agricultural fields retrieved from Landsat data. *Remote Sensing of Environment.* 112, 810–824, DOI: 10.1016/j.rse.2007.06.018.

Gregersen, P., Culetic, A., Boschian, L., & Krupinska, K.E. (2013). Plant senescence and crop productivity. *Plant Molecular Biology.* 82(6), 603–622. DOI: 10.1007/s11103-013-0013-8.

Hasan, M.M., Chopin, J.P., Laga, H., & Miklavcic, S.J. (2018). Detection and analysis of wheat spikes using Convolutional Neural Networks. *Plant Methods.* 14 (1), 100. DOI: 10.1186/s13007-018-0366-8.

Hasan, U., Sawut, M., & Chen, S. (2019). Estimating the Leaf Area Index of Winter Wheat Based on Unmanned Aerial Vehicle RGB–Image Parameters. *Sustainability.* 11 (23), 6829. DOI: 10.3390/su11236829.

Jimenez-Berni, J.A., Deery, D.M., Rozas-Larraondo, P., Condon, A.(T.)G., Rebetzke, G.J., James, R.A., … Sirault, X.R.R. (2018). High Throughput Determination of Plant Height, Ground Cover, and Above-Ground Biomass in Wheat with LiDAR. *Frontiers in Plant Science*. 9, 237. DOI: 10.3389/fpls.2018.00237.

Khadka, K., Earl, H.J., Raizada, M.N., & Navabi, A. (2020). A Physio-Morphological Trait-Based Approach for Breeding Drought Tolerant Wheat. *Front. Plant Sci*. 11, 715. DOI: 10.3389/fpls.2020.00715.

Kim, M., Lee, C., Hong, S., Kim, S.L., Baek, J.-H., & Kim, K.-H. (2021). High-Throughput Phenotyping Methods for Breeding Drought-Tolerant Crops. *Int. J. Mol. Sci.* 22 (15), 8266. DOI: 10.3390/ijms22158266.

Kim, Y., Glenn, D.M., Park, J., Ngugi, H.K., & Lehman, B.L. (2016). Characteristics of active spectral sensor for plant sensing. *American Society of Agricultural and Biological Engineers*. 55(1), 293–301. DOI: 10.13031/2013.41239.

Kipp, S., Mistele, B., Baresel, P., & Schmidhalter, U. (2013). High-throughput phenotyping early plant vigour of winter wheat. *Europ. J. Agronomy* 52, 271–278. DOI: 10.1016/j.eja.2013.08.009.

Kronenberg, L., Yates, S., Boer, M.P., Kirchgessner, N., Walter, A., & Hund, A. (2020). Temperature response of wheat affects final height and the timing of stem elongation under field conditions. *Journal of Experimental Botany.* 72(2), 700–717. DOI: 10.1093/jxb/eraa471.

Kuester, T., & Spengler, D. (2018). Structural and Spectral Analysis of Cereal Canopy Reflectance and Reflectance Anisotropy. *Remote Sens*. 10, 1767; DOI: 10.3390/rs10111767.

Laidig, F., Feike, T., Klocke, B., Macholdt, J., Miedaner, T., Rentel, D., & Piepho, H.P. (2021). Long-term breeding progress of yield, yield-related, and disease resistance traits in five cereal crops of German variety trials. *Theor Appl Genet.* 134 (12), 3805–3827. DOI: 10.1007/s00122-021-03929-5.

Li, D., Quan, C., & Song, Z. (2021). High-Throughput Plant Phenotyping Platform (HT3P) as a Novel Tool for Estimating Agronomic Traits from the Lab to the Field. *Front. Bioeng. Biotechnol.* 8, 1–24. DOI: 10.3389/fbioe.2020.623705.

Li, D., Quan, C., Song, Z., Li, X., Yu, G., Li, C., & Muhammad, A. (2021). High-Throughput Plant Phenotyping Platform (HT3P) as a Novel Tool for Estimating Agronomic Traits from the Lab to the Field. *Front. Bioeng. Biotechnol.* 8, 623705. DOI: 10.3389/fbioe.2020.623705.

Li, X., Ingvordsen, C.H., Weiss, M., Rebetzke, G.J., Condon, A.G., James, R.A., & Richards, R.A. (2019). Deeper roots associated with cooler canopies, higher normalized difference vegetation index, and greater

yield in three wheat populations grown on stored soil water. *Journal of Experimental Botany*. 70, (18), 4963–4974. DOI:10.1093/jxb/erz232.

Lin, Y. (2015). LiDAR: an important tool for next-generation phenotyping technology of high potential for plant phenomics? *Computers and Electronics in Agriculture*. 119, 61–73. DOI: 10.1016/j.compag.2015.10.011.

Lopes, M.S., & Reynolds, M. (2012). Stay-green in spring wheat can be determined by spectral reflectance measurements (normalized difference vegetation index) independently from phenology. *Journal of Experimental Botany.* 63 (10), 3789–98. DOI: 10.1093/jxb/ers071.

Mason, R.E., & Singh, R.P. (2014). Considerations When Deploying Canopy Temperature to Select High Yielding Wheat Breeding Lines under Drought and Heat Stress. *Agronomy.* 4, 191–201. DOI: 10.3390/agronomy4020191.

Morgounov, A., Gummadov, N., Belen, S., Kaya, Y., Keser, M., & Mursalova, J. (2014). Association of digital photo parameters and NDVI with winter wheat grain yield in variable environments. *Turkish J. Agric. For*. 38, 624–632. DOI: 10.3906/tar-1312-90.

Mullan, D.J., & Reynolds, M.P. (2010). Quantifying genetic effects of ground cover on soil water evaporation using digital imaging. *Functional Plant Biology.* 37(8), 703–712. DOI: 10.1071/FP09277.

Naser, M.A., Khosla, R., Longchamps, L., & Dahal, S. (2020). Using NDVI to Differentiate Wheat Genotypes Productivity Under Dryland and Irrigated Conditions. *Remote Sens*. 12, 824. DOI: 10.3390/rs12050824.

Nehe, A.S., Misra, S., Murchie, E.H., Chinnathambi, K., Singh Tyagi, B., & Foulkes, M.J. (2020). Nitrogen partitioning and remobilization in relation to leaf senescence, grain yield and protein concentration in Indian wheat cultivars. *Field Crops Research.* 251, 107778. DOI: 10.1016/j.fcr.2020.107778.

Nguyen, G.N., Maharjan, P., Maphosa, L., Vakani, J., Thoday-Kennedy, E., & Kant, S. (2019). A robust automated image-based phenotyping method for rapid vegetative screening of wheat germplasm for nitrogen use efficiency. *Frontiers in Plant Science*. 10, 1372. DOI: 10.3389/fpls.2019.01372.

Nguyen, G.N., & Kant, S. (2018). Improving nitrogen use efficiency in plants: Effective phenotyping in conjunction with agronomic and genetic approaches. *Functional Plant Biology*. 45(6), 606–619. DOI: 10.1071/FP17266.

Nie, S., Wang, C., Dong, P., & Xi, X. (2016). Estimating leaf area index of maize using airborne full-waveform lidar data. *Remote Sensing Letters*. 7 (2), 111–120. DOI: 10.1080/2150704X.2015.1111536.

Ortiz, R., Sayre, K.D., Govaerts, B., Gupta, R., Subbarao, G.V., Ban, T., … Reynolds M. (2008). Climate change: Can wheat beat the heat? *Agriculture, Ecosystems & Environment*. 126, 46–58. DOI: 10.1016/j.agee.2008.01.019.

Pask, A.J.D., Pietragalla, J., Mullan, D.M., & Reynolds, M.P. (2012). Physiological Breeding II: A Field Guide to Wheat Phenotyping. Mexico, D.F.: CIMMYT.

Prabhakaraa, K., Hively, W.D., & McCartyc, G.W. (2015). Evaluating the relationship between biomass, percent groundcover and remote sensing indices across six winter cover crop fields in Maryland, United States. *International Journal of Applied Earth Observation and Geoinformation.* 39, 88–102. DOI: 10.1016/j.jag.2015.03.002.

Prey, L., von Bloh, M., & Schmidhalter, U. (2018). Evaluating RGB Imaging and Multispectral Active and Hyperspectral Passive Sensing for Assessing Early Plant Vigor in Winter Wheat. *Sensors.* 18, 2931, DOI: 10.3390/s18092931.

Reynolds, M., Chapman, S., & Crespo-Herrera, L. (2020). Breeder friendly phenotyping. *Plant Science.* 295, 1–21. DOI: 10.1016/j.plantsci.2019.110396.

Reynolds, M.P., Pask, A.J.D., & Mullan, D.M. (2012). Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation. CIMMYT: Mexico City, Mexico.

Rosenqvist, E., Großkinsky, D.K., Ottosen, C-O., & van de Zedde, R. (2019). The Phenotyping Dilemma – The Challenges of a Diversified Phenotyping Community Front. *Plant Sci.* 10, 163. DOI: 10.3389/fpls.2019.00163.

Rubiales, D., Annicchiarico, P., Patto, M.C.V., & Julier, B. (2021). Legume Breeding for the Agroecological Transition of Global Agri-Food Systems: A European Perspective. *Front. Plant Sci*. 12, 782574. DOI: 10.3389/fpls.2021.782574.

Sultana, S.R., Ali, A., Ahmad, A., Mubeen, M., Zia-Ul-Haq, M., Ahmad, S., … Jaafar, H.Z.E. (2014). Normalized Difference Vegetation Index as a Tool for Wheat Yield Estimation: A Case Study from Faisalabad, Pakistan. *The Scientific World Journal.* 2014, Article ID 725326, 1–8. DOI: 10.1155/2014/725326.

Tietz, S., Hall, C.C., Cruz, J.A., & Kramer, D.M. (2017). NPQ (T): a chlorophyll fluorescence parameter for rapid estimation and imaging of non-photochemical quenching of excitons in photosystem-II-associated antenna complexes. *Plant Cell Environ.* 40 (8), 1243–1255. DOI: 10.1111/pce.12924.

Walter, J., Edwards, J., Cai, J., McDonald, G., Miklavcic, S.J., & Kuche, H. (2019). High-Throughput Field Imaging and Basic Image Analysis in a Wheat Breeding Programme. *Front. Plant Sci*. 10, 449. DOI: 10.3389/fpls.2019.00449.

White, J.W., Andrade-Sanchez, P., Gore, M.A., Bronson, K.F., Coffelt, T.A., Conley, M.M., … Wang, G. (2012). Field-based phenomics for plant genetics research. *Field Crops Research*. 133, 101–112. DOI: 10.1016/j.fcr.2012.04.003.

Würschum, T., (2019). Modern field phenotyping opens new avenues for selection. In: Applications of Genetic and Genomic Research in Cereals. *Woodhead Publishing*. 233–250. DOI: 10.1016/B978-0-08-102163-7.00011-9.

Yang, W., Feng, H., Zhang, X., Zhang, J., Doonan, J.H., Batchelor, W.D., … Yan, J. (2020). Crop Phenomics and High-Throughput Phenotyping: Past Decades, Current Challenges, and Future Perspectives. *Mol. Plant*. 13 (2), 187–214. DOI: 10.1016/j.molp.2020.01.008.

Zhang, Y., & Zhang, N. (2018). Imaging technologies for plant high-throughput phenotyping: A review. *Frontiers of Agricultural Science and Engineering.* 5 (4), 406–419. DOI: 10.15302/J-FASE-2018242.

 DOI: 10.22616/rrd.28.2022.004

PARAMETERS USED FOR THE EVALUATION OF POTATO (*SOLANUM TUBEROSUM* L.) NITROGEN USE EFFICIENCY: A REVIEW

***Lasma Rabante-Hane[1,2], Ilze Skrabule[1], Ina Alsina[2]**
[1]Institute of Agricultural Resources and Economics, Latvia
[2]Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: lasma.rabante@arei.lv

Abstract
Potato is one of the important crops worldwide, and cultivation requires a lot of resources and nitrogen (N) to ensure yield. This kind of growing technology can cause environmental pollution. It is necessary to optimize the management and use of potatoes with high nitrogen use efficiency (NUE) varieties as an alternative to the application of large amounts of fertilizers to improve the environmental impact of potato production without affecting yield and quality. The aim of this review is to find various morphological and physiological characteristics of the potato crop that can be used in potato breeding for NUE evaluation and to create new varieties with high NUE. Looking for traits such as yield, protein and starch content, each variety has its limits that can be affected by climatic conditions. Area Under Canopy Cover Progress Curve (AUCCPC) is potentially good for detecting NUE in field conditions. Nitrogen-efficient genotypes tend to have early canopy development but a low amount of N in tubers. Due to different factors that can interact with genotypes under field conditions, the experiments in controlled conditions as *in vitro* system can be used for the investigation of genotypes in a short period. Under *in vitro* conditions, root development can be observed very well, which can usually be impossible in soil experiments.
Key words: morphological parameters, *in vitro*, yield, protein, starch.

Introduction

Potato (*Solanum tuberosum* L.) is known to be the third most important crop in the world by production and the fifth by consumption (Haverkort & Struik, 2015; Devaux, Kromann, & Ortiz, 2014). According to Van Dingenen *et al*. (2019), potato tubers are a great source of starch, antioxidants, vitamins, essential amino acids, and important minerals. Historically, potato production in Latvia has been one of the most important branches of agriculture. Since 2000, the potato growing areas decreased by 33 thousand hectares and potato production has taken a downward turn by 370 thousand tonnes. To ensure potato cultivation at the same level as now, extending the potato growing area or increasing the yield is necessary (Ministry of Agriculture, 2021). The potato requires abundant nitrogen (N) (Haverkort, 2018). Most of the N in the soil is partly available for plants (Zebarth & Rossen 2007). Large N fertilization input, combined with the shallow root system of potatoes (Iwama, 2008), can result in nitrate leaching and subsequent contamination of groundwater (Frink, Waggoner, & Ausubel, 1999; Milburn *et al*., 1990; Sharifi & Zebarth, 2006), and atmosphere through gaseous emissions (Hirel *et al*., 2007). European legislation (Nitrate Directive (91/767/EEC) and Water Framework Directive (2000/60/EC)) has established limits on the N input in crop production in Europe (Vos, 2009). Still, directives have struggled with the low support of farmers as well as various conflicts between environmental and income support objectives (Hasler *et al*., 2022). New potato varieties with improved nitrogen use efficiency (NUE) will reduce the environmental impact of potato production without affecting yield and quality (Vos, 2009), will be acceptable for environmentally friendly farming systems and be beneficial to improve nutrient management. The aim of this review is to find various morphological and physiological traits of the potato crop that can be used in potato breeding for NUE evaluation in order to create new varieties with improved NUE.

Materials and Methods

The semi-systematic monographic method was used to analyse and summarise the main information on potato NUE and traits that could possibly be implemented as an alternative for NUE evaluation. NUE is considered as potatoes' ability to use uptake N in the development of canopy cover, protein and starch content, and yield.

Results and Discussion

Many crops, including potato, have high genetic variation, making breeding of NUE practical (Lammerts van Bueren 2010; Lammerts van Bueren *et al*., 2014). Unfortunately, when it comes to potatoes breeding strategies towards NUE, there is lack of information (Lammerts van Buren & Struik, 2017). Various quality traits such as tuber starch content, tuber protein content, tuber yield, and tuber size distribution are affected by the available N amount (Zebarth *et al*., 2004). Weather conditions need to be considered as well (Vos, 2009). Cohan et al. (2018) explained how the variation of results can be determined by Nitrogen × Environmental interaction.

Nitrogen Use Efficiency

Potato varieties with improved NUE will perform well under high and low N availability (Ospina *et al*., 2014). Various definitions of NUE have been described, but it may differ in various crops (Fageria

& Baligar, 2005). Moll, Kamprath, & Jackson (1982) defined NUE as the yield per unit of available N in the soil, including the residuals N present in the soil and the fertilizer. Mostly, potato NUE is explained as the production of dry matter per unit of N in soil (Getahun *et al*., 2020). In Meise et al. (2019) study, potato NUE has been calculated as fresh tuber yield produced per unit of N in the soil. There have been cases where potato NUE is defined as tuber dry matter (kg) per total N available in the soil (kg), also known as agronomic NUE (Tiemens-Hulscher, Lammerts van Bueren, & Struik, 2014). Hawkesford & Griffith's (2019) study established NUE based on cereal crop yield per unit of total available nitrogen in the soil. The value obtained is equivalent to potato dry matter yield per available N in the soil like mentioned in Tiemens-Hulscher, Lammerts van Bueren, & Struik (2014). It is suggested that NUE differs and depends on the potato genotype and maturity type (Milroy, Wang, & Sandras, 2019). According to Hirel et al. (2007), NUE can be divided into nitrogen uptake efficiency (NUpE) and nitrogen utilization efficiency (NUtE). NUpE describes the plant's ability to capture N from the soil and can be defined as the N content in the plant per available N (Meise *et al*., 2019; Shum & Jansen, 2014). The total N uptake reflects in the biomass (Ierna & Mauromicale, 2019) and canopy development (Tiemens-Hulscher, Lammerts van Bueren, & Struik, 2014). The NUpE can differ between years, N fertilizer amount and variety. NUtE is plants' ability to produce yield or quality parameters and can be defined as dry matter yield per available N, resulting not only in tuber yield but also in starch and protein content (Ospina *et al*., 2014; Tiwari *et al*., 2020). In potatoes with good NUE, NUtE will increase as crop available N decreases (Bohman, Rosen, & Mulla, 2021), because an increasing amount of N has a negative effect on NUE and NUtE (Mirosavljević *et al*., 2019). This is the reason why NUE is better detected in cases with a smaller amount of N in the growing media (Hawkesford & Griffiths, 2019).

Canopy Development

The potato crop is very sensitive to the amount of N fertilizer. Depending on a higher N availability, plants tend to have longer life cycles and even have larger leaves (Haris, 1992). Oliveira (2000) mentioned that more N can increase the number of photosynthetically active leaves as well as induce leaf appearance and branching upper part of the plant. On the contrary, Biemond & Vos (1992) described that leaf appearance on a branch is not affected by available N. There are several empirical models with a focus on potato canopy development (MacKerron & Waister, 1985). Canopy cover can be used in the vegetation season for the evaluation of NUE (Gastal *et al*., 2015; Tiemens-Hulscher, Lammerts van Bueren, & Struik, 2014). The Area Under Canopy Cover Progress Curve (AUCCPC) model developed by Khan (2012) uses three basic equations to describe canopy expansion, maintenance, and senescence. This AUCCPC model needs Canopy ground cover (%) (Ospina *et al*., 2014) and temperature, calculated in thermal time (Khan, 2012). According to Yin et al. (2003), instead of thermal time, beta thermal time can be used. The descriptive AUCCPC can be used to determine the types of potato maturity (Khan, van Eck, & Struik, 2013). Potato crops can adapt leaf development to limit N, while still maintaining productivity per leaf area by changing individual leaf size and branching (Vos, 2009). AUCCPC model can be used to describe the interaction between genotype and available N in soil and strongly correlate with NUE (Tiemens-Hulscher, Lammerts van Bueren, & Struik, 2014). The accumulation and production of dry matter in the potato crop are related to canopy development and leaf area index (Haverkort *et al*., 1991). The leaf area index was correlated with yield and yield parameters by increasing the proportion of large tubers (Van Oijen, 1991). These parameters can be increased by the amount of N available (Kleinkopf, Westermann, & Dvelle, 1981). Ospina et al. (2014) reported that nitrogen significantly affected the thermal time needed to reach maximum soil cover, which was higher in lover available N compared to high available nitrogen. Ospina (2014) also mentioned how NUE for genotypes that performed well under a rich N showed the same tendency at low N. AUCCPC is highly correlated with yield (Ospina *et al*., 2014). Tiemens-Hulscher, Lammerts van Bueren, & Struik (2014) under organic conditions observed that cultivars that rapidly established a high maximum soil cover can maintain this maximum for long and slowly leaf senescence potentially sustaining high yields. The study explained that nitrogen-efficient genotypes suitable for organic farming must have early canopy development with high agronomic NUE and NUtE, but a low amount of N in tubers.

Yield

The increase of N availability in the soil will increase potato yield. However, each variety has its limits (Fontes *et al*., 2010). Yield is the result of genotype, environment and genotype × environment interaction (Steyn *et al*., 2016). Higher N availability will induce leaf development, consequently inducing tuber bulking (Goffart, Olivier, & Frankinet, 2008). The results presented by Kasal et al. (2011) showed a significant relationship between NUE and the amount of rainfall and temperature levels in the vegetation season towards yield building. Crop's ability to uptake N and show its NUE can be affected by soil composition and microbial processes in the soil (Burger & Jackson, 2004; Walley *et al*., 2002). According to Milroy, Wang,

& Sadras (2019), yields increased with an increase in N availability during vegetation, especially when the genotype has a later maturity type. Still, the effects of nitrogen and maturity type depend on meteorological conditions in each location. In the case of the potato crop, Skrabule, Vaivode, & Ruža (2012) concluded that increasing the amount of N above 120 kg ha^{-1} will not result in a significant increase in yield, which can coincide with the work by Mőller et al. (2007), who indicates that 48% of the variation in yield can be determined by differences in nitrogen availability. Using a smaller amount of N, the potato will use more efficiently N compounds that are available in the soil (Skrabule, Vaivode, & Ruža, 2012). Plant density is also an important factor for establishing uniformity and ensuring high yields (Masarirambi *et al*., 2012). Nitrogen availability affects numerous traits and yield components, such as the final number of the tubers and harvest index (Biemond & Vos, 1992). Nitrogen also affects different quality aspects, such as tuber size distribution (Zebarth *et al*., 2004). Hawkesford (2014) conclude with Zebarth et al. (2004), that increasing the yield without additional N will result in better NUE and an effective limitation of N in an environment without the expense of quality.

Protein

According to Haile, Nigussie & Ayana (2012), protein content in wheat (*Triticum aestivum*) grains can be strongly influenced by the amount of available N, time of application, and genotype. The results between yield and protein, indicate an inverse yield-protein relationship. The amino acids originating from nitrogen uptake are also used for the synthesis of enzymes and proteins that build the architecture of plants. Protein content in plants rises after the flowering stage when a large amount of uptaken N is used for protein synthesis by realising free amino acids from protein hydrolysis that are exported to reproductive storage organs (Masclaux *et al*., 2001; Masclaux-Daubresse *et al*., 2010). The main potato protein patatin makes about 40% of the potato-soluble protein (Camire, Kubow, & Donnelly, 2009). This kind of protein can be found in tubers and stolons, and its quality aspects have better properties than soy (*Glycine max*) proteins (Waglay & Karboune, 2016). Bartá & Bártová (2008) and Bártová et al. (2013) have characterized patatin as a storage protein. The best connection between NUE and patatin is described in Lehesranta et al. (2007), where authors explain, that patatin and other storage proteins are negatively affected by lower available N in the soil.

Starch

The starch content and starch yield are significant parameters for potato starch processing. Varieties with higher starch content can help in cases when environmental conditions weren't so favourable for yield (Ruža, Skrabule, & Vaivode, 2013). The available N influences the starch content and starch yield by positively affecting canopy development (Koch *et al*., 2020). In most cases, increasing available N has a negative effect on starch content in tubers (Bachmann-Pfabe & Dehmer, 2020; Öztürk *et al*., 2010). Kumar et al. (2007) indicate that tuber quality is determined by genotype. However, the results of Ruža, Skrabule, & Vaivode (2013) showed that the starch content tends to decrease with a higher fertilization level. N deficiency results in the accumulation of carbohydrates such as sugars and starch (Remans *et al*., 2006; Scheible *et al*., 2004). Tuber yield negatively correlated with tuber starch content (Schönhals, 2014). However, Bombik, Rymuza, & Olszewski (2019) found no significant correlation between tuber yield and starch content. Any physiological and morphological changes are not only controlled by the environment but also genetically, to develop varieties with good NUE, knowledge about the genetics of the NUE and NUE-related traits, such as starch, is vital (Getahun, 2017). According to Zhang et al. (2020) experiment, N metabolism showed a close correlation with NUtE, which indicates different mechanisms of how potatoes respond to N deficiency.

NUE evaluation under controlled conditions

It may not be possible to fully assess the entire genotypes for NUE under field conditions, but it's possible to evaluate most of them by improving existing and evolving new phenotyping methods that are based on different growing conditions (Cohan *et al*., 2018). Field testing of potatoes allows only one or two trials per year, depending on the climate zone, while the use of *in vitro* culture systems allows investigating many plants under highly controlled conditions, excluding different pathogen effects in a short period (Schum & Jansen, 2014; Schum *et al*., 2017). *In vitro* culture can be a great opportunity to monitor root growth in different N supplies (Shum *et al*., 2017). Increased root growth under environmental stress conditions can be an advantage because it allows improved nutrient and water uptake by using resources from the remote soil zone (Ghanem *et al*., 2011). Such morphological characteristics as the number and length of roots depend on plant species, genotype and water availability (Malamy, 2005; Christensen *et al*., 2017). Changes in the soil can induce the adaptive response to development (Ghanem *et al*., 2011). N deficiency induces an increased outgrowth of lateral roots (Hawkesford, 2014). During the vegetative phase, the roots of plants behave as sink organs for the assimilation of inorganic N and the synthesis of amino acids originating from uptake and reduction of the nitrate assimilatory pathway (Hirel & Lea, 2001). Unfortunately, potatoes are known to have a shallow root system with genetically determined abundant

root development, but roots for genotypes with higher NUE (Sharifi, Zebarth, & Coleman, 2007) can develop better. According to Hajari, Snyman, & Watt (2014; 2015), experiments on NUE related parameters *in vitro* are rare. While Meise et al. (2018, 2019) mentioned pot trials as a great alternative to field trials to assess NUE and assess N deficiency. The same approach was used by Pourazari, Anderson, & Weih (2018) conducting experiments in the greenhouse to evaluate tuber yield associated with plants available N, as well as Kollaricsné Horváth et al. (2019), explored the genetic expression of NUE genes potato genotypes using pot trial. Xie et al. (2018) used a hydroponic approach to evaluate the shortage and availability of N in potatoes. According to Shum et al. (2017), the stability of plant performance under different amounts of N in the *in vitro* system can correlate to the yield stability of cultivars in pot trials and field trials not only for prescreening of germplasm and identification of different genotypes but also for the investigation of different NUE parameters.

Conclusions

It is necessary to optimize the management and use of high-NUE potato varieties as an alternative to the existing large amounts of fertilizer application existing to improve the environmental impact of potato production without affecting yield and quality standards. Varieties with high NUE will help increase potato yield and reduce the cost of production and the environmental impact. NUE can be calculated with different methods or detected by various traits of the potato crop. A very good predictor of NUE in field trials can be AUCCPC and yield. AUCCPC and yield are highly correlated between themselves and depend on the available N from the soil. Protein and starch content are also good traits that show how well the potato genotype interacts with the amount of N. Still, field trials are exposed to different factors and can take a lot of years and resources to conduct results, and NUE assessment in controlled conditions in greenhouses and laboratories are needed. The *in vitro* system allows the investigation of many plants under controlled conditions in a short period. Under *in vitro* conditions, root development can be observed very well, which can usually be impossible in soil experiments.

Acknowledgements

This research benefits from the Project on Fundamental and Applied Studies (FLPP) 'Breeding for low input and organic farming systems: nitrogen use efficiency and quality aspects of potato protein'.

References

Bachmann-Pfabe, S., & Dehmer, K.J. (2020). Evaluation of Wild Potato Germplasm for Tuber Starch Content and Nitrogen Utilization Efficiency. *Plants.* 9 (7), 833–852. DOI: 10.3390/plants9070833.

Bartá, J., & Bártová, V. (2008). Patatin, the major protein of potato (*Solanum tuberosum* L.) tubers, and its occurrence as genotype effect: Processing versus table potatoes. *Czech Journal of Food Sciences*. 26(5), 347–359.

Bártová, V., Diviš, J., Bárta, J., Brabcová, A., & Švajnerová, M. (2013). Variation of nitrogenous components in potato (Solanum tuberosum L.) tubers produced under organic and conventional crop management. *European Journal of Agronomy.* 49, 20–31. DOI: 10.1016/j.eja.2013.02.009.

Biemond, H., & Vos, J. (1992). Effects of nitrogen on the development and growth of the potato plant. 2. The partitioning of dry matter, nitrogen and nitrate. *Annals of Botany.* 70(1), 37–45. DOI: 10.1093/oxfordjournals.aob.a088437.

Bohman, B.J., Rosen, C.J., & Mulla, D.J. (2021). Relating nitrogen use efficiency to nitrogen nutrition index for evaluation of agronomic and environmental outcomes in potato. *Field Crops Research*. 262, 108041. DOI: 10.1016/j.fcr.2020.108041.

Bombik, A., Rymuza, K., & Olszewski, T. (2019). Variation and correlation of starch potato utility features and tuber quality traits. *Acta Agrophys.* 26, 29–42. DOI: 10.31545/aagr/114397.

Burger, M., & Jackson, L.E. (2005). Plant and microbial nitrogen use and turnover: rapid conversion of nitrate to ammonium in soil with roots. *Plant and Soil*. 266(1), 289–301. DOI: 10.1007/s11104-005-1362-0.

Camire, M.E., Kubow, S., & Donnelly, D.J. (2009). Potatoes and human health. *Critical Reviews in Food Science and Nutrition.* 49(10), 823–840. DOI: 10.1080/10408390903041996.

Christensen, C.T., Zotarelli, L., Haynes, K.G., & Colee, J. (2017). Rooting characteristics of *Solanum chacoense* and *Solanum tuberosum* in vitro. *American Journal of Potato Research*. 94(6), 588–598. DOI: 10.1007/s12230-017-9597-x.

Cohan, J.P., Hannon, C., Houilliez, B., Gravoueille, J.M., Geille, A., Lampaert, E., & Laurent, F. (2018). Effects of potato cultivar on the components of nitrogen use efficiency. *Potato Research*. 61(3), 231–246. DOI: 10.1007/s11540-018-9371-6.

Devaux, A., Kromann, P., & Ortiz, O. (2014). Potatoes for sustainable global food security. *Potato Research*. 57(3), 185–199. DOI: 10.1007/s11540-014-9265-1.

European Parliament and the Council. (1991). *Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources*.

European Parliament and of the Council. (2000). *Directive 2000/60/EC establishing a framework for Community action in the field of water policy*. Retrieved February 10, 2022, from http://data.europa.eu/eli/dir/2000/60/oj.

Fageria, N.K., & Baligar, V.C. (2005). Enhancing nitrogen use efficiency in crop plants. *Advances in agronomy*. 88, 97–185. DOI: 10.1016/S0065-2113(05)88004-6.

Fontes, P.C., Braun, H., Busato, C., & Cecon, P.R. (2010). Economic optimum nitrogen fertilization rates and nitrogen fertilization rate effects on tuber characteristics of potato cultivars. *Potato Research*. 53(3), 167–179.

Frink, C.R., Waggoner, P.E., & Ausubel, J.H. (1999). Nitrogen fertilizer: retrospect and prospect. *Proceedings of the National Academy of Sciences*. 96(4), 1175–1180. DOI: 10.1073/pnas.96.4.1175.

Gastal, F., Lemaire, G., Durand, J.L., & Louarn, G. (2015). Quantifying crop responses to nitrogen and avenues to improve nitrogen-use efficiency. In *Crop physiology* (pp. 161–206). Lusignan, France: Academic Press.

Getahun, B.B. (2017). *Genetic Diversity of Potato for Nitrogen Use Efficiency under Low Input Conditions in Ethiopia*. Doctoral dissertation, University of Wageningen University, Wageningen, The Netherlands.

Getahun, B.B., Kassie, M.M., Visser, R.G., & van der Linden, C.G. (2020). Genetic diversity of potato cultivars for nitrogen use efficiency under contrasting nitrogen regimes. *Potato Research*. 63(2), 267–290. DOI: 10.1007/s11540-019-09439-8.

Ghanem, M.E., Hichri, I., Smigocki, A.C., Albacete, A., Fauconnier, M.L., Diatloff, E., ... Pérez-Alfocea, F. (2011). Root-targeted biotechnology to mediate hormonal signalling and improve crop stress tolerance. *Plant cell reports.* 30(5), 807–823. DOI: 10.1007/s00299-011-1005-2.

Goffart, J.P., Olivier, M., & Frankinet, M. (2008). Potato crop nitrogen status assessment to improve N fertilization management and efficiency: past–present–future. *Potato Research*. 51(3), 355–383.

Hajari, E., Snyman, S.J., & Watt, M.P. (2014). Inorganic nitrogen uptake kinetics of sugarcane (*Saccharum spp*.) varieties under in vitro conditions with varying N supply. *Plant Cell, Tissue and Organ Culture (PCTOC)*. 117(3), 361–371. DOI: 10.1007/s11240-014-0445-0.

Hajari, E., Snyman, S.J., & Watt, M.P. (2015). Nitrogen use efficiency of sugarcane (Saccharum spp.) varieties under in vitro conditions with varied N supply. *Plant Cell, Tissue and Organ Culture (PCTOC*). 122(1), 21–29. DOI: 10.1007/s11240-015-0746-y.

Haile, D., Nigussie, D., & Ayana, A. (2012). Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. *Journal of soil science and plant nutrition*. 12(3), 389–410.

Haris, P.M. (1992). Mineral nutrition. In Haris, P.M. (Eds.) *The potato crop* (pp. 162–213). Springer, Dordrecht.

Hasler, B., Termansen, M., Nielsen, H.Ø., Daugbjerg, C., Wunder, S., & Latacz-Lohmann, U. (2022). European agri-environmental policy: Evolution, effectiveness, and challenges. Review of Environmental Economics and Policy, 16(1), 000–000.

Haverkort, A.J., Uenk, D., Veroude, H., & Van de Waart, M. (1991). Relationships between ground cover, intercepted solar radiation, leaf area index and infrared reflectance of potato crops. *Potato Research*. 34(1), 113–121. DOI: 10.1007/BF02358105.

Haverkort, A.J., & Struik, P.C. (2015). Yield levels of potato crops: recent achievements and future prospects. *Field Crops Research*. 182, 76–85. DOI: 10.1016/j.fcr.2015.06.002.

Haverkort, A.J. (2018). *Potato handbook. Crop of the future.* Wageningen, The Netherlands: Aardappelwereld BV.

Hawkesford, M.J. (2014). Reducing the reliance on nitrogen fertilizer for wheat production. *Journal of cereal science*. 59(3), 276–283. DOI: 10.1016/j.jcs.2013.12.001.

Hawkesford, M.J., & Griffiths, S. (2019). Exploiting genetic variation in nitrogen use efficiency for cereal crop improvement. *Current opinion in plant biology*. 49, 35–42. DOI: 10.1016/j.pbi.2019.05.003.

Hirel, B., & Lea, P.J. (2001). Ammonia assimilation. In *Plant nitrogen* (pp. 79–99). Berlin, Germany, Springer.

Hirel, B., Le Gouis, J., Ney, B., & Gallais, A. (2007). The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. *Journal of experimental botany*. 58(9), 2369–2387. DOI: 10.1093/jxb/erm097.

Ierna, A., & Mauromicale, G. (2019). Sustainable and profitable nitrogen fertilization management of potato. *Agronomy*. 9(10), 582. DOI: 10.3390/agronomy9100582.

Iwama, K. (2008). Physiology of the potato: new insights into root system and repercussions for crop management. *Potato Research*. 51(3), 333–353. DOI: 10.1007/s11540-008-9120-3.

Kasal, P., Ruzek, P., Kusa, H., & Cepl, J. (2011). Effective ways of mineral nitrogen fertilizer applications and their effect on nitrogen use by potatoes, yield and potato quality. In 18th Triennial Conference of the European Association for Potato Research. July 24th – 29th 2011. (p. 151).

Khan, M.S. (2012). *Assessing genetic variation in growth and development of potato*. Doctoral dissertation, Wageningen University and Research, Wageningen, The Netherlands.

Khan, M.S., van Eck, H.J., & Struik, P.C. (2013). Model-based evaluation of maturity type of potato using a diverse set of standard cultivars and a segregating diploid population. *Potato Research,* 56(2), 127–146.

Kleinkopf, G.E., Westermann, D.T., & Dwelle, R.B. (1981). Dry matter production and nitrogen utilization by six potato cultivars. *Agronomy Journal*. 73, 799–802.

Koch, M., Naumann, M., Pawelzik, E., Gransee, A., & Thiel, H. (2020). The importance of nutrient management for potato production Part I: Plant nutrition and yield. *Potato research*. 63(1), 97–119. DOI: 10.1007/s11540-019-09431-2.

Kollaricsné Horváth, M., Hoffmann, B., Cernák, I., Baráth, S., Polgár, Z., & Taller, J. (2019). Nitrogen utilization of potato genotypes and expression analysis of genes controlling nitrogen assimilation. *Biologia Futura*. 70(1), 25–37. DOI: 10.1556/019.70.2019.04.

Kumar, P., Pandey, S.K., Singh, B.P., Singh, S.V., & Kumar, D. (2007). Effect of nitrogen rate on growth, yield, economics and crisps quality of Indian potato processing cultivars. *Potato Research*. 50(2), 143–155.

Lammerts van Bueren, E.T. (2010). A collaborative breeding strategy for organic potatoes in the Netherlands. *Ecology and farming.* 2010(feb), 50–53.

Lammerts van Bueren, E.T., Thorup-Kristensen, K., Leifert, C., Cooper, J.M., & Becker, H.C. (2014). Breeding for nitrogen efficiency: concepts, methods, and case studies. *Euphytica*. 199(1), 1–2. DOI: 10.1007/s10681-014-1206-1.

Lammerts van Bueren, E.T., & Struik, P.C. (2017). Diverse concepts of breeding for nitrogen use efficiency. A review. *Agronomy for Sustainable Development.* 37(5), 1–24. DOI: 10.1007/s10681-014-1206-1.

Lehesranta, S.J., Koistinen, K.M., Massat, N., Davies, H.V., Shepherd, L.V., McNicol, J.W., & Leifert, C. (2007). Effects of agricultural production systems and their components on protein profiles of potato tubers. *Proteomics*. 7(4), 597–604. DOI: 10.1002/pmic.200600889.

MacKerron, D.K.L., & Waister, P.D. (1985). A simple model of potato growth and yield. Part I. Model development and sensitivity analysis. *Agricultural and Forest Meteorology*. 34(2–3), 241–252.

Malamy, J.E. (2005). Intrinsic and environmental response pathways that regulate root system architecture. *Plant, cell & environment*. 28(1), 67–77. DOI: 10.1111/j.1365-3040.2005.01306.x.

Masarirambi, M.T., Mandisodza, F.C., Mashingaidze, A.B., & Bhebhe, E. (2012). Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). *International Journal of Agriculture & Biology*. 14(4).

Masclaux, C., Quillere, I., Gallais, A., & Hirel, B. (2001). The challenge of remobilisation in plant nitrogen economy. A survey of physio-agronomic and molecular approaches. *Annals of applied Biology*, 138(1), 69–81. DOI: 10.1111/j.1744-7348.2001.tb00086.x.

Masclaux-Daubresse, C., Daniel-Vedele, F., Dechorgnat, J., Chardon, F., Gaufichon, L., & Suzuki, A. (2010). Nitrogen uptake, assimilation and remobilization in plants: challenges for sustainable and productive agriculture. *Annals of Botany*. 105(7), 1141–1157. DOI: 10.1093/aob/mcq028.

Meise, P., Seddig, S., Uptmoor, R., Ordon, F., & Schum, A. (2018). Impact of nitrogen supply on leaf water relations and physiological traits in a set of potato (*Solanum tuberosum* L.) cultivars under drought stress. *Journal of Agronomy and Crop Science*. 204(4), 359–374. DOI: 10.1111/jac.12266.

Meise, P., Seddig, S., Uptmoor, R., Ordon, F., & Schum, A. (2019). Assessment of yield and yield components of starch potato cultivars (*Solanum tuberosum* L.) under nitrogen deficiency and drought stress conditions. *Potato Research*, 62(2), 193–220. DOI: 10.1007/s11540-018-9407-y.

Ministry of Agriculture (2021). *Report of Agriculture 2020*. Rīga: Ministry of Agriculture. Retrieved February 10, 2022, from 2020_lauksaimniecibas_gada_zinojums.pdf (zm.gov.lv).

Milburn, P., Richards, J. E., Gartley, C., Pollock, T., O'Neill, H., & Bailey, H. (1990). *Nitrate leaching from systematically tiled potato fields in New Brunswick, Canada* (Vol. 19, No. 3, pp. 448–454). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. DOI: 10.2134/jeq1990.00472425001900030016x.

Milroy, S.P., Wang, P., & Sadras, V.O. (2019). Defining upper limits of nitrogen uptake and nitrogen use efficiency of potato in response to crop N supply. *Field Crops Research*. 239, 38–46. DOI: 10.1016/j.fcr.2019.05.011.

Mirosavljević, M., Aćin, V., Sabadoš, V., & Dorotić, D. (2019). Variation in nitrogen use efficiency of winter wheat. *Genetika.* 51(3), 1165–1174. DOI: 10.2298/GENSR1903165M.

Moll, R.H., Kamprath, E.J., & Jackson, W.A. (1982). Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization 1. *Agronomy journal*. 74(3), 562–564. DOI: 10.2134/agronj1982.00021962007400030037x.

Mőller, K., Habermayer, J., Zinkernagel, V., & Reents, H. (2007). Impact and interaction of nitrogen and Phytophophtora infestas as a yield-limiting and yield-reducing factors in organic potato (*Solanum tuberosum* L.) crops. *Potato Research.* 49, 281–301.

Oliveira, C.A.D.S. (2000). Potato crop growth as affected by nitrogen and plant density. *Pesquisa Agropecuária Brasileira*. 35(5), 940–950.

Ospina, C.A., Lammerts van Bueren, E.T., Allefs, J.J.H.M., Engel, B.V., Van der Putten, P.E.L., Van der Linden, C.G., & Struik, P.C. (2014). Diversity of crop development traits and nitrogen use efficiency among potato cultivars grown under contrasting nitrogen regimes. *Euphytica*. 199(1), 13–29. DOI: 10.1007/s10681-014-1203-4.

Öztürk, E., Kavurmacı, Z., Kara, K., & Polat, T. (2010). The effects of different nitrogen and phosphorus rates on some quality traits of potato. *Potato research*. 53(4), 309–312. DOI: 10.1007/s11540-010-9176-8.

Pourazari, F., Andersson, M., & Weih, M. (2018). Altered tuber yield in genetically modified high-amylose and oil potato lines is associated with changed whole-plant nitrogen economy. *Frontiers in Plant Science*. 9, 342.

Remans, T., Nacry, P., Pervent, M., Girin, T., Tillard, P., Lepetit, M., & Gojon, A. (2006). A central role for the nitrate transporter NRT2. 1 in the integrated morphological and physiological responses of the root system to nitrogen limitation in Arabidopsis. *Plant physiology*. 140(3), 909–921. DOI: 10.1104/pp.105.075721.

Ruža, A., Skrabule, I., & Vaivode, A. (2013). Influence of nitrogen on potato productivity and nutrient use efficiency. In Proceedings of the Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences. 67, 247–253.

Scheible, W.R., Morcuende, R., Czechowski, T., Fritz, C., Osuna, D., Palacios-Rojas, N., ... Stitt, M. (2004). Genome-wide reprogramming of primary and secondary metabolism, protein synthesis, cellular growth processes, and the regulatory infrastructure of Arabidopsis in response to nitrogen. *Plant physiology*, 136(1), 2483–2499. DOI: 10.1104/pp.104.047019.

Schönhals, E.M. (2014). *Identifying novel diagnostic SNP markers for potato (Solanum tuberosum L.) tuber starch and yield by association mapping*. Doctoral dissertation, Universität zu Köln.

Schum, A., & Jansen, G. (2014). In vitro method for early evaluation of nitrogen use efficiency associated traits in potato. *Journal of Applied Botany and Food Quality*, 87, 256–264.

Schum, A., Meise, P., Jansen, G., Seddig, S., & Ordon, F. (2017). Evaluation of nitrogen efficiency associated traits of starch potato cultivars under in vitro conditions. *Plant Cell, Tissue and Organ Culture (PCTOC)*. 130(3), 651–665. DOI: 10.1007/s11240-017-1254-z.

Sharifi, M., & Zebarth, B.J. (2006). Nitrate influx kinetic parameters of five potato cultivars during vegetative growth. *Plant and soil*. 288(1), 91–99. DOI: 10.1007/s11104-006-9092-5.

Sharifi, M., Zebarth, B.J., & Coleman, W. (2007). Screening for nitrogen-use efficiency in potato with a recirculating hydroponic system. Communications in soil science and plant analysis, 38(3–4), 359–370.

Skrabule, I., Vaivode, A., & Ruža, A. (2012). The influence of nitrogen fertilizer norm on indicators of nutrient use for potato. Zinātniski praktiskā konference, Zinātne Latvijas Lauksaimniecības Nākotnei: Pārtika, Lopbarība, Šķiedra un Enerģija, Jelgava, Latvia, 23–24 February 2012 (pp. 90–94). Jelgava, Latvija, Latvijas Lauksaimniecības Universitāte (LLU).

Steyn, J.M., Franke, A.C., Van der Waals, J.E., & Haverkort, A.J. (2016). Resource use efficiencies as indicators of ecological sustainability in potato production: a South African case study. *Field Crops Research.* 199, 136–149. DOI: 10.1016/j.fcr.2016.09.020.

Tiemens-Hulscher, M., Lammerts van Bueren, E.T., & Struik, P.C. (2014). Identifying nitrogen-efficient potato cultivars for organic farming. *Euphytica*, 199(1), 137–154. DOI: 10.1007/s10681-014-1143-z.

Tiwari, J.K., Sapna, D.E.V.I., Buckseth, T., Nilofer, A.L.I., Singh, R.K., Zinta, R., & Chakrabarti, S.K. (2020). Precision phenotyping of contrasting potato (*Solanum tuberosum* L.) varieties in a novel aeroponics system for improving nitrogen use efficiency: In search of key traits and genes. *Journal of Integrative Agriculture*, 19(1), 51–61. DOI: 10.1016/S2095-3119(19)62625-0.

Van Dingenen, J., Hanzalova, K., Salem, M.A.A., Abel, C., Seibert, T., Giavalisco, P., & Wahl, V. (2019). Limited nitrogen availability has cultivar-dependent effects on potato tuber yield and tuber quality traits. *Food Chemistry*, 288, 170–177. DOI: 10.1016/j.foodchem.2019.02.113.

Van Oijen, M. (1991). Light use efficiencies of potato cultivars with late blight (*Phytophthora infestans*). *Potato research*, 34(2), 123–132. DOI: 10.1007/BF02358033.

Vos, J. (2009). Nitrogen responses and nitrogen management in potato. *Potato research*, 52(4), 305–317.

Waglay, A., & Karboune, S. (2016). Potato proteins: Functional food ingredients. In Singh, J. & Lovedeep, K. (Eds.) *Advances in potato chemistry and technology* (pp. 75–104). Wageningen, The Netherlands, Academic Press.

Walley, F., Yates, T., van Groeningen, J.W., & van Kessel, C. (2002). Relationships between soil nitrogen availability indices, yield, and nitrogen accumulation of wheat. *Soil Science Society American Journal* 66, 1549–1561. DOI: 10.2136/sssaj2002.1549.

Xie, X., Li, X.Q., Zebarth, B.J., Niu, S., Tang, R., Tai, H.H., ... Haroon, M. (2018). Rapid screening of potato cultivars tolerant to nitrogen deficiency using a hydroponic system. *American journal of potato research*, 95(2), 157–163. DOI: 10.1007/s12230-017-9621-1.

Yin, X., Goudriaan, J.A.N., Lantinga, E.A., Vos, J.A.N., & Spiertz, H.J. (2003). A flexible sigmoid function of determinate growth. *Annals of botany*, 91(3), 361–371. DOI: 10.1093/aob/mcg029.

Zebarth, B.J., Tai, G., Tarn, R.D., De Jong, H., & Milburn, P.H. (2004). Nitrogen use efficiency characteristics of commercial potato cultivars. *Canadian Journal of Plant Science*, 84(2), 589–598.

Zebarth, B.J., & Rosen, C.J. (2007). Research perspective on nitrogen BMP development for potato. *American Journal of Potato Research*, 84(1), 3–18. DOI: 10.1007/BF02986294.

Zhang, J., Wang, Y., Zhao, Y., Zhang, Y., Zhang, J., Ma, H., & Han, Y. (2020). Transcriptome analysis reveals Nitrogen deficiency induced alterations in leaf and root of three cultivars of potato (*Solanum tuberosum* L.). *PloS one*.15(10), e0240662. DOI: 10.1371/journal.pone.0253994.

 DOI: 10.22616/rrd.28.2022.005

INTERNAL DECAY ASSESSMENT USING DRILLING RESISTANCE IN MATURE COMMON ALDER (*ALNUS GLUTINOSA* (L.) GAERTN.) STANDS

Alise Bleive[1,2], *Janis Liepins[1], Kaspars Liepins[1]
[1]Latvian State Forest Research Institute 'Silava', Latvia
[2]Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: janis.liepins@silava.lv

Abstract
The occurrence of wood decay in common alder stems (*Alnus glutinosa* (L.) Gaertn.) was studied based on data obtained in seven matured stands in Latvia age ranging from 65 to 122 years. The study was intended as a pilot study to test the possible use of nondestructive micro-drill (Rinntech Resistograph® R650) for detection of the different stages of wood decay within common alder stems. The drilling profiles were visually compared with the wood samples obtained from increment borer or cross-cut sections at actual drilling height.
The study confirmed initially proposed hypothesis that drilling profiles obtained using the Resistograph enabled the diagnosis of the common alder stem health condition. Wood decay stages – spongy rot and cavity can be detected successfully by the Resistograph; however, this non-destructive method does not detect discoloration in the wood, which is the earlier stage of wood decay. We found significant (p<0.05) positive correlation between decay occurrence and some of examined forest stand characteristics such as mean stand diameter, stand age and mean tree volume.
The tree inspection showed that the preservation of old common alder stands can lead to a significant loss of wood quality. Based on this pilot study, we conclude that if the economic interests are prioritized in management of studied stands, the reduction of actual harvesting age of the common alder stands have to be considered.
Key words: health condition, Resistograph, wood quality, decay occurrence, degraded wood.

Introduction

Common or black alder (*Alnus glutinosa* (L.) Gaertn.) is a deciduous tree with wide distribution area preferring moist and fertile soils with relatively high groundwater level, that are unfavorable conditions for most of other tree species (Laganis *et al*., 2008). Common alder forests play a very distinct role particularly to riparian ecosystems fostering the services they provide. Alders have very strong, deep and vertically oriented root system able to anchor a tree in wet soils; therefore, it is widely used for soil protection and strengthening banks around rivers, lakes and other water bodies (Salca, 2019; Thoirain *et al*., 2007). This tree species have great potential in nitrogen fixation in soil by root system, which increases the fertility of it (Rodríguez-González *et al*., 2014). In sites where tree roots cannot reach groundwater for a notable time and with low precipitation level, common alder is not capable to effectively produce annual height and diameter increments, being the reason why the species distribution area gradually reduces towards the south (Marques *et al*., 2018; Rodríguez-González *et al*., 2014) or to the north, where winters last more than six months and soil is frozen for a long period (Salca, 2019).

According to national forest inventory (NFI) data, common alder forest stands cover 6.0% of the total forest area in Latvia (Official statistics portal, 2021a). Common alder is second most popular broadleaved species in forest planting in our country, and it lags only behind silver birch. Along with birch (*Betula* spp.), European aspen and grey alder, the common alder prevails on abandoned lands naturally overgrown after cessation of agricultural activities (Liepins *et al*., 2008). In the year 2021, 280 thousand m^3 of common alder's roundwood was harvested in Latvia (Official statistics portal, 2021b) with the main use for wood particle board industry, energy-wood production and carpentry. The wood of common alder is well suited for the woodworking industry and can be easily machined, stained and otherwise treated (Salca *et al*., 2015). Common alder breeding activities are launched in Latvia indicating good potential for improvement of productivity and wood quality (Gailis & Jansons, 2010).

Common alder stands reaches its growing peak at 70 years (8 – 14 m^3 ha^{-1} per year); however, by increasing age, growth becomes less intense and tree resistance to various pathogens starts to decrease. After reaching 50 years, the risk of internal stem decay rapidly increases, the similar observation is also for trees with large diameter (Claessens *et al*., 2010). In Europe north region countries the lowest occurrence of decay is observed in first 20 growing years while at this age common alder stands can reach even 150 – 190 m^3 ha^{-1} of wood stock (Vares *et al*., 2004). A high proportion of wood decay in stems may cause significant losses of roundwood yield.

The European Union (EU) has taken responsibility to achieve climate neutrality by 2050. Forests play a crucial role for reaching the EU objectives enhancing ambition on climate change mitigation and adaptation. This means that impact of economic activities potentially contributing to climate change mitigation or causing significant harm to any of the other environmental objectives needs to be assessed

(Official Journal of the EU, 2021). Studies approves that grey alder stands at middle-age stages act as carbon sink, while mature stands become carbon source (Uri *et al*., 2017). It can be hypothesized that also common alder matured stands at some stage can become a carbon source because of declined net primary production and stem decay. It is still poorly studied; however, internal stem decay in living trees most likely results in the release of stored carbon back into the atmosphere (Marra *et al*., 2018) and can be a primary cause of tree failures during storms. Better understanding of factors affecting spread of decay within stems of common alder could help to improve the guidelines both for management of stands for quality roundwood production and enhancing of carbon storage capacity.

Internal stem decay is wood cell degradation process, which usually is almost impossible to identify just by external tree visual assessment, and in many cases destructive sampling (tree felling) is not possible or reasonable (Terho, 2009). This is why it is attractive to use in internal decay studies innovative, cost-effective and non-destructive solutions for its identification (Fundova *et al*., 2018; Rinn *et al*., 1996). Rinntech Resistograph® R650 is the one of devices which allows to assess stem decay presence and distribution without limiting future tree growing or endangers potential uses of wood material (Rinn, 2016). It is a mechanical micro-drill which penetrates fine needle (diameter up to 3 mm) at constant rotation speed and straight line movement, and very precisely measures the resistance of the study object (Fundova *et al*., 2018). Adjusting the needle rotation and straight-line movement speed makes it possible to ensure even measurements for each tree species (Todoroki *et al*., 2021). The changes in the resistance and density, also changes the energy consumption of drills engine, which is represented graphically (Rinn, 2016). With analyzing these graphical changes, obtained after Resistograph work, it is possible to derive conclusions about tree internal condition – to detect decay, deep insect damages, cracks and to collect data about annual radial increments as well as track natural changes in wood density (Wang & Allison, 2008). When it comes to decay, gradual decline or rise in the graph during drilling indicates that stem may have different wood decay development stages – from slightly colored wood to even cavity (Todoroki *et al*., 2021).

The aim of this study is to test the potential of micro-drill to nondestructive detection of decay in stems of common alder and assess the occurrence of the internal tree decay in common alder stands. We hypothesized that the quality and health status of a common alder stems can be assessed by visual inspection of the drilling profiles produced by the Resistograph.

Materials and Methods

Seven mature (age ranged from 65 to 122 years) naturally regenerated stands dominated by common alder were chosen for the present study (Table 1) located in central-eastern part and southern-western part of Latvia (Madona, Smiltene, Auce municipalities). All investigated stands were growing on fertile soils with increased groundwater level. Forest types were determined based on Latvian forest site classification (Zālītis & Jansons, 2013). Study material was collected during the spring and summer of 2021. Four investigated common alder stands were growing in *Dryopteriosocaricosa* forest type, and one stand was growing in *Oxalidosa turf. Mel*, *Caricoso-phragmitosa* and *Myrtilloso-sphagnosa* forest types.

To assess the occurrence of stem decay in forest stands dominated by common alder, 500 m^2 circular sample plot was established in each of it. Plots were placed subjectively into spots most accurately representing the actual situation in each forest site. To evaluate relationships between stand characteristics and tree health conditions, the measurements of

Table 1

Main characteristics of studied common alder stands

Stand No.	Stand age, years	DBH_g, cm	H_g, m	G, m^2ha^{-1}	Mean tree volume, m^3	Stand volume, m^3 ha^{-1}	Number of trees, ha^{-1}	Forest type (according (Zālītis & Jansons, 2013))
1	98	31.8	25.3	52.4	0.95	647.9	660	*Dryopteriosocaricosa*
2	87	31.2	26.8	45.9	0.97	591.2	600	*Oxalidosa turf. mel.*
3	122	32.3	23.7	19.7	0.92	227.5	240	*Dryopteriosocaricosa*
4	111	32.6	25.4	25.0	1.00	307.0	300	*Caricoso-phragmitosa*
5	65	23.3	26.2	33.3	0.53	419.1	780	*Myrtilloso-sphagnosa*
6	74	20.6	24.1	24.6	0.38	286.2	740	*Dryopteriosocaricosa*
7	72	23.1	22.8	37.7	0.45	418.4	900	*Dryopteriosocaricosa*

DBH_g – basal area weighted mean diameter at breast height; H_g – basal area weighted mean height; G – weighted average stands basal area.

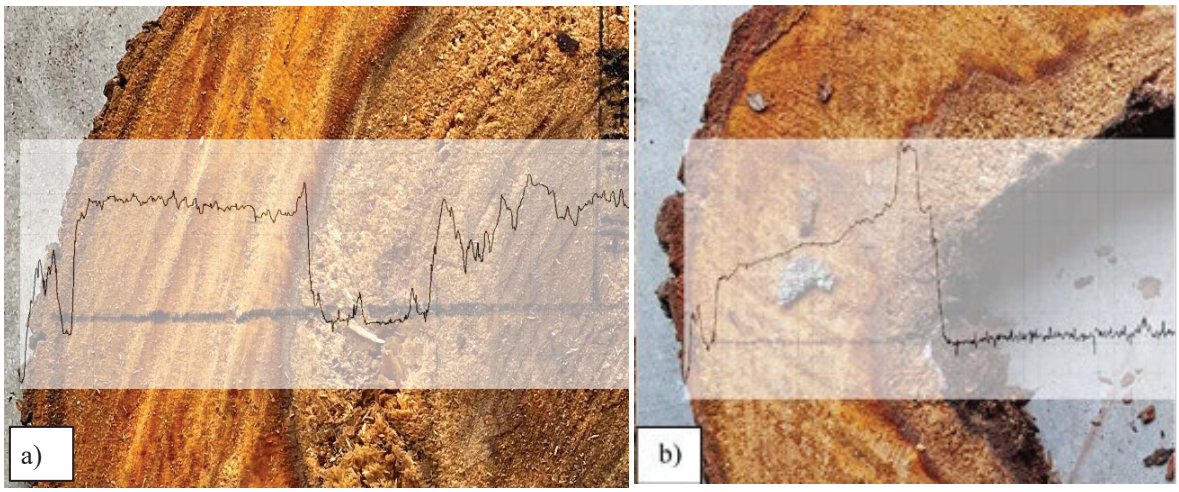

Figure 1. Rinntech RESISTOGRAPH® R650 drilling profile and actual cross-cut at corresponding height: a) intact wood, spongy rot and discoloration; b) intact wood, spongy rot and cavity.

diameter at breast height and tree height were made in all sample plots. Average tree age in a stand is determined according to the forest inventory information but the other stand characteristics are calculated from the obtained tree measurement data. During primarily visual inspection, information about any significant tree damage that may cause internal wood condition changes also was fixed.

In plots, all common alder trees were drilled by mechanical micro-drill Resistograph horizontally at stump level from three different directions towards the core. Altogether, 211 sample trees were drilled in seven common alder stands. It was done with the aim to detect decay presence in stem as precisely as possible. Each drilling has an individual graph or so-called drilling profile and after quick visual analysis of it, it allows to make assumption about sample tree internal condition. Figure 1 represents individual drilling profiles in comparison with actual cross-cuts at a stump level. When drilling profile is stable and has no changes, there is intact or healthy wood, fluctuations may indicate on changes on wood mechanical properties caused by internal stem decay presence. In field conditions, it is possible to distinguish two wood decay development stages – a) spongy rot and b) cavity, because graph line fluctuations are very notable.

In each sample plot, all common alder trees were chosen for detection of decay via Resistograph. Trees without considerable fluctuations in the drilling profile were also inspected with increment borer, while trees with internal decay were felled to obtain more precise assumptions about internal stem condition (5 sample trees per plot). After all field works, data from Resistograph was exported to computer where detailed micro-drill profiles were analyzed with scientific program Rinntech e.K. DecomTM.

Spearman's rank-order correlation coefficient was used to measure the strength and direction of association between stand characteristics and the occurrence of internal wood decay because our data set is limited and does not follow a normal distribution. Data normality assumptions were tested using the Shapiro-Wilk test. All the tests were performed at a level $\alpha = 0.05$ using R statistical software (Bates *et al*., 2015).

Results and Discussion

Our study revealed high variation in occurrence of decayed stems in studied mature common alder stands ranging from 6.7% to 93.3% (Table 2). With increased age and dimensions of common alder, the risk of reduced stem quality because of internal decay is more profound. Although based on limited stand data, there is a distinct pattern that incidence of decay in stems of common alders sharply increases in stands older than 60 years (Figure 2). This is in line with Claessens et al., (2010) who referenced that onset of wood decay in common alder stands starts at the age 50…70 years. The highest proportion of decay-affected wood is located within the heartwood at the bottom of stem indicating that this disease is a significant threat for commercial wood usage for high quality products. In Latvia, common alder trees felling age is 71 years and Arhipova (2012) concluded that by that age on average 75% of all trees may be infected with internal wood decay. According to the Latvian NFI data, the total wood volume in common alder stands is approximately 42.16 million m^3, and most of it consists of stands older than 51 years.

Age-related decline of stand biomass accumulation and loss of productivity in old growth forest is well described process (Ryan *et al*., 1997). The life span of the trees is often dictated by size-related stress,

Table 2

Decay occurrence in mature common alder stands

Stand No.	Number of inspected trees	Healthy, %	Spongy rot, %	Cavity, %	Occurrence of decayed trees in stand, %
1	33	54.5	36.4	9.1	45.5
2	30	56.7	26.7	16.6	43.3
3	12	50.0	33.3	16.7	50.0
4	15	6.7	40.0	53.3	93.3
5	39	82.1	12.8	5.1	17.9
6	37	86.5	10.8	2.7	13.5
7	45	93.3	4.4	2.3	6.7

abiotic stress, pathogens or rot-inducing fungi that digest their woody bodies (Ryan *et al*., 1997). Similar relationship between spread of decay within stems of matured living trees showed by our results were observed in grey alders stands (Arhipova *et al*., 2011) and trembling aspen (Schneider *et al*., 2008). Analysis revealed a significant positive correlation between such stand characteristics as mean diameter (r=0.964), age (r=0.857), mean tree volume (r=0.821) and total occurrence of stem internal decay (Table 3). This is confirming that preserving of old common alder stands leads to loss of wood quality if the economical interests are prioritized in management of these stands. It has to be mentioned that our study is based on just seven stands, and there is high variation of decay spread among them indicating that other factors than studied ones also could be involved in the loss of vitality of trees.

To accurately interpret Resistograph data, it should be taken into account that internal stem decay is a natural process of wood cell decomposition during which their density rapidly decreases, and it may occur differently for each tree species or growing conditions (Rinn, 2016). Two wood decay stages – spongy rot and cavity was detected with Resistograph (Table 2). Spongy rot dominated in all investigated decayed common alder stands (on average 38.6%), whereas the cavity was found less frequently – on average in 15.1% of drilled trees in a stand. The highest occurrence of cavity (decay development stage where no more wood is observed) was in oldest study stands, respectively, with greater diameter at breast height and mean tree volume (Table 1).

After visual inspection of wood samples obtained via increment borer, in many cases a wood discoloration was found. This is usually considered as the earliest decay development stage, when wood has already changed its color, but it has no significant effect on mechanical properties. This stage was hardly detectable with drilling resistance in this study, because at early stages wood cell degradation process only slightly affects wood basic density and hence the drilling resistance. Also, Quarles (1999) concluded that Resistograph cannot detect decay at early decay stages when wood weight loss is less than 20%, which contradicts with consumptions made by Rinn, (2016)

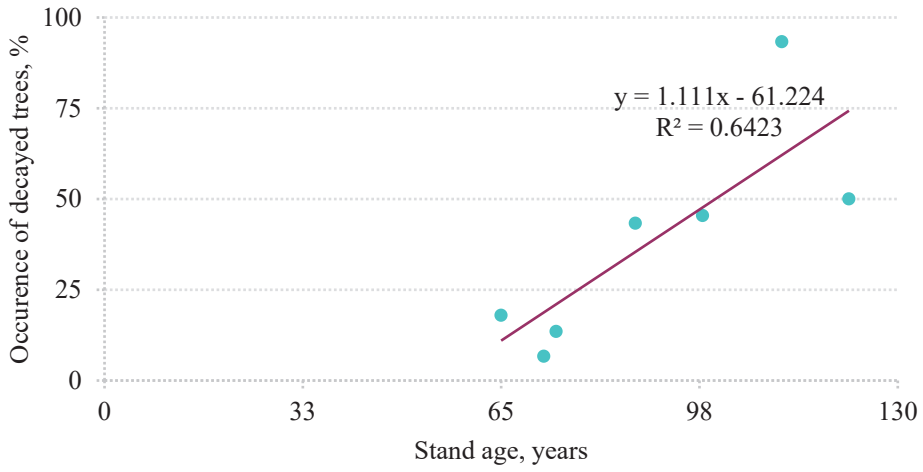

Figure 2. Occurrence of decayed trees in mature and common alder stands.

Table 3

Spearman's correlations between common alder stand characteristics and occurrence of internal stem decay

Decay occurrence, %	DBH_g, cm	H_g, m	Stand age, years	Stand volume, $m^3\ ha^{-1}$	Mean tree volume, m^3	G, m^2
Total	0.964*	0.286	0.857*	-0.107	0.821*	-0.179
Spongy rot	0.929*	0.357	0.786	0.107	0.857*	0.035
Cavity	0.920*	0.392	0.821*	-0.142	0.857*	-0.214

*labelled correlation coefficients are significant at $p < 0.05$. DBH_g – weighted average diameter at breast height; H_g – weighted average tree height; G – weighted average stand basal area.

that micro-drill is capable to detect decay in every development change. This is leading to presumption that amount of decay damaged trees in studied common alder stands is higher than detected with Resistograph. Spongy rot and cavity were successfully detected by the drilling resistance method for all trees sampled; however, it could be quite difficult to accurately predict the extent of decay because the internal decay is irregularly shaped and the drill needle not always can be pointed towards the center of the stem.

Most likely the biological age of the trees is the main trigger of spreading of decay in mature common alder stands, and the possibilities to slow down this process is limited. In this study, we did not have information on the actual age of trees in the stand (forest inventory data was used) which probably explains why the occurrence of the stem decay was most closely correlated with the mean diameter of trees. To obtain more accurate data about the internal decay occurrence in common alder stands in Latvia, we recommend continuing the study with more extensive data set. In the ongoing study, we will assess the carbon concentration and its changes affected by internal stem decay presence of different development stages. This will make contribution to better understand the carbon sequestration processes in matured and old-grown common alder stands and to plan the silvicultural measures that can increase the climate mitigation capabilities of our forests.

Conclusions

The presence of cavities and internal decay in tree stems results in the release of stored carbon back into the atmosphere and has been noted as the primary cause of tree failures. Study approved that occurrence of internal stem decay in mature common alder stands depend on tree size and stand age. We found significant positive correlation between occurrence of decayed trees at various stages and stand characteristics such as mean diameter, age, mean tree volume. Preserving of old-grown common alder stands leads to loss of wood quality because of internal decay. If the wood industry interests are prioritized in management of these stands, the reduction of actual harvesting age of the common alder stands have to be considered.

Two wood decay stages – spongy rot and cavity were successfully detected with a drilling resistance method; however, the presence of discoloration in common alder wood cannot be noticed with this non-destructive method.

Acknowledgement

Research was financed by the European Regional Development Fund (ERDF), postdoctoral research project No. 1.1.1.2/VIAA/4/20/687 'Reducing uncertainty in the calculation of forest stand biomass and carbon stock in Latvia'.

References

Arhipova, N., Gaitnieks, T., Donis, J., Stenlid, J., & Vasaitis, R. (2011). Decay, yield loss and associated fungi in stands of grey alder (*Alnus incana*) in Latvia. *Forestry*, 84(4), 337–348.

Arhipova, N. (2012). *Heart Rot of Spruce and Alder in Forests of Latvia: Impact and Possibilities for Silvicultural Control*. Doctoral disertation. Faculty of Natural Resources and Agricultural Sciences, Department of Forest Mycology and Plant Pathology, Uppsala, Sweden.

Arhipova, N., Gaitnieks, T., Donis, J., Stenlid, J., & Vasaitis, R. (2012). Heart-rot and associated fungi in Alnus glutinosa stands in Latvia. *Scandinavian Journal of Forest Research*. 27(4), 327–336.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*. 67(1), 1–48. DOI: 10.18637/jss.v067.i01.

Claessens, H., Oosterbaan, A., Savill, P., & Rondeux, J. (2010). A review of the characteristics of black alder (*Alnus glutinosa* (L.) Gaertn.) and their implications for silvicultural practices. *Forestry*, 83(2), 163–175. DOI: 10.1093/forestry/cpp038.

Fundova, I., Funda, T., & Wu, H.X. (2018). Non-destructive wood density assessment of Scots pine (Pinus sylvestris L.) using Resistograph and Pilodyn. *PLoS ONE*, 13(9). DOI: 10.1371/journal.pone.0204518.

Gailis, A., & Jansons, Ā. (2010). Results of black alder (*Alnus glutinosa* (L.) Gaertn.) improvement in Latvia. In Research for Rural Development 2010 International Scientific Conference Jelgava, Latvia University of Agriculture (pp. 255–260).

Gomes Marques, I., Campelo, F., Rivaes, R., Albuquerque, A., Ferreira, M.T., & Rodríguez-González, P.M. (2018). Tree rings reveal long-term changes in growth resilience in Southern European riparian forests. *Dendrochronologia*, 52, 167–176. DOI: 10.1016/j.dendro.2018.10.009.

Laganis, J., Pečkov, A., & Debeljak, M. (2008). Modeling radial growth increment of black alder (*Alnus glutionsa* (L.) Gaertn.) tree. *Ecological Modelling*, 215(1), 180–189. DOI: 10.1016/j.ecolmodel.2008.02.018.

Liepa, I. (1996). *Pieauguma mācība* (Increment science). Jelgava: LLU. (in Latvian).

Liepins, K., Lazdins, A., Lazdina, D., Daugaviete, M., & Miezite, O. (2008). Naturally afforested agricultural lands in Latvia - Assessment of available timber resources and potential productivity. In 7th International Conference on Environmental Engineering, ICEE 2008 – Conference Proceedings (pp. 194–200).

Marra, R.E., Brazee, N.J., & Fraver, S. (2018). Estimating carbon loss due to internal decay in living trees using tomography: Implications for forest carbon budgets. *Environmental Research Letters*, 13(10). DOI: 10.1088/1748-9326/aae2bf.

Official Journal of the EU (2021). *Commission delegated regulation (EU) 2021/2139*. Retrieved February 21, 2022, from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R2139&from=EN.

Official statistics portal (2021a). *Felling areas and stock volume*. Retrieved February 21, 2022, from https://stat.gov.lv/en/statistics-themes/business-sectors/forestry/tables/mep060-inventoried-forest-areas-and-standing.

Official statistics portal (2021b). *Inventoried forest areas and standing timber by main tree species in regions, cities, towns, municipalities and rural territories*. Retrieved February 21, 2022, from https://stat.gov.lv/en/statistics-themes/business-sectors/forestry/8922-felling-areas-and-stock-volume.

Quarles, S.L. (1999). Detection of wood decay in blue gum and elm: an evaluation of the RESISTOGRAPH ® and the portable drill. *Journal of Arboriculture*, 25(6), 311–318.

Rinn, F. (2016). Intact-decay transitions in profiles of density-calibratable resistance drilling devices using long thin needles. *Arboricultural Journal*, 38(4), 204–217. DOI: 10.1080/03071375.2016.1228336.

Rinn, F., Schweingruber, F.-H., & Schär, E. (1996). RESISTOGRAPH and X-ray density charts of wood comparative evaluation of drill resistance profiles and X-ray density charts of different wood species. *Holzforschung*, 50(4), 303–311. DOI: 10.1515/hfsg.1996.50.4.303.

Rodríguez-González, P.M., Campelo, F., Albuquerque, A., Rivaes, R., Ferreira, T., & Pereira, J.S. (2014). Sensitivity of black alder (*Alnus glutinosa* [L.] Gaertn.) growth to hydrological changes in wetland forests at the rear edge of the species distribution. *Plant Ecology*, 215(2), 233–245. DOI: 10.1007/s11258-013-0292-9.

Ryan, M.G., Binkley, D., & Fownes, J.H. (1997). Age-Related Decline in Forest Productivity: Pattern and Process. *Advances in Ecological Research,* 27, 213–262. DOI: 10.1016/S0065-2504(08)60009-4.

Salca, E. (2019). Black Alder (*Alnus glutinosa* L.) – a Resource for Value-Added Products in Furniture Industry Under European Screening. *Current Forestry Reports*, 5(1), 41–54. DOI: 10.1007/s40725-019-00086-3.

Salca, E., Gobakken, L.R., & Gjerdrum, P. (2015). Progress of discoloration in green, freshly cut veneer sheets of black alder (*Alnus glutinosa* L.) wood. *Wood Material Science & Engineering*, 10(2), 178–184. DOI: 10.1080/17480272.2014.929175.

Schneider, R., Riopel, M., Pothier, D., & Côté, L. (2008). Predicting decay and round-wood end use volume in trembling aspen (*Populus tremuloides* Michx.). *Annals of Forest Science*, 65(6), 608–608. DOI: 10.1051/forest:2008042.

Terho, M. (2009). An assessment of decay among urban Tilia, Betula, and Acer trees felled as hazardous. *Urban Forestry and Urban Greening*, 8(20), 77–85 DOI: 10.1016/j.ufug.2009.02.004.

Thoirain, B., Husson, C., & Marçais, B. (2007). Risk factors for the Phytophthora-induced decline of alder in northeastern France. *Phytopathology*, 97(1), 99–105. DOI: 10.1094/PHYTO-97-0099.

Todoroki, C.L., Lowell, E.C., & Filipescu, C.N. (2021). Wood density estimates of standing trees by micro-drilling and other non-destructive measures. *New Zealand Journal of Forestry Science*, 51(6), 1–16. DOI: 10.33494/NZJFS512021X74X.

Uri, V., Kukumägi, M., Aosaar, J., Varik, M., Becker, H., Soosaar, K., … Karoles, K. (2017). Carbon budgets in fertile grey alder (*Alnus incana* (L.) Moench.) stands of different ages. *Forest Ecology and Management*, 396, 55–67. DOI: 10.1016/J.FORECO.2017.04.004.

Vares, A., Lõhmus, K., Truu, M., Truu, J., Tullus, H., & Kanal, A. (2004). Productivity of black alder (*Alnus glutinosa* (L.) Gaertn.) Plantations on reclaimed oil-shale mining detritus and mineral soils in relation to rhizosphere conditions. *Oil Shale*, 21(1), 43–58.

Wang, X., & Allison, R.B. (2008). Decay detection in red oak trees using a combination of visual inspection, acoustic testing, and resistance microdrilling. *Arboriculture and Urban Forestry*, 34(1), 1–4.

Zālītis, P., & Jansons, J. (2013). *Latvijas meža tipoloģija un tās sākotne*. (Latvian forest typology and its origin). Salaspils: Saule. (in Latvian).

 DOI: 10.22616/rrd.28.2022.006

CASE STUDY ON GREENHOUSE GAS (GHG) FLUXES FROM FLOODED FORMER PEAT EXTRACTION FIELDS IN CENTRAL PART OF LATVIA

***Aldis Butlers, Andis Lazdiņš**
Latvian State Forest Research Institute 'Silava', Latvia
*Corresponding author's email: aldis.butlers@silava.lv

Abstract
Flooded Land is defined as water bodies where human activities have caused changes in the amount of surface area covered by water, typically through water level regulation. Former peat extraction fields are a type of flooded lands which are often mentioned as significant source of greenhouse gas (GHG) emissions. In Latvia, the area of flooded lands in former peat extraction fields is 5.3 kha.
The aim of the study is to evaluate GHG emissions from flooded former peat extraction fields to define that the flooded lands are the key source of GHG emissions and approve that further studies are necessary to elaborate country specific emission factors. The study is implemented in three areas in central part of the country, where peat extraction was stopped 25-35 years ago. Measures continued for 12 months, in 9 subplots, each was represented by 3 measurement points. Water and air temperature, as well as water level was measured during the study.
According to the study results, flooded areas are a significant source of CO_2 emissions (967±107 kg CO_2-C ha^{-1} yr^{-1}); however, the most significant agent of GHG emissions in flooded areas is methane (CH_4) – 435±98 kg CH_4-C kg ha^{-1} yr^{-1}. Flooded areas are not significant source of nitrous oxide (N_2O) emissions. The net emissions from flooded areas are 18.1±3.7 tons CO_2 eq ha^{-1} yr^{-1}. According to the study results, flooded lands are a significant (one of the largest) source of emissions, and further studies are necessary to improve GHG modelling solutions and activity data.
Key words: greenhouse gas, emissions, flooded land, peat extraction.

Introduction

Organic soils are formed by accumulation of dead organic matter. Organic soils are outcome of a long development process during which vegetation adds litter into soil and the stock of C in the litter exceeds the amount of C losses due to decomposition of the recently added litter and in formerly added organic C. Organic soils are typically found in wetlands, where high groundwater level ensures anoxic conditions and decomposition of organic matter is generally slow; however, anaerobic decomposition continues (Straková *et al*., 2012).

The development of northern peatlands began more than 15000 years ago, and they expanded during the Holocene period (the past 12000 years after the latest glaciations) on land that became exposed when glaciers retreated (MacDonald *et al*., 2006). Most of the organic soils we have currently are located in temperate and boreal regions. Peatlands and other organic soils hold about 20-25% of global soil C stock but occupy only 2-3% of the world's ice-free land surface (Hiraishi *et al*., 2013; Mokma, 2005).

In Latvia, total area of organic soils is 1205 kha (19% of the country area), including 629 kha of drained and 577 kha of naturally wet organic soils. In wetlands (according to the definition of Intergovernmental panel on Climate Change – IPCC), the area of drained soil is 12.8% of the total area of wetlands (Ministry of Environmental Protection and Regional Development, 2021). The area of former peat extraction sites is 54.9 kha. Significant areas of drained wetlands used for peat extraction earlier are already afforested (mostly naturally), flooded area is about 5.3 ha (Butlers & Ivanovs, 2018). No significant potential to increase the flooded area is found (Krīgere, Dreimanis *et al*., 2019; Krīgere, Kalniņa *et al*., 2019).

The National GHG inventory of Latvia (Ministry of Environmental Protection and Regional Development, 2021) uses default (tier 1) method to calculate GHG emissions from flooded peat extraction fields. The emission factors for rewetted areas are applied to avoid potential underestimation of the GHG emissions; specifically, emission factor (EF) for CO_2, 0.5 tons CO_2-C ha^{-1} yr^{-1} (Table 3.1 Tier 1 CO_2 from rewetted organic soils (temperate, nutrient rich soil)), EF DOC, 0.24 tons CO_2-C ha^{-1} yr^{-1} (Table 3.2 Default DOC emission factors (EF DOC_REWETTED in tonnes CO_2-C ha^{-1} yr^{-1}) for rewetted organic soil (temperate climate zone), EF CH_4 216 kg CH_4-C ha^{-1} yr^{-1} (Table 3.3 Default emission factors for CH_4 from rewetted organic soils (temperate, rich)). Total GHG emissions from flooded lands equal to 7.2 tons CO_2 eq yr^{-1}. Emission factors for nutrient rich soils are used to avoid underestimation of GHG emissions, since the activity data (soil type) are usually very uncertain.

During recent years significant improvements were applied to the National GHG inventory to calculate GHG fluxes from organic soils. Improved emission factors are applied to peat extraction sites (Lazdiņš & Lupiķis, 2019), croplands and grasslands (Licite & Lupikis, 2020) and forest lands (Lupiķis, 2019). Reporting of land use and land use changes are significantly improved (Krumšteds *et al*., 2019). Soil carbon stock modelling tools are not jet implemented; however, knowledge on carbon turnover, e.g., litter input and soil moisture regime are now in place

and should be integrated with modelling solutions (Bārdule *et al*., 2021; Ivanovs *et al*., 2017).

Flooded lands are a potential key source of the GHG emissions, and there are proposals to implement flooding as a mitigation measure; therefore, it is important to acquire measurement based information on the GHG fluxes from flooded areas. This study is aimed to provide such information to avoid inefficient use of the state funding aimed at reduction of GHG emissions.

Materials and Methods

GHG measures were implemented in 3 sites in central part of Latvia in Zilākalna and Tēvgāršas swamps (former raised bogs). Peat extraction in these areas was terminated 25-30 years ago leaving 0.6-2.8 m deep peat layer in the measurement sites. Water level in the measurement sites at minimum level was 0.2-0.4 m and at maximum level – 1.2-1.8 m (Table 1).

Large opaque chambers are used to take GHG samples. Floating collars and footbridges are used to position chambers during gas sampling (Figure 1). Footbridges, collars and chambers are moved from site to site. A set of five collars are used for gas sampling. Three permanent subplots are established in every site, respectively, in total data from 45 sampling sites are used in analysis. Sampling was repeated once per 3 weeks during vegetation season (March to October) and once per month in November to February, from January to December, 2021; respectively, every month is represented by 1-2 measurement series. During ice cover period sampling was done from surface of ice. If ice was not strong enough to hold duckboards, it was broken and removed from water surface. Gas sampling was done at least one hour after removing ice.

Gas samples are collected in 50 ml glass bottles which are vacuumized before sampling. Samples are collected directly after chamber is located on a collar, then in 10, 20 and 30 minutes; 4 samples per set. In parallel to gas sampling, air and water temperature, wind speed, cloudiness and water level are fixed. Gas analyses are performed using Shimadzu Nexis GC-2030 gas chromatograph equipped with an electron capture detector (ESD), a flame ionization detector, and automatic sampling device (Loftfield *et al*., 1997).

Data quality control involves separation of data sets, having coefficient of determination less than 0.95 for the CO_2 concentration change, except data sets with concentration change less or equal to the method uncertainty. These data sets were not excluded.

The emission level of each gas is calculated assuming a linear increase in gas concentration over time at the specified chamber area and volume. Following formula is used to calculate GHG fluxes:

$$CO_2 - C[\mu g C m^{-2} h^{-1}] =$$

$$= \frac{M[g mol^{-1}] * P[Pa] * V[m^3] * \delta v[ppm(v)] * f_1}{R[m^3 Pa K^{-1} mol^{-1}] * T[K] * t[h] * A[m^2] * ppm},$$ where

P – air pressure during measurement, Pa – 101300;

Table 1

Description of measurement plots

Object	Abbreviation	Coordinates (LKS92)		Comment
		X	Y	
Zilākalna swamp	ZILĀ_2	383725	569608	flooded area, 0.7-1.2 m deep, decrease by up to 0.5 m during summer
Tēvgāršu swamp	TĒVG_2	392382	556892	flooded area, 1.0-1.5 m deep, decrease by up to 0.6 m during summer
Zilākalna swamp	ZILĀ_1	384112	569884	8 m wide channel, water depth – 0.8-1.8 m, relatively stable (0.3 m difference) during vegetation season

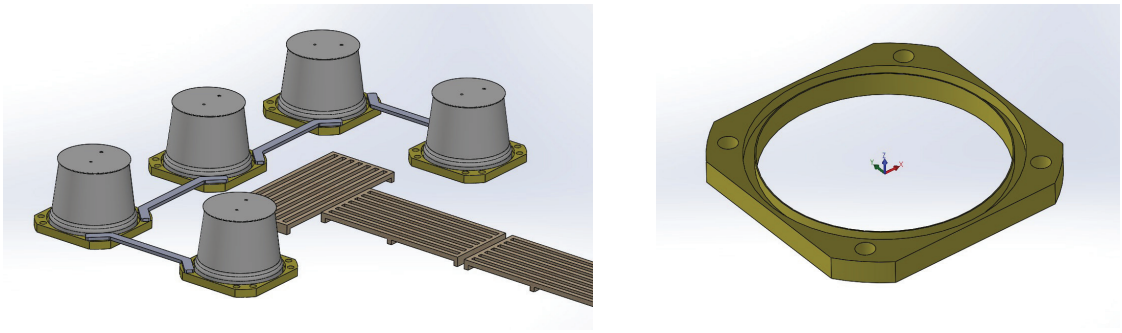

Figure 1. Gas measurement chambers, floating platform and the whole sampling setup.

δv – slope of volumentric concentration changes during measurement period, ppm(v);

R – universal gas constant, m^3 Pa K^{-1} mol^{-1} – 8.3143;

t – measurement period, h – 0.5;

T – air temperature during sampling, Kelvins;

V – volume of chamber, m^3 – 0.0655;

A – surface area of chamber, m^2 – 0,19625;

M CO_2, g mol^{-1} – 44,01;

M CH_4, g mol^{-1} – 16,04;

M N_2O, g mol^{-1} – 44,01;

f_1 – recalculation factor (for CO_2 0.27, for CH_4 0.75 and for N_2O 0.64).

Recalculation to GHG emissions to monthly base is done by calculation of average monthly fluxes (the average values from samples series collected in a particular month from each sampler) and multiplication with number of days in a month. Yearly emissions are calculated as sum of monthly averages. Uncertainty is represented as standard error of mean following to methodology applied in the National GHG inventory (Ministry of Environmental Protection and Regional Development, 2021).

Results and Discussion

Data from 3 measurement sites are used to evaluation of the GHG fluxes in flooded areas. After initial quality assessment by separation of the data sets where concentration gradient of CO_2 $R^2 < 0.95$, Ttest is used to compare data sets acquired in different sites and average monthly data on CO_2, N_2O and CH_4 fluxes. No significant difference is found between the data sets; however, in Zilākalna swamp (ZILĀ_2) CO_2 emissions in spring and autumn months are significantly smaller than from other sites; while CH_4 emissions in this site are significantly bigger than in other sites.

Comparison of the average monthly fluxes is provided in Figure 1. Not surprising, during summer months all fluxes are increasing, but in winter GHG fluxes are negligible. N_2O fluxes are negligible during the whole year and flooded areas in former peat extraction sites can be considered as not a source of N_2O emissions. Monthly fluctuations of CO_2 and CH_4 emissions can be explained by polynomial equations with statistically significant coefficient of correlation.

Average monthly fluxes are summarized in Figure 3. CO_2 emissions exceed uncertainty rate (standard error of mean) during the whole year, except the period when water is covered with ice. In further studies, it is reasonable to measure GHG fluxes only during ice-free period and the CO_2 modelling tools should consider this parameter. CH_4 emissions exceed uncertainty range from June to October. During other months CH_4 emissions are negligible; therefore, this source can also be measured only during summer and autumn months. However, temperature regime in spring can have an impact on GHG emissions. N_2O emissions are negligible during the whole period; however, in summer and autumn months the N_2O emissions slightly exceed uncertainty range. This can point to a potentially significant N_2O emissions from nutrient rich soils or water bodies receiving nutrient rich inflow. The acquired results also point out necessity to increase regularity of measurements during spring period to catch out GHG fluxes, which occur during ice melting period, and cracks and openings in ice should also be considered by measurement of fluxes, by

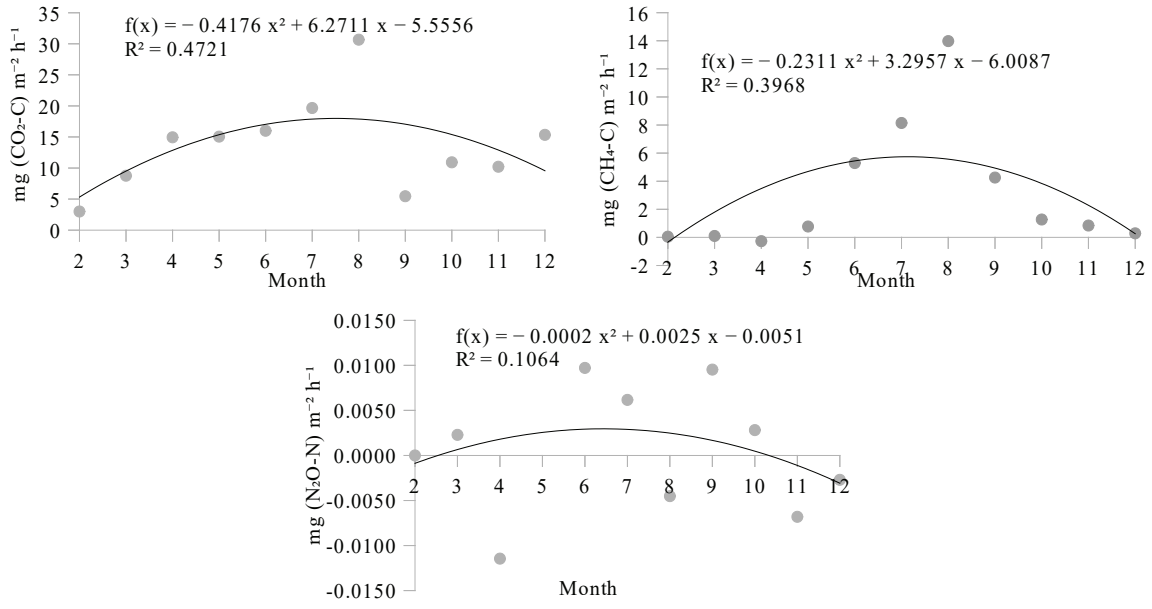

Figure 2. GHG fluxes from flooded lands in different months.

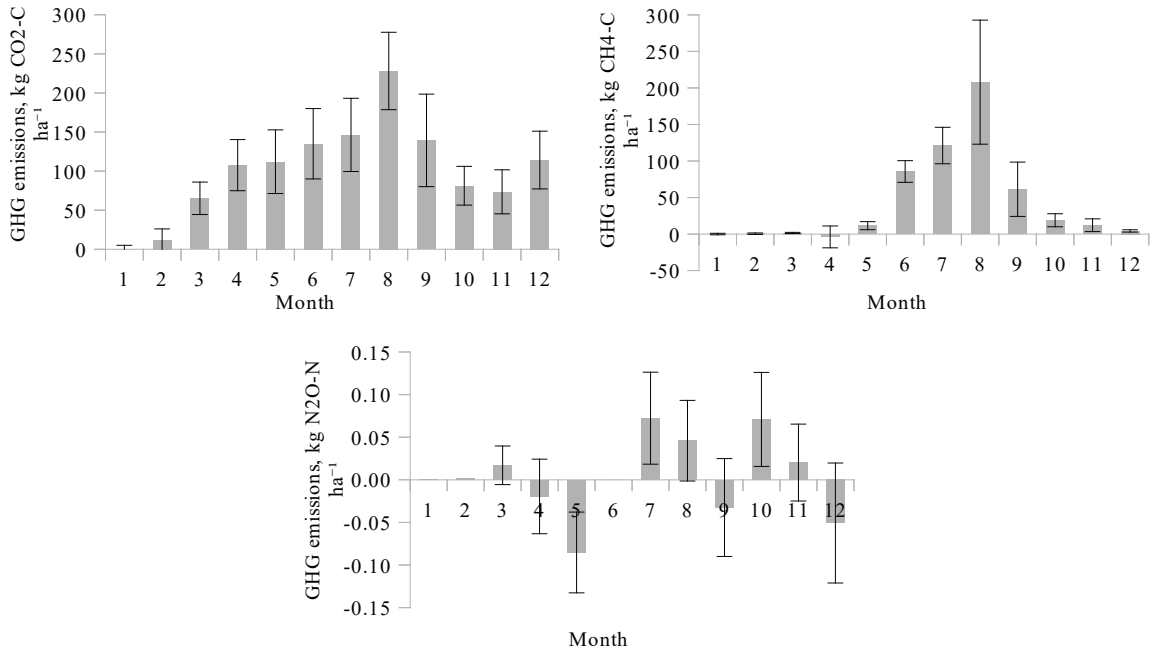

Figure 3. GHG emissions from water surface recalculated to area.

improvement of activity data and / or by introduction of a correction factor characterizing sporadic fluxes during ice melting period.

One of the parameters, which can be easily acquired and applied to model GHG emissions is air temperature; however, due to different heat exchange properties and other differences air temperature is not equal in air and water, especially in spring and autumn, which can lead to underestimation of the emissions during these seasons. Figure 4 shows relationship between the air and water temperature, explaining why flooded areas remain sources of emissions even if air temperature is negative – water remains warm and flooded area continues to create emissions. Therefore, it is important to improve activity data to apply in a model water temperature. Daily data in combination with information on ice-free period should be used to increase the accuracy of the assessment, especially in future, considering increase of the air temperature in winter.

The relationship between water temperature and CO_2 emissions from water surface is weak and can be explained by polynomial equation (Figure 5), while CH_4 emissions have good correlation with water temperature. In case of CO_2 weak correlation can be explained either by different solubility of CO_2 in different temperatures, impact of additional chemicals, e.g., bicarbonate anion in water on the solubility (Tang *et al*., 2015), or amount of dissolved oxygen. These parameters have to be studied further.

The net GHG emissions from flooded peat extraction sites equal to 18.07±3.73 tons CO_2 eq ha^{-1} yr^{-1}. Most of the emissions occur during summer and autumn months (figure 6). The most

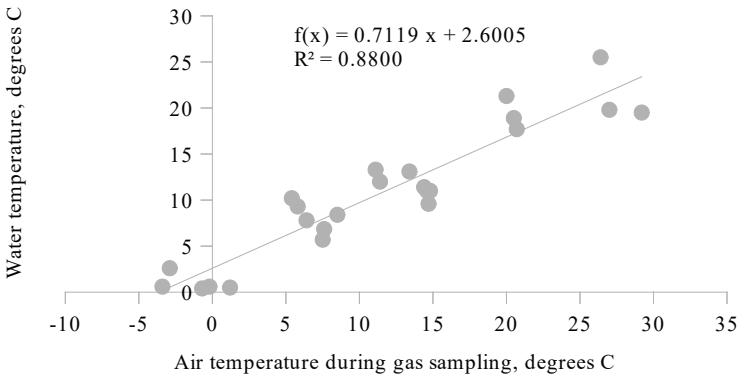

Figure 4. Relationship between water and air temperature.

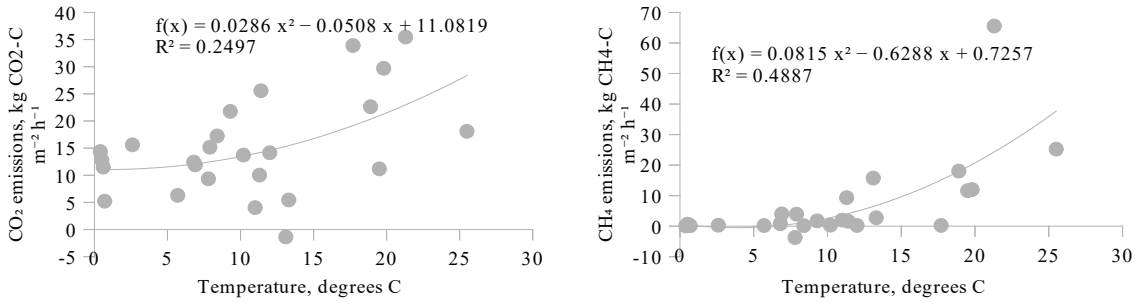

Figure 5. Relationship between water temperature and GHG fluxes.

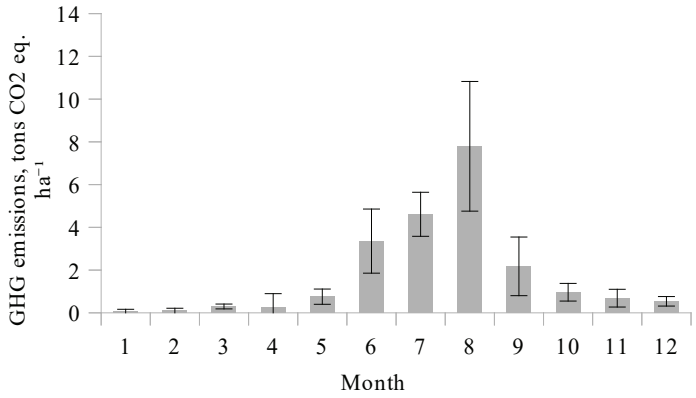

Figure 6. Total GHG emissions from water surface in flooded areas.

significant source of emissions from flooded areas is CH_4 (14.5±3.3 tons CO_2 eq ha^{-1} yr^{-1}). If compared to other land uses, GHG emissions from flooded peat extraction sites exceed the emissions from the most of the land use categories, except arable lands (by 360% more than afforested peatland, by 288% more than from peat extraction field and by 199% more than from rewetted area (Lazdiņš & Lupiķis, 2019; Upenieks & Rudusāne, 2021).

The project also highlighted another issue, which can affect the emissions – water level fluctuations in the measurement sites exceed 0.5 m, in flat landscape significantly affecting the area covered with water during the season; therefore, it is necessary to estimate GHG emissions also from periodically dried areas. The implemented pilot study clearly demonstrates significance of flooded peatlands as a source of GHG emissions. Net GHG emissions from flooded peatlands would increase to 95.8 Gg CO_2 eq yr^{-1}, if the project results are applied in the GHG inventory. Potential increase of the GHG emissions in case of flooding of all extracted peatlands would increase to 832 Gg CO_2 eq yr^{-1}.

Conclusions

1. Flooded areas in Latvia are a significant source of CO_2 emissions (967±107 kg CO_2-C ha^{-1} yr^{-1}) and the net CO_2 emissions from flooded areas may be about twice bigger than currently accounted in the National GHG inventory.
2. The most significant source of GHG emissions in flooded areas is CH_4 (435±98 kg CH_4-C kg ha^{-1} yr^{-1}) pointing out that currently accounted CH_4 emissions from flooded lands in the National GHG inventory may be about twice smaller than those proved by the study.
3. CO_2 and CH_4 fluxes are correlating with water temperature, especially, CH_4 emissions, which are occurring only if water temperature is above 5 °C. CO_2 emissions continue also during winter months, except the period, when water body is covered with ice.
4. The net GHG emissions from flooded areas are 18.1±3.7 tons CO_2 eq ha^{-1} yr^{-1}, which is about twice than the currently accounted GHG emissions in the National GHG inventory. Further studies are necessary to increase accuracy of the elaborated emission factors, as well as to improve activity data – period when water bodies are covered with ice, water temperature regime and other parameters, which could increase accuracy of the estimate.
5. Flooding of peatlands cannot be recommended as climate change mitigation measure before more detailed studies are done and additional GHG emissions should be considered if this option is selected, e.g., to increase the ecosystem value of peatlands.

Acknowledgements

The study is implemented within the scope of the project European Regional Development Fund Project 'Development of greenhouse gas emission factors and decision support tools for management of peatlands after peat extraction' (No. 1.1.1.1/19/A/064).

References

Bārdule, A., Petaja, G., Butlers, A., Purviņa, D., & Lazdiņš, A. (2021). Estimation of litter input in hemi-boreal forests with drained organic soils for improvement of GHG inventories. *BALTIC FORESTRY*, *27*(2), Article 2. DOI: 10.46490/BF534.

Butlers, A., & Ivanovs, J. (2018). Improved activity data for accounting greenhouse gas emissions due to management of wetlands. *Annual 24th International Scientific Conference Research for Rural Development 2018*, *1*, 27–33. DOI: 10.22616/rrd.24.2018.004.

Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Fukuda, M., Troxler, T., & Jamsranjav, B. (2013). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (p. 354). IPCC.

Ivanovs, J., Sietiņa, I., Lazdiņš, A., Skola, U., Zvirgzdiņš, A., & Zvaigzne, Z.A. (2017). Identification of wet areas in forest by using LiDAR based DEM. In: *Proceedings from Joint Seminar Arranged by NB – NORD and NOFOBE*, 54.

Krīgere, I., Dreimanis, I., Ozola, I., Dreimanis, I., & Lazdiņš, A. (2019). Establishment of paludiculture fields. In A. Priede & A. Gancone (Eds.), *Sustainable and responsible after-use of peat extraction areas* (pp. 169–173). Baltijas Krasti.

Krīgere, I., Kalniņa, L., Dreimanis, I., Pakalne, M., & Lazdiņš, A. (2019). Rewetting (re-creating mire conditions). In A. Priede & A. Gancone (Eds.), *Sustainable and responsible after-use of peat extraction areas* (pp. 195–202). Baltijas Krasti.

Krumšteds, L.L., Ivanovs, J., Jansons, J., & Lazdiņš, A. (2019). Development of Latvian land use and land use change matrix using geospatial data of National forest inventory. *Agronomy Research*, *17*. DOI: 10.15159/AR.19.195.

Lazdiņš, A., & Lupiķis, A. (2019). LIFE REstore project contribution to the greenhouse gas emission accounts in Latvia. In A. Priede & A. Gancone (Eds.), *Sustainable and responsible after-use of peat extraction areas* (pp. 21–52). Baltijas Krasti.

Licite, I., & Lupikis, A. (2020). Impact of land use practices on greenhouse gas emissions from agriculture land on organic soils. *Proceedings of 19th International Scientific Conference Engineering for Rural Development*, 1823–1830. DOI: 10.22616/ERDev.2020.19.TF492.

Loftfield, N., Flessa, H., Augustin, J., & Beese, F. (1997). Automated Gas Chromatographic System for Rapid Analysis of the Atmospheric Trace Gases Methane, Carbon Dioxide, and Nitrous Oxide. *Journal of Environment Quality*, *26*(2), 560. DOI: 10.2134/jeq1997.00472425002600020030x.

Lupiķis, A. (2019). Results of GHG emission measurements in differently managed peatlands in Latvia – the basis for new national GHG emission factors. *Sustainable and Responsible Management and Re-Use of Degraded Peatlands in Latvia*, 24–26.

MacDonald, G.M., Beilman, D.W., Kremenetski, K.V., Sheng, Y., Smith, L.C., & Velichko, A.A. (2006). Rapid Early Development of Circumarctic Peatlands and Atmospheric CH_4 and CO_2 Variations. *Science*, *314*(5797), 285–288. DOI: 10.1126/science.1131722.

Ministry of Environmental Protection and Regional Development. (2021). *Latvia's National Inventory Report Submission under UNFCCC and the Kyoto protocol Common Reporting Formats (CRF) 1990-2019* (p. 545). Ministry of Environmental Protection and Regional Development of the Republic of Latvia.

Mokma, D.L. (2005). ORGANIC SOILS. In *Encyclopedia of Soils in the Environment* (pp. 118–129). Elsevier. DOI: 10.1016/B0-12-348530-4/00034-5.

Straková, P., Penttilä, T., Laine, J., & Laiho, R. (2012). Disentangling direct and indirect effects of water table drawdown on above- and belowground plant litter decomposition: Consequences for accumulation of organic matter in boreal peatlands. *Global Change Biology*, *18*(1), 322–335. DOI: 10.1111/j.1365-2486.2011.02503.x.

Tang, Y., Bian, X., Du, Z., & Wang, C. (2015). Measurement and prediction model of carbon dioxide solubility in aqueous solutions containing bicarbonate anion. *Fluid Phase Equilibria*, *386*, 56–64. DOI: 10.1016/j.fluid.2014.11.025.

Upenieks, E.M., & Rudusāne, A. (2021). Afforestation as a type of peatland recultivation and assessment of its affecting factors in the reduction of GHG emissions. *Proceedings of the International Scientific Conference 'Rural Development'*, 295–300. DOI: 10.15544/RD.2021.0.

 DOI: 10.22616/rrd.28.2022.007

FRUIT PROPERTIES OF SWEET CHERRY (*PRUNUS AVIUM* L.) SUITED FOR WOOD PRODUCTION

***Santa Celma[1,2], Austra Zusevica[1], Mudrite Daugaviete[1], Dagnija Lazdina[1]**
[1]Latvian State Forest Research Institute 'Silava', Latvia
[2]Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: santa.celma@silava.lv

Abstract
Sweet cherry *Prunus avium* L. cultivated for wood production is selected and bred mainly based on its growth rate and stem properties to maximize the valuable timber outcome. However, the fruit of sweet cherry has ecological value as food source for animals and can also serve as an income source prior felling. It could be beneficial to consider fruit properties in selection and breeding of cherries for wood production purpose. In this study, we compare the properties, such as volume and moisture content, of fruit collected from cherry orchard and two plantations, where sweet cherry is cultivated for wood production. Based on fruit and trunk properties we select genotypes from cherry orchard, that are promising for further studies and development of locally sourced planting material. Fruit of ten genotypes cultivated for fruit and nine genotypes cultivated for wood was collected in July, 2020. Fruit was then scanned to calculate volume, pitted, weighted and oven dried to obtain dry matter and moisture content. The results show that fruit cultivated in orchard have greater volume and weight, as well as have more pulp compared to genotypes selected for wood production. The relative moisture and dry matter content of the pulp does not follow the same trend, and is not directly associated with morphological properties. Based on fruit size, moisture content and trunk diameter 'Kazdangas', 'Agrais Lielajiem Ķiršiem', 'Brjanskaja Rozovaja' and 'Muiža' are the most promising genotypes for further studies aimed to develop planting material with good fruit yield and timber outcomes.
Key words: cherry plantation, fruit traits, cherry fruit volume, pomology, wild cherry.

Introduction

Sweet or wild cherry *Prunus avium* L. syn. *Cerasus avium* (L.) Moench has gained interest as a fast growing hardwood tree species, that has been studied since the late 80's of the last century (Ducci *et al*., 2013; Russell, 2003; Welk, de Rigo, & Caudullo, 2016). Cherry trees can be cultivated specifically for timber production (Kobliha, 2002; Pryor, 1988); however, historically it has mainly been selected, bred and cultivated for its fruit properties. While the interest in sweet cherry plantation establishment is increasing in Latvia, at the moment sweet cherry wood production happens only on a small scale (Daugaviete *et al*., 2021). Management approaches differ depending on the aims of a plantation. Fruit orchards require regular weed and pest control, trees are heavily pruned, trained and are typically kept at a low height of about 3-4 m (Green, 2005)tall, freestanding trees to much higher planting densities utilizing two approaches to tree training and management. The first system, named the Lenswood tie down system, relies on extensive tying of vigorous branches to a horizontal orientation to induce cropping and manage vigor. This system has often resulted in excessive vigor and shading from the manipulated branches. The second system is a modification of the Spanish bush system. Two versions of this have evolved: the Aussie bush (4 leader bush. Wood producing plantations require less intense management – weed control is crucial in early stage of development (Pryor, 1988) and trees are pruned to reduce competition and promote production of straight and thick trunks. In wood producing plantations, stock material of foreign origin (usually Swedish or Danish) is typically used, as it has shown better growth results compared to locally sourced planting material. On the other hand, selection and breeding of local forms for superior fruit properties, winter hardiness and disease tolerance has been ongoing for decades. There is limited available information on fruit properties of genotypes selected for wood production and vice versa. Some of the genotypes that bear desirable fruit also possess dendrometric qualities that are promising for wood production (Kobliha, 2002). Assessment of the actual growth rate and dendrometric features of these genotypes still needs to be carried out, especially in field conditions. Thus, in this study we focus on fruit properties. Fruit yield may serve as an additional source of income from cherry stands established for wood production (Hasanbegovic, Hadziabulic, & Aliman, 2020). In addition, selection of genotypes that produce high fruit yields can increase the ecological value of sweet cherry as a food source for wild animals (Welk, de Rigo, & Caudullo, 2016). The aim of this study was to evaluate and compare fruit properties of sweet cherry genotypes selected specifically for wood production and genotypes that have been mainly selected for their fruit quality but possess dendrometric properties – thick and straight trunks – potentially suitable for wood production.

Materials and Methods

Sweet cherry fruit was collected from two plantations and one orchard. In plantation located in Skriveri (56.69 N, 25.14 E), Swedish clone 10 and Swedish clone 13 were planted in 2011. In another plantation, located in Īslīce (56.33 N, 24.11 E),

planting material developed in Denmark – Truust F791 provenience – was planted in 2011, fruits of seven trees (genotypes Truust 1, Truust 2, Truust 3, Truust 4, Truust 5, Truust 6 and Truust 7) were collected, as the trees are not genetically identical and fruit differs among individual trees. Ten sweet cherry tree genotypes with straight and thick trunks were selected for fruit collection in cherry orchard located in the Institute of Horticulture in Dobele (56.61 N, 23.30 E) – 'Agrais Lielajiem Ķiršiem', 'Aizkraukles Saldais', 'Brjanskaja Rozovaja', 'Kalniņa Sējenis', 'Kārzdabas', 'Muiža', 'Muiža 2', 'PU 14 498', 'Smiltenes' and 'Smiltenes 9'. In cherry orchard trees were planted in 2006. During fruit collection trunk diameter at 1.3 m height (diameter at breast height) of selected genotypes was measured. Cherry fruits were collected at random heights and face of the crown. There is a small number of individual trees per each genotype in the cherry orchard, thus, only in some cases it was possible to collect fruit from multiple trees of the same genotype. Fully ripe fruits were collected during the period 24.-31. July, 2020.

From each genotype, 50 fruits were scanned using EPSON Expression 12000XL scanner, pitted and 50 cherry pits were scanned. Fruit and pit length, width and volume were calculated based on scanned images WinSEEDLE™ Pro (version 2019a; Regent Instruments Canada Inc.).

Fifty fresh fruits of each genotype were weighted, pits were removed and weighted (with 0.01 g precision). The average weight per fruit and pit and their proportion was calculated. Fifty grams of fresh pulp per genotype was dried at 40 °C until constant weight to evaluate pulps' moisture content. Due to pooled sample approach the statistical analysis for these parameter was not conducted.

All data analysis and visualization was carried out using R version 4.0.5 (R Core Team, 2021). Non-parametric Kruskal-Wallis test and HDS Tukey's post hoc test were used to compare the groups. Clustering dendrogram was created based on fruit volume (mm^3), length (mm), width (mm), fresh weight (g), pits' fresh weight (g), pulps' proportion (%), pits' proportion (%), pulpls' fresh and dry weight (g), moisture content (%) and dry matter content (%).

Results and Discussion

In terms of morphological features, cherries cultivated for fruit production had larger and heavier fruit, with exception of 'Kalniņa Sējenis', that was more similar to genotypes selected for wood production. The mean pit volume followed similar pattern as the whole fruit – larger pits were typical to larger cherry fruits (Figure 1). Fruit of larger mean volume also had higher variance compared to smaller fruits collected from trees that are bred and cultivated

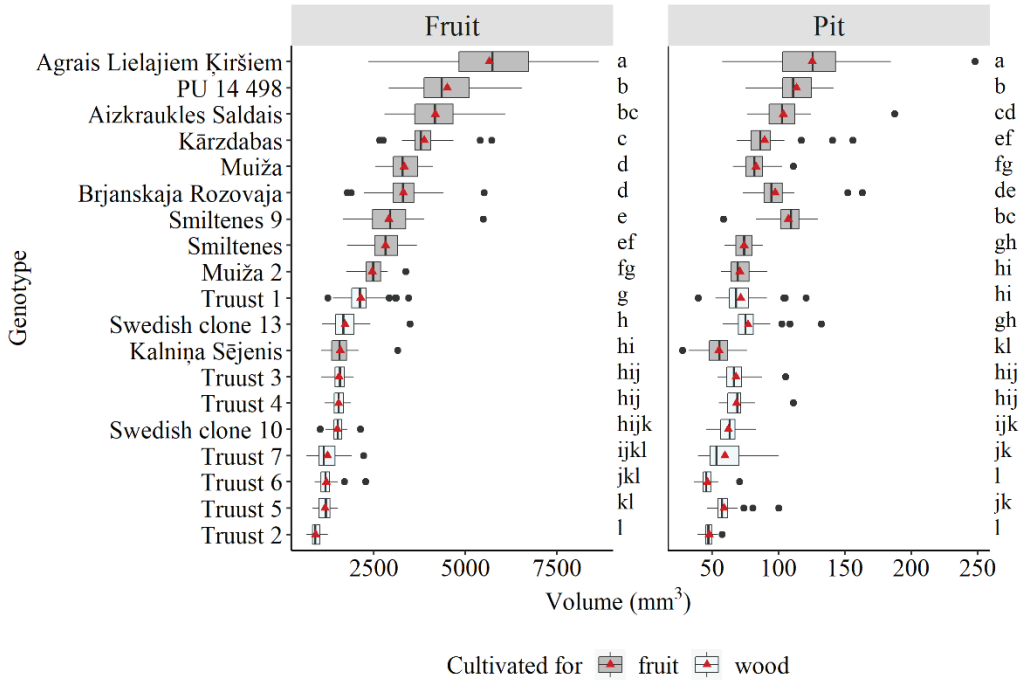

Figure 1. Volume of sweet cherry fruits and their pits depending on genotype and cultivation purpose. Different letters on the right side represent significant (p <0.05) differences between genotypes. Box shows interquartile range (25-75%), vertical line in the box represents median, red triangle shows the mean, whiskers represent maximum and minimum values and black dots show outliers.

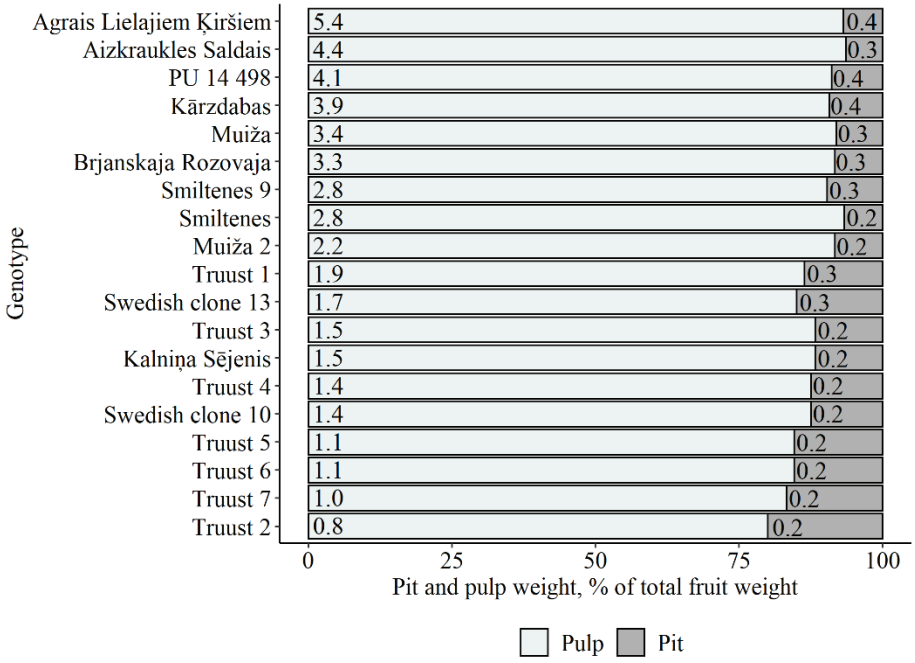

Figure 2. Relative weight of sweet cherry fruit pulp and pit depending on genotype. Values inside bars represent average pulp and pit weight in grams.

for wood production. There were significant fruit and pit volume differences amongst fruit produced by Truust F791 provenience originated planting material. Truust genotypes have been selected and bred for rapid growth and straight trunks, but some, such as Truust 1, can also produce desirable fruit. It should be noted that fruit analysed in this study was collected from different areas under different managements, thus, the local microclimate as well as management practices may affect the results.

Fruit weight followed the same pattern as the volume, where 'Agrais Lielajiem Ķiršiem' had the heaviest fruit with mean weight of 5.8 grams, followed by 'Aizkraukles Saldais', 'PU 14 498' and 'Kārzdabas'. The fruit of these genotypes had bigger volume, total weight and more absolute as well as relative pulp compared to most other studied genotypes. In addition, these genotypes had heavier and bigger pits, making them better suited for propagation via seeds. Cherries cultivated for wood had smaller fruit, they had less relative pulp (82.5-88.5%), whereas cherries cultivated for fruit production had more absolute (1.5-5.4 g) as well as relative pulp (89.5-94.0%) (Figure 2). Overall, pits comprised from 6.0 to 17.5% of the total fruit (11.5-17.5% of fruit from trees cultivated for wood and 6.0-10.5% of fruit from trees cultivated for fruit).

In terms of marketing, fruit physical properties, such as the density of the pulp, water content, skin thickness as well as morphological and visual features and taste quality are of great importance (Bujdosó *et al.*, 2020). Water content of cherry fruit (Figure 3) did not follow the same trend as size properties (Figure 1). Water content has to do with fruit firmness as well as their ripeness stage during harvest. While 'Kārzdabas', 'PU 14 498' and 'Aizkraukles Saldais' had some of the biggest and heaviest fruit, their relative moisture content was also high compared to other genotypes. Based on the relatively small size and non-uniform shape, as well as high moisture content, thus, reduced transportability and possibly lower resilience to long term storage, all of the studied fruit are better suited for processing market rather than fresh market. In other studies the preferred weight of a cherry fruit has been found to vary between 11 and 13 g (Kappel, Fisher-Fleming, & Hogue, 1996)based on average fruit weight, for sweet cherries was ll to 12 g. A nine- row or 29- to 30-mm-diameter sweet cherry would be the equivalent industry standard. When two separate panels were conducted with overlapping samples, panelists had similar results for optimum fruit size. The optimum color is represented by the 6 color chip of the prototype of the Centre Technique lnterprofessionnel des Fruits et Legumes (CTIFL, which is at least twice as much as the heaviest cherries – 'Agrais Lielajiem Ķiršiem' (Figure 2) – in this study. Consumer and producer aim for fruit size from 21 mm up to more than 29 mm in diameter (Bujdosó *et al.*, 2020; Ladner *et al.*, 2008; Turner *et al.*, 2008), and only three genotypes – 'Agrais Lielajiem Ķiršiem', 'Aizkraukles Saldais' and 'PU 14 498' – had the average size above 21 mm. However, the taste is still

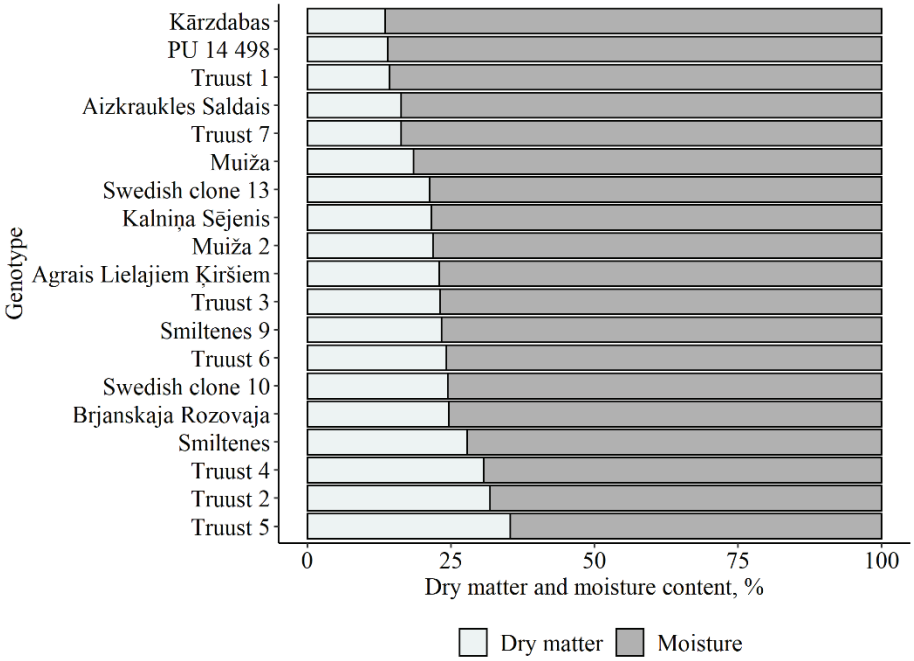

Figure 3. Dry matter and moisture content of sweet cherry fruit pulps depending on genotype.

the main determining factor of consumers' preference (Turner *et al.*, 2008).

Based on the properties studied, genotypes were grouped in four clusters (Figure 4). 'Agrais Lielajiem Ķiršiem' is the most different of the genotypes in terms of fruit (Figure 1 and 2), having the biggest fruit size. 'Aizkraukles Saldais', 'Kārzdabas' and 'PU 14 498' also have desirable fruit; however, 'Aizkraukles Saldais' and 'PU 14 498' had the smallest trunk diameter at breast height (13.9 and 13.4 cm respectively), whereas 'Kārzdabas' was the thickest (23.6 cm) of trees selected from cherry orchard. The replicate number in orchard is too low to evaluate if these stem properties are typical to the genotype. Thus, further growth studies must be carried out, to accurately assess the wood producing potential of selected genotypes. 'Smiltenes 9', 'Smiltenes', 'Muiža', 'Brjanskaja Rozovaja' and 'Muiža 2' have medium fruit. Of this cluster, 'Smiltenes' was the thickest – 23.2 cm – followed by 'Brjanskaja Rozovaja' – 19.8 cm. 'Kalniņa sējenis' is more similar to genotypes grown in plantations –

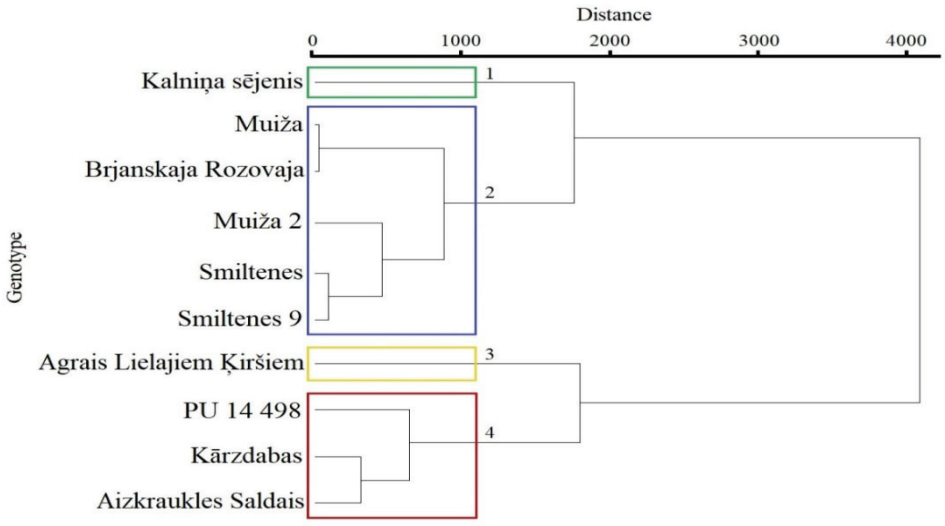

Figure 4. Dendrogram showing results of hierarchical cluster analysis conducted on seven fruit traits and tree diameter at breast height of ten sweet cherry genotypes (based on Euclidian distance). Numbers on the dendrogram branches represent four clusters.

with relatively small fruit, but good trunk properties (diameter at breast height – 19.8 cm). If the diameter at breast height is considered in combination with fruit properties, 'Kārzdabas', 'Agrais Lielajiem Ķiršiem', 'Brjanskaja Rozovaja' and 'Muiža' are the most promising genotypes for propagation with intent to obtain a good compromise between fruit and timber production.

The results of this study show, that cherries bred and cultivated for wood production have small fruit that can compete with fruit from orchards only in terms of dry matter and moisture content (thus, the potential juice yield). Greater biomass accumulation occurs when more resources can be allocated into growth rather than other processes (including reproductive processes and fruit bearing) (Castro-Díez, Montserrat-Martí, & Cornelissen, 2003; Martín *et al*., 2015). Thus, there will always be some trade-offs between wood and fruit production. However, some compromise could be achieved through selective breeding and also by adapting management practices accordingly. To obtain some financial benefit from fruit in plantations established with purpose of wood production, fruit harvesting could be carried out simultaneously with pruning operations. While intensive pruning can decrease tree growth rate (Springmann, Rogers, & Spiecker, 2011)pruning artificially is the only practical option. The study analysed the effect of conventional whorl-wise pruning and selective pruning, on height growth, diameter growth and secondary shoot development of wild cherry. Four pruning treatments were applied on cherry trees in summer 2007, one group of cherries was left unpruned to serve as a control: treatment C1 (upper 5 whorls left, summer pruning effect on fruit productivity is either positive or neutral (Measham *et al.*, 2017; Roversi, Ughini, & Monteforte, 2008)various combinations of winter and summer pruning treatments were imposed on eight-year-old trees of four sweet cherry varieties. For each variety, 5 different types of pruning strategies were imposed, combining winter pruning (made with 2 levels of pruning intensity. However, in pruning the lower portion of branches that bear relatively smaller fruit (Davidson & George, 1959) is typically removed. It has been found, that younger branches bear fruit of higher quality (San Martino, Hochmaier, & Manavella, 2014) and shoots up to 20 cm in length produce larger number of flower and leaf buds (Thurzó *et al*., 2008). Thus, specific pruning approaches and training systems need to be developed to maximize harvest without compromising stem growth in plantations where wood production is the main goal.

To increase the ecological resilience of tree stands, it is recommended to use multiple species and genotypes instead of strictly monoculture or clonal material (Liu, Kuchma, & Krutovsky 2018). In mixed genotype stands with different fruit set timing, but similar stem properties, the period of fruit harvest could be prolonged and, thus, benefit from fruit exploitation increased.

Conclusions

Overall, there was a clear difference between the size of cherry fruit collected from trees growing in orchard and from trees specifically cultivated for production of wood. In case of cherry trees cultivated for wood production, it is not clear, if the small size of fruit is a result of biological trade-offs between wood and fruit production, or if the fruit properties have simply been neglected during the breeding and selection processes. Combining the results of this study with further germination and growth assessment of referred genotypes will help evaluate if fruit harvesting can be feasibly incorporated into systems where wood and timber production is the main goal. Further studies should focus on 'Kārzdabas', 'Agrais Lielajiem Ķiršiem', 'Brjanskaja Rozovaja' and 'Muiža', as we found these genotypes to have the most promising equilibrium between fruit and trunk properties.

Acknowledgements

This study is a part of PhD research 'Sweet cherry (*Prunus avium* L.) in forest stands and tree plantations in Latvia' undertaken by Santa Celma and was conducted under LAD project 19-00-A01620-000088 'Testing the Sweet Cherry Propagation Methods and Selecting Superior Clones for Plantation Cultivation of Sweet Cherry for Timber in the Climatic Conditions of Latvia'. The authors would like to thank the Institute of Horticulture and the owners of 'Ziediņi' (in Īslīce) for providing the opportunity to collect the cherry fruits and Uldis Daugavietis for help with data acquisition.

References

Bujdosó, G., Hrotkó, K., Feldmane, D., Giovannini, D., Demirsoy, H., Tao, R., Ercisli, S., Ertek, N., & Malchev, S. (2020). What kind of sweet cherries do the final consumers prefer? *South-Western Journal of Horticulture, Biology and Environment*, 11(1), 37–48.

Castro-Díez, P., Montserrat-Martí, G., & Cornelissen, J. (2003). Trade-offs between phenology, relative growth rate, life form and seed mass among 22 Mediterranean woody species. *Plant Ecology*, 166, 117–129. DOI: 10.1023/A:1023209230303.

Daugaviete, M., Lazdiņa, D., Feldmane, D., Treigute, D., Daugavietis, U., Celma, S., & Zuševica, A. (2021). Sweet Cherry (*Prunus avium* L. Syn. *Cerasus avium* Moench.): A Study of its Distribution in Latvia and Superior Clone Selection for Cherry Plantations for Wood in Local Climatic Conditions. *Proceedings of the Latvian Academy of Sciences: Section B. Natural, Exact, and Applied Sciences*, 75(4), 282–291. DOI: 10.2478/prolas-2021-0041.

Davidson, T.R., & George, J.A. (1959). Variation in weight, volume and diameter of sour cherry fruits from individual trees. *Canadian Journal of Plant Science*, 39(2), 210–214. DOI: 10.4141/cjps59-030.

Ducci, F., De Cuyper, B., De Rogatis, A., Dufour, J., & Santi, F. (2013). Wild Cherry Breeding (Prunus avium L.). In L. Pâques (Eds.), *Forest Tree Breeding in Europe. Managing Forest Ecosystems* (Vol. 25, pp. 663–511). Dordrecht, Springer. DOI: 10.1007/978-94-007-6146-9_10.

Green, K. (2005). High density cherry systems in Australia. *Acta Horticulturae*, 667, 319–324. DOI: 0.17660/ActaHortic.2005.667.46.

Hasanbegovic, J., Hadziabulic, S., & Aliman, J. (2020). Morphological characteristics of autochthonous genotypes of sweet cherry (*Prunus avium* L.) cv. 'Alica' and 'Hrust' in area of Herzogovina. In Proceedings of the XI International Scientific Agricultural Symposium 'Agrosym 2020', 8-9 October 2020 (pp. 112–120). Jahorina, Boznia and Herzegovina.

Kappel, F., Fisher-Fleming, B., & Hogue, E. (1996). Fruit characteristics and sensory attributes of an ideal Sweet Cherry. *HortScience*, 31(3), 443–446. DOI: 10.21273/hortsci.31.3.443.

Kobliha, J. (2002). Wild cherry (Prunus avium L.) breeding program aimed at the use of this tree in the Czech forestry. *Journal of Forest Science*, 48(5), 202–218. DOI: 10.17221/11876-jfs.

Ladner, J., Zürcher, M., Leuenberger, Y., & Schwizer, T. (2008). The bigger the cherries, the better the income? *Acta Horticulturae*, 795(2), 767–773. DOI: 10.17660/actahortic.2008.795.123.

Liu, C.L.C., Kuchma, O., Krutovsky, K.V. (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. *Global Ecology and Conservation*, 15, e00419, DOI: 10.1016/j.gecco.2018.e00419.

Martín, D., Vázquez-Piqué, J., Carevic, F.S., Fernández, M., Alejano, R. (2015). Trade-off between stem growth and acorn production in holm oak. *Trees*, 29, 825–834. DOI: 10.1007/s00468-015-1162-y.

Measham, P.F., MacNair, N., Bound, S.A., & Quentin, A. (2017). To cut or not to cut: The role of extension growth in fruit quality. *Acta Horticulturae*, 1161, 627–632. DOI: 10.17660/ActaHortic.2017.1161.100.

Pryor, S.N. (1988). The Silviculture and Yield of Wild Cherry. *Forestry Commission*, Bulletin 75, 1–22.

R Core Team. (2021). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2021.

Roversi, A., Ughini, V., & Monteforte, A. (2008). Productivity of four sweet cherry varieties as influenced by summer and winter pruning. *Acta Horticulturae*, 795(2), 517–524. DOI: 10.17660/ActaHortic.2008.795.80.

Russell, K. (2003). Technical Guidelines for genetic conservation and use of Wild Cherry (*Prunus avium*). *Euforgen*. (p. 6).

San Martino, L., Hochmaier, V., & Manavella, F.A. (2014). Sweet cherry (*Prunus avium* L.) fruit quality in relation to wood age and fruit position on the branch. *Acta Horticulturae*, 1020, 271–276. DOI: 10.17660/actahortic.2014.1020.39.

Springmann, S., Rogers, R., & Spiecker, H. (2011). Impact of artificial pruning on growth and secondary shoot development of wild cherry (*Prunus avium* L.). *Forest Ecology and Management*, 261(3), 764–769. DOI: 10.1016/j.foreco.2010.12.007.

Thurzó, S., Szabó, Z., Nyéki, J., Racskó, J., Drén, G., Szabó, T., Nagy, J., Holb, I.J., & Veres, Z. (2008). Some fruit-bearing shoot characteristics of nine sweet cherry cultivars in Hungary. *Acta Horticulturae*, 795(2), 673–676. DOI: 10.17660/ActaHortic.2008.795.106.

Turner, J., Seavert, C., Colonna, A., & Long, L.E. (2008). Consumer sensory evaluation of sweet cherry cultivars in Oregon, USA. *Acta Horticulturae*, 795(2), 781–786. DOI: 10.17660/ActaHortic.2008.795.125.

Welk, E., de Rigo, D., & Caudullo, G. (2016). *Prunus avium* in Europe: distribution, habitat, usage and threats. In J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, A. Mauri (Eds.), *European Atlas of Forest Tree Species*. Publication Office of the European Union, Luxembourg, e01491d+.

 DOI: 10.22616/rrd.28.2022.008

REVIEW OF CLIMATE CHANGE MITIGATION MEASURES APPLICABLE IN DEGRADED PEATLANDS IN LATVIA

***Santa Kaleja**, **Arta Bardule**
Latvian State Forest Research Institute 'Silava', Latvia
*Corresponding author's email:santa.kaleja@silava.lv

Abstract
Former peat extraction fields and currently employed peatlands are significant source of GHG emissions. Total area of degraded peatlands, which are not yet afforested or flooded is 39.5 kha and the net emissions, excluding peat produced for the horticulture applications, is 0.33 mill. tons CO_2 eq. Large emissions means also significant mitigation potential; therefore, available knowledge on the GHG mitigation potential should be summarized to define research priorities and propose quantifiable measures.
The aim of the study is to summarize literature and expert questionnaires based information on potentially valuable climate change mitigation measures applicable in degraded peatlands formerly used for peat extraction. The evaluation involves substantiation of the effect, criteria for site selection, addressed carbon pools and GHG emissions, methods for the effect assessment at local and national level, existing LPIS and other monitoring systems, duration of effect and supplementary measures to sustain the effect, estimation of cost and benefit ratio, existing support schemes, knowledge gaps to be filled, uncertainties and collaboration needed.
The study proved that degraded peatlands can contribute significantly to the climate change targets, and this is identified by scientific community in multiple publications and research reports; however, quantitative assessment is missing in most of the cases. The most of the proved mitigation measures are associated with afforestation, which can be implemented in approximately 50% of degraded peatlands.
Key words: greenhouse gas, GHG, emissions, degraded peatlands, mitigation measures.

Introduction

According to the guidelines of Intergovernmental Panel on Climate Change (IPCC), Latvia is located in a temperate cool & moist (TCM) climate zone. Organic soils in the TCM region is a significant source of greenhouse gas (GHG) emissions. In Latvia, organic soils contribute to 100% of GHG emissions from cropland and grassland in land use, land use change and forestry (LULUCF) sector (Ministry of Environmental Protection and Regional Development, 2021). The total area of organic soils, usually not separated into nutrient-rich and -poor soils in the National GHG inventory reports, in the project partner countries is 17 mill. ha, representing 48% of organic soils in the EU and 75% of organic soils in TCM climate zone (Līcīte *et al*., 2019). GHG emissions from organic soils in the EU is 117 mill. tons CO_2 eq. including 32 mill. tons CO_2 eq. (27% form the EU GHG emissions from organic soils) in the participating countries). GHG emissions from organic soils are characterized by high uncertainty rate and significant differences between countries in the same climate zone (Lupiķis & Lazdins, 2017).

In Latvia, 41.3% of total organic soils are occupied by forests, 40.1% – by wetlands (excluding peat extraction areas and flooded wetlands), 9.6% – by cropland, 5.0% – by grassland, 3.2% – peat extraction areas and 0.7% by flooded and rewetted wetlands (Līcīte *et al*., 2019). Emission factors used to calculate carbon stock changes in organic soils in different

Table 1

Emission factors used to calculate carbon stock changes in organic soils in different land use types in Latvia (Ministry of Environmental Protection and Regional Development, 2021)

Land use		Net carbon stock change in organic soils per area, t C ha^{-1}
Category	Sub-category	
Wetlands	Wetlands remaining wetlands (average)	-0.22
	Peat extraction remaining peat extraction	-2.80
	Flooded land remaining flooded land	Included elsewhere (IE)
	Other wetlands remaining other wetlands	Not applicable
	Land converted to wetlands (average)	-2.27
	Land converted to peat extraction	Not applicable
	Land converted to flooded land	IE
	Land converted to other wetlands	-2.71

Table 2

Emission factors for calculation of emissions from drainage and rewetting and other management of organic soils in Latvia (Ministry of Environmental Protection and Regional Development, 2021)

Type of soil	Emission factors			
	CO_2, tons CO_2 ha^{-1}	N_2O-N, kg N_2O-N ha^{-1}	CH_4, kg CH_4 ha^{-1}	CH_4, kg CH_4 ha^{-1} from ditches
Peat extraction fields	1.21	0.44	10.83	542.00
Rewetted and flooded organic soils	0.50	-	216.00	-

wetland categories within National GHG Inventory 2021 are summarized in Table 1.

Emission factors for calculation of emissions and removals from organic soils in wetlands in Latvia are summarized in Table 2. In rewetted and flooded lands default emission factors are applied. Country specific emission factors are elaborated for peat extraction fields and other drained, nutrient poor soils (Lazdiņš & Lupiķis, 2019).

Climate change mitigation targeted measures applied to managed organic soils reported by Latvia under Article 10 of the LULUCF Decision and listed in the Reports on Policies and Measures under Article 13 and on Projections under Article 14 of Regulation (EU) No 525/2013 of the European Parliament and of the Council are based on the Latvian Rural Development Programme 2014-2020. No measures are directly addressed to restoration of wetlands; however, afforestation is often listed as the most valuable climate change mitigation measure (Upenieks & Rudusāne, 2021). Information about rewetting is controversial; according to earlier studies in Latvia

Table 3

Contents of experts questionnaire about climate change mitigation targeted measures

No	Type	Description
	Title	Simple and short title describing core of the measure.
	Substantiation of the impact	Brief description of impact of the measures.
	Criteria for site selection	Criteria for selection of suitable sites where the selected measures can be implemented to ensure the proposed effect.
	Addressed carbon pools and GHG emissions	Carbon pools and GHG fluxes positively or negatively affected by the measure.
	Methods and models applied for impact assessment at local and national level	Existing calculation methods including assumptions for listing the measure under GHG emissions reduction targeted activities.
	How existing land parcel information system (LPIS) and other monitoring systems should be improved to verify the impact	Existing and necessary activity data sources on carbon stock changes, which can be used in calculations.
	Duration of impact and supplementary measures to sustain the impact	Duration of the impact of the measure, additional activities necessary to maintain the achieved mitigation effect or to ensure that the proposed impact will be achieved.
	Quantitative implementation potential at a national level	Quantitative impact assessment – tons CO_2 eq ha^{-1} and at national level, different pools can be evaluated separately, as well as pools missing information on climate change mitigation can be added.
	Conformity with sustainability criteria	Conformity with sustainability criteria listed in the LULUCF regulation and national policies.
	Estimation of cost and benefit ratio	Information on implementation costs, investments and potential financial outcome by selling of wood.
	Interferences and synergies with other sectors, land uses and policies	Description of impact on other sectors, e.g. agriculture or energy sector.
	Knowledge gaps to be filled, uncertainties, collaboration needed	Missing knowledge on the impact of the measure, application area, activity data sources and monitoring tools to follow up to implementation of the measure.

and Finland, rewetting may not decrease emissions, at least in short term (Butlers *et al*., 2021; Ojanen & Minkkinen, n.d.).

The aim of the study is to summarize literature and expert questionnaires based information on potentially valuable climate change mitigation measures applicable in degraded peatlands formerly used for peat extraction.

Materials and Methods

The review is based on the expert questionnaires and literature studies. Expert questionnaire is used to identify potential measures. Questions asked to experts and reviewed in the scientific literature are listed in Table 3. Seven experts or expert teams from Latvia, Lithuania, Estonia, Finland and Germany were involved in completion of the questionnaire. The most of the experts providing answers are involved in the GHG inventory process.

Results and Discussion

Climate change mitigation measures in former peat extraction fields are mostly associated with afforestation and management of afforested lands or rewetting; however, verified quantitative information is available only for forest management related activities. Mitigation measures are grouped into land use changes, forest products, productivity, risk management and other forest management related measures in Table 4, highlighting (by bolding) the description of the most critical measures.

The most of the measures having proved mitigation potential require afforestation of degraded peatlands. This is realistic scenario in about half of the

Table 4

Identified climate change mitigation measures

Group	Title of measure	Group	Title of measure
Land use changes	**Afforestation of former peat extraction fields**	Increasing productivity	Adaptation of drainage systems to optimal depth of groundwater and inflow
	Conversion of peat extraction fields into woody paludicultures for HWP and biofuel production		**Application of mineral fertilizers and shortening of rotation**
	Intensive cultivated short rotation forests in peat extraction fields		Drainage and intensification of forest management on fertile wet organic soils
	Rewetting of peatlands – conversion to wetlands		**Fertilization with wood ash**
Forest products	Improved bucking instructions, laser scanning and image analysis technologies to improve the output of assortments		**Improvement of genetic properties and adaptiveness of planting material and forest regeneration methods**
	Increase efficiency of utilization of timber – less biofuel and pulpwood and more harvested wood products		Introduction of innovative soil scarification methods and improved planting material
	Introduction of low impact logging technologies to avoid formation of methane hotspots and distribution of root rot		Pre-commercial thinning
	More efficient harvesting technologies to reduce timber damages		Remedial ditching to enhance regeneration of forests with wet soils
Forest management	Rewetting of low valued drained forests with limited growth potential	Risk management	Avoiding degradation of natural surface water flows during thinning and regenerative felling
	Continuous-cover forestry		**Elimination of hotspots of methane emissions – establishment of shallow ditch network to ensure aeration of topsoil layer**
			Fire prevention – mineralized belts, early warning systems, better equipment
			Prevention of wind throws and snow-break risk by intensified rotations and more resilient stands
			Reduction of risk of distribution of pests by increase of resilience of forest stands
			Slowing down of root rot distribution

degraded peatlands (Lazdiņš, 2022), while the rest can be rewetted or flooded because of high groundwater level under natural conditions. Afforestation is only the 1st step of the climate change mitigation. Further actions are necessary to increase the mitigation effect and to ensure resilience of afforested areas. The most critical measures in afforested sites are proper soil preparation (large mounds and network of furrows to avoid methane emissions), use of appropriate planting materials, fertilization with wood ash or complex fertilizers (repeated application before afforestation and after every thinning should be considered), wildfire prevention measures and gradual felling (continuous-cover forestry) as a way of forest regeneration. Other measures listed in Table 4 can enhance the mitigation effect if the most critical measures are implemented.

Improved planting material increases productivity and resilience of future forests. The effect can be estimated using forest growth models assuming additional relative increments in the areas where improved material is used. Detailed estimates are not yet possible. Stand wise forest inventory data can be used to locate areas where the measures are implemented to obtain local level activity data. National LPIS system needs to be improved to keep the track of areas where the measures are implemented. Additional measures which should be implemented are early tending, thinning and forest protection. Fertilization is basically mandatory. Additional costs in current prices is about 450 € ha^{-1} (planting material, soil scarification and planting or sowing) in current prices. Average price per ton of CO_2 in current prices is 6.1 € ton^{-1} CO_2 (Līcīte *et al*., 2019). Considerable additional increment and outputs of roundwood and forest biofuel will create significant input to energy sector and wood processing industry. Higher yields and more active forest regeneration would increase fuel consumption in forest operations, which can reach 5% of the CO_2 output with biofuel and wood logs. The measure can positively interfere with climate change adaptation policy (Lazdiņš *et al*., 2015). There is general remark in national forest policy of Latvia that forest management should ensure that forest value is not decreasing; however, there is no direct support to forest regeneration.

Mounding is soil scarification method which is more and more commonly used in forestry. Long term effect of this measure is not yet evaluated; especially, reduction of losses due to natural disturbances. The long term effect depends on further forest management steps, particularly, on timely implemented thinning and regenerative felling. Impact on soil GHG fluxes needs to be evaluated (Dzerina *et al*., 2016). Stand wise forest inventory can provide information on areas where this measure is contributing to additional CO_2 removals at a local and national scale. The projections highly depend on early management and probabilities of different development scenarios. These probabilities need to be developed to create projections at a national level. A short term impact, which can be relatively easily estimated just by assuming faster growth of planted trees is relatively small and does not have a significant impact on carbon stock changes in a short term. The measure has continuous impact during the lifetime of the forest stand. The impact of the measure accumulates through several rotations and can be increased by application of other measures like remedial drainage, maintenance of drainage systems and fertilization. Implementation of this measure increases resilience and potential value of forests on nutrient-rich soils contributing to implementation of sustainability criteria associated with forest value. Mounding increases soil scarification cost by about 150 € ha^{-1}; however, it can also contribute to reduction of cost during early tending and pre-commercial thinning. Conventional management systems need to be updated to utilize the potential of fertile forest soils more efficiently. This measure is not supported; however, there is a proposal to consider support for purchasing of planting machines in the Rural Development Program 2021-2027, which will boost application of mounding in forest regeneration.

Application of mineral fertilizers is identified as potentially the most valuable method in Latvia to reach 2030 targets. It is also supported by the government in Norway. Linear additional increment rates are considered according to the applied dosage of fertilizer assuming that forest management is optimized to ensure the additional increment (Petaja *et al*., 2018). The estimation of long term impact of changes in forest management is not yet done; therefore, only a short term impact is considered. Stand wise forest inventory data can be used to estimate carbon stock changes at local and national level. However, national LPIS does not provide information on application of fertilizers. Projections of long term effect can be verified by application of remote sensing (vegetation indexes, LiDAR) data. Short term effect continues for 10-20 years; long term effect continues during the whole rotation, especially if it is associated with changes in the management regime. No additional measures are necessary to ensure the short term effect; ensuring the long term effect requires following to the good practice guidelines in thinning, regenerative felling and maintenance of drainage systems.

Fertilization cost is 160 € ha^{-1} according to a price level in 2017. Cost of CO_2 removals, if the short term impact is considered, equals to 8 € ton^{-1} CO_2 eq. (Bērziņa *et al*., 2018). Fertilization increases N_2O emissions from soil; however, this effect is far less than the net removals (Okmanis *et al*., 2018; Petaja

et al., 2018). No support is considered for fertilization in national legislation; however, it is not restricted either.

Wood ash recycling is another type of fertilization, which can be combined with mineral fertilizers to substitute expensive P and K mineral fertilizers and can be added alone in moderately rich soils not suffering from shortage of nitrogen. Linear additional increment (around 15 m^3 ha^{-1} per treatment) is considered in several studies assuming that the forest management is optimized to ensure the additional increment (Okmanis *et al*., 2018; Okmanis, Lazdiņš *et al*., 2015; Okmanis, Polmanis *et al*., 2015). There are no models elaborated for Latvia to estimate impact of changes in the forest management; therefore, only a short term impact is considered. National LPIS does not provide information on application of wood ash; therefore, reporting of forest fertilization with wood ash at a stand wise level should be implemented. These data can be utilized in stand wise inventory to report additional CO_2 removals. A short term impact continues for 10-20 years; a long term impact continues during the whole rotation, especially if it is associated with changes in the management regime. No additional measures are necessary to ensure a short term effect; a long term effect requires following to good practice guidelines in thinning, timely regenerative felling and maintenance of drainage systems. Commercially more valuable species (birch, spruce, pine) have to be planted instead of low quality stands. Fertilization cost in Latvia in 2017 was 120 € ha^{-1}. Cost of CO_2 removals, if short term impact is considered, equals to 6 € ton^{-1} CO_2 eq (Petaja *et al*., 2018). No support is considered for wood ash recycling in forests in national legislation in Latvia.

Methane hotspots are terrain depressions with high groundwater level, which are usually significant source of CH_4 emissions. Terrain data analysis based tools can be used to identify potentially affected area. Growth models can be used to determine additional CO_2 removals in living biomass and other carbon pools. Wet areas cannot be easily identified because of outputs of groundwater creating depressions in areas where the models driven by precipitation and terrain data cannot find any depression. Existing LPIS system needs to be improved and supplied with maps characterizing 'wetness', respectively, information necessary to identify hotspots of CH4 emissions (Melniks *et al*., 2019). Digging up to 30 cm deep ditches in forest is in line with national regulations and does not require permission. Cost benefit ratio of the measure is not yet estimated. The measure is not supported in national policies; however, considering contribution to CH_4 and Hg reduction (Bishop & Lee, 1997; Lidskog *et al*., 2018), this measure has a significant implementation potential.

Fire prevention is especially important for organic soils, and it is critical to retain carbon pools developed by other measures. Methods for quantitative assessment are not developed yet, because it is complicated to predict amount of soil organic matter incinerated during forest fires. LPIS can be used to estimate risk of forest fires; however, the effect of the measure cannot be easily verified. Quantitative impact on the GHG emissions is not evaluated yet in Latvia; however, the importance of this measure is recognized. Cost benefit ratio is not estimated yet in Latvia. Prevention of forest fires avoid emissions of harmful substances like PAHs and dioxins, thus contributing to maintenance of healthy environment. In Latvia, maintenance of fire prevention systems is supported at national level by the Rural development program. Continuous development and automation of the system ensures more efficient identification of forest fires and continuous avoiding of the GHG emissions due to forest fires (Ministry of Agriculture, 2018).

Gradual regenerative felling is aimed to reduce an increase of groundwater level and following CH_4 emissions after felling, and it is identified as potentially valuable measure in Finland and Latvia with ongoing research activities in Finland. Activity data may be obtained from harvesting reports collected by forest authorities. Active management is required for a long-term impact. Cost – benefit ratio is not available yet (Korkiakoski *et al*., 2019; Nieminen *et al*., 2018; Ojanen & Minkkinen, 2019).

In Latvia, in spite of potential benefits of this method, quantitative assessment, even at experimental scale is not done due to multiple constrains, e.g. root rot distribution in spruce stands and unpredictable impact of different stress factors. Current experience in commercial thinning demonstrates a significant increase in mortality in spruce stands after thinning sooner or later leading to salvage logging and regeneration of the stand (Līcīte *et al*., 2019). However, there should be potential of strip harvesting in pine stands with following artificial regeneration with pine or birch. Stand wise forest inventory data can be used to locate areas where the measure is implemented to obtain local level activity data. National LPIS system needs to be improved to keep track of areas where the measure is implemented. Remote sensing related methods can be developed to monitor and verify growth; however, scientific approval of this method needs to be developed at first. Duration of effect is not verified yet, and can be considered as a long term measure in case of strip cleaning and a short term in case of selective harvest, because artificial forest regeneration is possible only in strips. Quantitative effect also is not estimated yet. The measure is not supported by specific legal acts but can be applied

voluntary by a forest owner. Selective harvests of pine are mandatory in coastal areas; however, degraded peatlands are minor in these areas.

It is important to point out that former peat extraction fields are usually located in nutrient poor soils with limited growth potential; therefore, GHG mitigation potential in these areas is relatively small, and biodiversity targets might be prioritized to implement mitigation measures in other, more fertile lands, e.g. organic soils in cropland and grassland by substitution of biologically valuable areas with rewetted peatlands.

Conclusions

1. The potential role of the degraded peatlands in implementation of the climate change targets is identified by scientific community in multiple publications and research reports; however, controversial results, e.g. on rewetting or conversion to grassland, highlights knowledge gaps and missing activity data.
2. National policy and climate change mitigation strategy recognize the role of organic soils in the reduction of GHG emissions; however, only afforestation may have an indirect impact assuming that certain proportion of the afforested areas will have organic soils.
3. Mitigation measures in national policies usually lack quantitative assessment and quantitative targets. The implementation requirements, e.g. moisture regime or soil type, may no be sufficiently detailed thus significantly increasing uncertainty of the impact assessment.
4. The most of the measures are not soil specific; however, the impact, as well as the implementation conditions may differ for mineral and organic soils. The quantitative impact can be estimated for land use and management system changes related measures; however, the uncertainty rates are high.
5. National LPIS system, as well as soil and moisture maps should be improved to ensure ability to estimate and to project the impact of the proposed climate change mitigation measures. Country specific methodologies should be elaborated to ensure efficient use of resources for the emission reduction in degraded wetlands.

Acknowledgements

The study is implemented within the scope of the project European Regional Development Fund Project 'Development of greenhouse gas emission factors and decision support tools for management of peatlands after peat extraction' (No. 1.1.1.1/19/A/064).

References

Bērziņa, L., Degola, L., Grīnberga, L., Kreišmane, D., Lagzdiņš, A., Lazdiņš, A., Lēnerts, A., Lupiķis, A., Naglis-Liepa, K., Popluga, D., Rivža, P., & Sudārs, R. (2018). *Siltumnīcefekta gāzu emisiju samazināšanas iespējas ar klimatam draudzīgu lauksaimniecību un mežsaimniecību Latvijā (Possibilities to reduce GHG emissions in Latvia by applying climate friendly measures in agriculture and forestry)*. Monograph. Jelgava: Latvia University of Life Sciences and Technologies, p. 277. (in Latvian).

Bishop, K.H., & Lee, Y.H. (1997). Catchments as a source of mercury/methylmercury in boreal surface waters. Marcel Dekker. Retrieved February 10, 2022, from https://scholar.google.com/scholar_lookup?title=Catchments+as+a+source+of+mercury%2Fmethylmercury+in+boreal+surface+waters&author=Bishop%2C+K.H.&publication_year=1997.

Butlers, A., Bārdule, A., Spalva, G., & Muižnieks, E. (2021). N2O and CH4 emissions from naturally wet and drained nutrient-rich organic forest soils. *Proceedings of the International Scientific Conference 'Rural Development'*, 196–200. DOI: 10.15544/RD.2021.030.

Dzerina, B., Girdziusas, S., Lazdina, D., Lazdins, A., & Jansons, J. (2016). Influence of spot mounding on height growth and tending of Norway spruce: Case study in Latvia. *Forestry Studies*, *65*, 24–33.

Korkiakoski, M., Tuovinen, J.-P., Penttilä, T., Sarkkola, S., Ojanen, P., Minkkinen, K., Rainne, J., Laurila, T., & Lohila, A. (2019). Greenhouse gas and energy fluxes in a boreal peatland forest after clear-cutting. *Biogeosciences*, *16*(19), 3703–3723. DOI: 10/gf963f.

Lazdiņš, A. (2022, February 14). *Climate change mitigation options in hemiboreal Baltic (a case study of Latvia)*. OPAL-Life final webinar. Land use change and optimization to mitigate climate change, Teams platform.

Lazdiņš, A., Liepiņš, K., Lazdiņa, D., Jansons, Ā., Bārdule, A., & Lupiķis, A. (2015). *Mežsaimniecisko darbību ietekmes uz siltumnīcefekta gāzu emisijām un CO_2 piesaisti novērtējums (2011.-2015. gads) (Assessment of the impact of forestry activities on greenhouse gas emissions and CO_2 sequestration (2011-2015)).* 2 5.5-5.1/001Y/110/08/8; p. 145 (in Latvian).

Lazdiņš, A., & Lupiķis, A. (2019). LIFE REstore project contribution to the greenhouse gas emission accounts in Latvia. In A. Priede & A. Gancone (Eds.), *Sustainable and responsible after-use of peat extraction areas* (pp. 21–52). Baltijas Krasti.

Lidskog, R., Bishop, K., Eklöf, K., Ring, E., Åkerblom, S., & Sandström, C. (2018). From wicked problem to governable entity? The effects of forestry on mercury in aquatic ecosystems. Forest Policy and Economics, 90, 90–96. DOI: 10.1016/j.forpol.2018.02.001.

Līcīte, I., Lupiķis, A., Peters, J., Butlers, A., Armolaitis, K., Soosaar, K., Laiho, R., Čiuldiene, D., & Jauhiainen, J. (2019). *Report on the identified climate change mitigation targeted management practices on organic soils* (No. 2019-A1|3-1; Demonstration of Climate Change Mitigation Measures in Nutrients Rich Drained Organic Soils in Baltic States and Finland, p. 119). Latvia State Forest Research Institute 'Silava'.

Lupiķis, A., & Lazdins, A. (2017). Soil carbon stock changes in transitional mire drained for forestry in Latvia: A case study. *Research for Rural Development*, *1*, 55–61.

Melniks, R., Ivanovs, J., & Lazdins, A. (2019). Method for shallow drainage ditch network generation using remote sensing data. *Proceedings of the 9th International Scientific Conference Rural Development 2019*. DOI: 10.15544/RD.2019.008.

Ministry of Agriculture. (2018). *Latvia Rural Development Programme (National)* (2014LV06RDNP001; p. 572). Ministry of Agriculture of Latvia. Retrieved February 10, 2022, from https://www.zm.gov.lv/public/files/CMS_Static_Page_Doc/00/00/01/08/04/Programme_2014LV06RDNP001_4_1_lv002.pdf.

Ministry of Environmental Protection and Regional Development. (2021). *Latvia's National Inventory Report Submission under UNFCCC and the Kyoto protocol Common Reporting Formats (CRF) 1990-2019* (p. 545). Ministry of Environmental Protection and Regional Development of the Republic of Latvia. Retrieved February 10, 2022, from https://unfccc.int/documents/271530.

Nieminen, M., Hökkä, H., Laiho, R., Juutinen, A., Ahtikoski, A., Pearson, M., Kojola, S., Sarkkola, S., Launiainen, S., Valkonen, S., Penttilä, T., Lohila, A., Saarinen, M., Haahti, K., Mäkipää, R., Miettinen, J., & Ollikainen, M. (2018). Could continuous cover forestry be an economically and environmentally feasible management option on drained boreal peatlands? *Forest Ecology and Management*, *424*, 78–84. DOI: 10.1016/j.foreco.2018.04.046.

Ojanen, P., & Minkkinen, K. (n.d.). Rewetting offers rapid climate benefits for tropical and agricultural peatlands but not for forestry-drained peatlands. *Global Biogeochemical Cycles*, *n/a*(n/a), e2019GB006503. DOI: 10.1029/2019GB006503.

Ojanen, P., & Minkkinen, K. (2019). The dependence of net soil CO2 emissions on water table depth in boreal peatlands drained for forestry. *Mires and Peat*, *24*, 1–8. DOI: 10.19189/MaP.2019.OMB.StA.1751.

Okmanis, M., Kalvis, T., & Lazdiņa, D. (2018). Initial evaluation of impact of evenness of spreading wood ash in forest on additional radial increment. *Engineering for Rural Development*, 1902–1908. DOI: 0.22616/ERDev2018.17.N491.

Okmanis, M., Lazdiņš, A., Lazdiņa, D., & Jansons, Ā. (2015). Case study of impact of forest fertilization on carbon stock in spruce stand. *Abstracts*, 117–120. Retrieved February 10, 2022, from https://drive.google.com/file/d/0B_cPAeeFPI52YXBEV3hhM2dWTzA/view?usp=sharing.

Okmanis, M., Polmanis, K., & Skranda, I. (2015). *Economic assessment of wood ash spreading in forest*. 37–38.

Petaja, G., Okmanis, M., Makovskis, K., Lazdiņa, D., & Lazdiņš, A. (2018). Forest fertilization: Economic effect and impact on GHG emissions in Latvia. *Baltic Forestry*, *24*(1), 9–16.

Upenieks, E.M., & Rudusāne, A. (2021). Afforestation as a type of peatland recultivation and assessment of its affecting factors in the reduction of GHG emissions. *Proceedings of the International Scientific Conference 'Rural Development'*, 295–300. DOI: 10.15544/RD.2021.052.

 DOI: 10.22616/rrd.28.2022.009

EFFECT OF DIFFERENT SPECTRAL COMPOSITION LED LIGHTING ON SILVER BIRCH *IN VITRO* PLANTLET MORPHOLOGY

***Toms Kondratovičs, Mārtiņš Zeps**
Latvian State Forest Research Institute 'Silava', Latvia
*Corresponding author's email: toms.kondratovics@silava.lv

Abstract
We tested effects of different spectral compositions on morphological parameters of ten silver birch (*Betula pendula* Roth.) clone *in vitro* cultures. Three different spectral compositions – red & blue (RB), red, green & blue (RGB) and red, green, blue, yellow & orange (RGBYO) LED luminaires and fluorescent light (FL) as control were used. Photon flux density of 110 µmol m^{-2} s^{-1} and 16/8h light/dark photoperiod was maintained for all luminaires. Stem and leaf morphological characteristics were affected by clone specific reaction to light treatment, while fresh and dry weight were affected only by clone. Partially opposite effect of red light amount in combination with yellow and orange light (RGBYO and FL luminaires) was observed on total plant length and main shoot elongation for two of ten birch clones. Length of third internode (four of ten clones) and leaf total and average area (three of ten clones) were stimulated by red light in combination with yellow and orange light. In general, our study shows that silver birch *in vitro* cultures exhibit clone specific, light-dependent morphological plasticity. We conclude that fluorescent lamps can be replaced with RGBYO, due to optimal spectral composition emitted by this luminaire and potential to adjust proportion of red light, thus providing individual approach for propagation of high-quality genotypes.
Key words: micro cuttings, clonal propagation, fluorescent lamps.

Introduction

The demand for wood and wood-based products is expected to increase globally in coming decades due to human population growth, economic growth, increasing prosperity and other reasons (Taylor, Lyons, & Jeffries, 2012). In European context Nordic and Baltic countries have the potential to increase its wood production, since they have favourable conditions for forest growth and already have extensive areas covered with forests. This is also important for mitigating climate change, since Nordic and Baltic countries have set a goal to reach carbon neutrality by 2050 (IEA, 2013; Nordiska Ministerrådet, 2009), with woody biomass supplying 50-97% of renewable energy (Rytter *et al*., 2016).

One of the strategies to increase wood supply is to enhance the productivity of planted forests by establishing superior genotypes of native species (Silva, Freer-Smith, & Madsen, 2018). Silver birch (*Betula pendula* Roth) has a high potential for cultivation in the Northern Europe and Baltic states, it is one of the most common tree species in the region (Brus *et al*., 2012; Forest Europe, 2011), it is highly productive and has a higher adaptation capacity to various environmental conditions compared to other native species (Dubois, Verkasalo, & Claessens, 2020). Birch timber is used for various products, like plywood, sawn-wood, wood-based panel, pulpwood, as well as for bioenergy production (Dubois, Verkasalo, & Claessens, 2020).

The use of LED luminaires is becoming more popular not only for indoor farming systems, but also as light source for plant propagation in controlled environment by tissue cultures (Fu *et al*., 2013; Morrow, 2008; Yang *et al*., 2018). Main advantages of LEDs over traditionally used fluorescent lamps include energy-efficiency, lower heat emission, compact size of LED modules, longer life-span compared to other lamp types, as well as the ability to adjust spectral composition and light intensity to specific requirements (Chen *et al*., 2020; Morrow, 2008). Knowledge on light-specific responses of species allows to adjust spectral composition of light so that spectral regions of emitted light correspond to absorption of photoreceptors, thus providing better growth by increasing photosynthetic, photomorphogenic, seed germination rates and accumulation of biomass (Bourget, 2008; Li-li *et al*., 2020; Massa *et al*., 2008; Morrow, 2008). Responses to different spectral regions of light are species specific – in general, it is observed that red (R) and blue (B) spectral regions affect morphogenesis and photosynthesis the most (Wang *et al*., 2015). However, plants have adapted to grow in broad spectral composition of sunlight, where development is determined by interaction of different spectral regions (Chen *et al*., 2020; Li *et al*., 2017; Liu *et al*., 2018). When cultivating *in vitro* cultures, where photosynthetic rate is limited, different spectral regions and their suitability for selected taxa can greatly affect photomorphogenesis (George & Davies 2008; Grout & Price, 1987; Kozai *et al*., 1991). Several researches on *in vitro* propagation of silver birch clones have been conducted; however, effects of lighting conditions on morphological characteristics of woody species have been rarely studied (Gailis *et al*., 2021; Meier-Dinkel, 1992). The aim of this study was to investigate the effect of different spectral composition LED treatment on *in vitro* microshoot morphology of silver birch (*Betula pendula* Roth).

Materials and Methods

This study was conducted in Laboratory of Plant Physiology of LSFRI 'Silava' during spring season of the year 2021. To evaluate the responses of silver birch clone *in vitro* cultures to different light spectrum, four spectral compositions of light were tested under controlled conditions. Tests were performed in a climatic chamber, where temperature was maintained at 25 °C and relative humidity at 30-40%. Four multi-store shelving systems with shelf size 120×100 cm and shelf height of 35 cm were placed in climatic chamber. Each shelf was equipped with luminaries placed 30 cm above the shelf surface. Non-transparent screens between shelf systems to prevent light contamination from other treatments were installed. The tested light treatments were combination of 1) red and blue LED light (RB), 2) red, green (G), and blue LED light (RGB), 3) red, green, blue, yellow (Y) and orange (O) LED light (RGBYO) (Table 1). Far-red (FR) diodes were incorporated in the RB and RGB luminaires to provide spectral region necessary according to phytochrome absorbance (Distefano *et al*., 2013; Liu *et al*., 2018). In RGBYO treatment, FR spectrum was provided by yellow diode, which emitted a broader spectrum light. Philips Master TL-D 36W (Koninklijke Philips N.V., Amsterdam, The Netherlands) warm white fluorescent lamps were used as the control. All LED luminaire treatments had red:blue (R:B) ratio of 3.2:1 and red: far-red (R:FR) ratio ranging from 28–36:1. The fluorescent light (FL) had R:B ratio of approximately 0.64:1 and R:FR 3:1 (Table 1), thus distinguishing it from others. The photon flux density of 110±10 µmol m^{-2} s^{-1} (range 400 to 750 nm) and 16/8h (light/dark) photoperiod was maintained for all light treatments. To ensure the uniformity and intensity of illumination, each shelf was divided into 10×10 cm sections and light spectrum and intensity was measured on each section using AvaSpec ULS2048 spectrometer (Avantes, Apeldoorn, The Netherlands).

Silver birch was represented by ten clones of open-pollinated progenies of plus-trees from Latvia (55°40′–58°05′N, 20°58′–28°14′E), which were obtained from a progeny trial in the central part of Latvia (56°44' N, 24°49' E) (Gailis *et al*., 2020). The studied clones were selected according to their field performance. In the clone collection, birch plantlets were cultivated on woody plant medium (WPM) (Lloyd & McCown, 1980), supplemented with WPM micronutrients, WPM vitamins, 0.1 mg L^{-1} zeatin, 20 g L^{-1} of sucrose, and 6 g L^{-1} agar (Sigma-Aldrich, St. Louis, MO). The pH of the medium was adjusted to 5.8 before autoclaving for 15 min (110 kPa, 121 °C).

Approximately 1.5 cm long silver birch plantlet apices were excised and planted in test tubes containing 5 mL of growth medium. Plant material was divided into three parts and randomly distributed on the different shelves for each light treatment. At least 30 plants in test tubes were used for each clone on each light treatment (at least 120 plants for each clone in total). To evaluate the effect of the light treatments on development of plantlets, microshoot cultures were cultivated under the experimental light treatments for 30 days.

Morphological parameters of regenerated cultures were determined: 1) main shoot elongation was determined for the longest and healthiest of shoots, independently of its origin; 2) total plantlet length was determined as a sum of lengths of main shoot, axillary and adventitious shoot(s); 3) length of third internode starting from apex was measured.

Leaf area parameters were measured by detaching and subsequently spreading newly formed leaves on a tablet and scanning them with Canon LC4800P

Table 1

Spectral composition % of total photon flux (from 400 to 750 nm) emitted by luminaires

Spectral regions and ratios	Red & Blue (RB)	Red & Green & Blue (RGB)	Red & Green & Blue & Yellow & Orange (RGBYO)	Fluorescent tubes (FL)
Blue 400 – 500 nm	23	18	17	17
Green 500 – 570 nm	0	22	17	25
Yellow 570 – 590 nm	0	0	3	7
Orange 590 – 625 nm	2	1	5	36
Red 625 – 700 nm	73	57	56	11
Far-red 700 – 750 nm	2	2	2	4
Red: Blue (R:B)	3.17	3.17	3.29	0.65
Red: Far-red (R:FR)	36.5	28.5	28	2.75
Blue: Green (B:G)	n/a	0.82	1.00	0.68

n/a – not applicable.

Table 2

Effect of different light spectral compositions on stem and leaf morphological properties

Morphological variables	Light treatment	Clone	Light by clone
Main shoot elongation, cm	ns	***	***
Total plantlet length, cm	ns	***	***
Length of third internode, mm	**	***	***
Leaf fresh weight, g	ns	***	ns
Stem fresh weight, g	ns	***	ns
Leaf dry weight, g	ns	***	ns
Leaf dry weight, g	ns	***	ns
Total leaf area, cm^2	***	***	***
Average leaf area, cm^2	***	***	***

ns – non significant ($p>0.05$); ** – significant at $p<0.01$; *** – significant at $p<0.001$.

scanner (Canon Inc., Tokyo, Japan). Obtained Tag Image File Format (.TIFF) images were analyzed with Winfolia Pro 2019 (Regent instruments Inc., Quebec, Canada) – average single leaf area was determined for each light treatment. Additionally, total leaf area was determined as the leaf area sum of one plant.

For determination of plant fresh and dry weight 1.5 cm long shoot segments with at least two leaves were planted in 300 mL glass jars containing 30 mL of the same medium as mentioned above. Eight shoots per jar were cultivated. For plant fresh and dry weight five plants from each jar were randomly chosen. Leaves were detached from stems and both were weighted separately. Dry weight was determined after drying plant material for 16 h at 60 °C. In total, five jars (replications) were used for each clone and each lighting treatment).

The effects of light treatments and clone on the morphology of plantlets were assessed using linear mixed-effect models or generalized linear mixed-effect models applying Poisson residual distribution according to data type analyzed. The statistical models in the general form were as follows:

$$Yijklm = \mu \pm LEDi \pm Cj \pm LEDi \times Cj \pm lk \pm \pm ikl \pm \varepsilon ijklm \quad (1)$$

where Yijklm is the response variable, μ is the overall mean; LEDi, Cj, and LEDi×Cj are the fixed effects of light treatment, clone, and the light treatment by clone interaction, respectively. The lk and ikl are the random effects, and εijklm is the random error.

The models were fit using the restricted maximum likelihood approach. The estimated marginal means for the levels of significant effects were compared using Tukey's HSD multiple comparison test. The data analysis was performed in R v. 4.1.2. (R Core Team, 2018) using packages 'lme4' (Bates *et al*., 2015) and 'emmeans' (Lenth, 2021).

Results and Discussion

Specific adaptation mechanisms to illumination are expressed through morphogenic characteristics by affecting size and form of a plant, thus determining *in vitro* propagation process in long term. Main objective of *in vitro* plant propagation is to obtain maximum number of high-quality explants in shortest period of time possible; therefore, conditions such as propagation medium content, spectral composition and intensity of light and length of propagation cycle should be adjusted according to requirements of selected species (Fu *et al*., 2013). Morphological characteristics of birch *in vitro* cultures were significantly affected by light treatments used in this study (Table 2). However, the response to light was clone-specific, indicating differences in exposure to light, highlighting the need for an individual approach. Significant effect of light and interaction of light and clone was observed on length of 3rd internode as well as average and total leaf area. Other stem morphological characteristics (main shoot elongation, total plant length) were significantly affected by interaction of light and clone, while stem and leaf fresh and dry weight was determined by clone (Table 2).

The development of the stem and leaves is affected by the processes of photomorphogenesis under the influence of different light signals (Cioć & Pawłowska, 2020; Wang *et al*., 2015), which show the reactions of clones to different light spectral composition in this experiment. Clone 54-229 formed significantly higher main shoot and total plantlet length, as well as larger total leaf area under FL compared to RGBYO treatment, while no significant differences with other LED treatments (Table 3). Results suggest that clone 54-229 specifically reacts to lowered red light amount in combination with yellow and orange light emitted by FL treatment (Table 1). On contrary, clone Med36 had significantly higher total plant length under RGBYO compared to FL, while main shoot length and length of third internode did not show significant differences

Table 3

Main shoot, total plantlet and length of third internode, average leaf area, total leaf area of silver birch *in vitro* plantlets under fluorescent (FL) light and different composition LED light (RGBYO, RB, RGB)

Clone	Light treatment	Main plantlet length, cm	Total plantlet length, cm	Length of third internode, mm	Average leaf area, cm^2	Total leaf area, cm^2
54-229	FL	1.65±0.28^{a}	3.59±0.50^{a}	3.90±0.79	0.42±0.07	2.25±0.40^{a}
	RB	1.16±0.27^{ab}	2.95±0.49^{ab}	2.94±0.78	0.27±0.07	1.27±0.38^{ab}
	RGB	1.42±0.27^{ab}	2.72±0.49^{ab}	3.66±0.79	0.41±0.07	2.01±0.39^{ab}
	RGBYO	1.01±0.27^{b}	2.50±0.48^{b}	2.76±0.87	0.39±0.08	1.50±0.39^{b}
54-286	FL	0.39±0.27	1.46±0.48	5.01±0.40^{a}	0.51±0.09	0.89±0.39
	RB	0.30±0.28	1.34±0.50	1.51±0.40^{b}	0.60±0.11	0.75±0.42
	RGB	0.22±0.30	1.33±0.53	1.72±0.50^{b}	0.54±0.10	0.71±0.40
	RGBYO	0.37±0.27	1.77±0.48	2.51±0.60^{b}	0.57±0.12	1.05±0.52
54-299	FL	0.51±0.26	1.69±0.46	5.33±2.29^{a}	0.73±0.10^{a}	1.26±0.39
	RB	0.54±0.25	2.22±0.46	1.38±0.39^{b}	0.68±0.12^{ab}	1.39±0.46
	RGB	0.33±0.27	1.58±0.48	2.00±1.16^{a}	0.79±0.09^{a}	1.60±0.42
	RGBYO	0.51±0.26	2.15±0.46	1.67±0.92^{b}	0.48±0.10^{b}	1.13±0.46
589-353	FL	1.82±0.27	3.07±0.48	2.60±0.72	0.31±0.07^{b}	1.70±0.38^{b}
	RB	1.94±0.28	3.53±0.5	3.00±0.75	0.29±0.08^{b}	2.06±0.41^{b}
	RGB	2.38±0.27	3.75±0.49	2.55±0.72	0.33±0.07^{b}	2.23±0.39^{b}
	RGBYO	2.09±0.27	3.83±0.48	3.38±0.69	0.54±0.07^{a}	3.67±0.39^{a}
589-805	FL	1.61±0.25	2.93±0.45	2.78±0.68	0.57±0.07^{a}	4.10±0.37^{a}
	RB	1.37±0.27	2.63±0.48	2.69±0.78	0.28±0.08^{b}	1.27±0.38^{b}
	RGB	1.54±0.26	2.84±0.47	2.40±0.73	0.55±0.07^{a}	3.88±0.40^{a}
	RGBYO	1.54±0.26	3.14±0.46	2.76±0.72	0.49±0.07^{a}	3.42±0.38^{a}
Ma29	FL	1.11±0.27	1.62±0.48	3.15±0.8^{b}	0.35±0.07	1.40±0.39
	RB	0.99±0.27	1.77±0.48	3.84±0.75^{ab}	0.24±0.07	1.01±0.37
	RGB	1.24±0.27	1.67±0.49	4.07±0.73^{ab}	0.35±0.07	1.56±0.38
	RGBYO	1.17±0.27	1.95±0.49	5.14±0.79^{a}	0.31±0.08	1.06±0.37
Med36	FL	1.89±0.27^{ab}	3.19±0.49^{b}	6.29±0.77^{a}	0.56±0.08	2.48±0.38
	RB	1.53±0.27^{b}	3.47±0.48^{ab}	3.6±0.72^{b}	0.47±0.07	2.23±0.37
	RGB	1.49±0.29^{b}	3.17±0.52^{b}	5.31±0.93^{a}	0.51±0.08	2.80±0.43
	RGBYO	2.33±0.28^{a}	4.29±0.50^{a}	6.78±0.76^{a}	0.51±0.07	2.53±0.40

^{a,b} – different letters in superscript represent significant differences ($p<0.05$) between light treatments for a concrete morphological variable of a concrete clone according to Tukey's HSD test results. Numbers after plus-minus signs represent 95% confidence intervals.

compared to FL. Clones 54-229 and Med36 showed response to red light in combination with yellow and orange, only this response was opposite. In general, both clones show response to combination of red light (therefore R:B and R:FR ratios as well) with yellow and orange. Similarly, other studies show that addition of yellow and orange light to red and blue light has positive effect on plant growth (Dougher & Bugbee, 2001; Li *et al*., 2017). No significant differences of total plantlet and main shoot length between light treatments for other clones were detected.

Effect of light and clone interaction on length of third internode was observed on four clones (Table 3): Clone 54-286 had significantly longer third internode under FL in comparison to LED treatments. Opposite effect was observed for clone Ma29, where length of third internode was significantly higher under RGBYO and RB as compared to FL. Both 54-286 and Ma29 indicate sensitivity to red light; however, responses of both clones are opposite. Clone 54-299 formed significantly longer third internode when grown under FL and RGB treatments as compared to RB and RGBYO, and could be explained by clone-specific reaction to green light amount, that is related to 'shade avoidance' response and is determined by B:G ratio of illumination (Smith, McAusland, &

Table 4

Total leaf area, average leaf area and length 3rd internode of silver birch *in vitro* plantlets under fluorescent (FL) light and different composition LED light (RGBYO, RB, RGB)

Light treatment	Total leaf area, cm^2	Average leaf area, cm^2	Length of third internode, mm
FL	2.2±0.12[a]	0.585±0.01[a]	4.15±0.7[a]
RB	1.69±0.13[b]	0.553±0.01[b]	2.71±0.64[b]
RGB	2.25±0.13[a]	0.589±0.01[a]	3.4±0.68[ab]
RGBYO	2.25±0.13[a]	0.606±0.01[a]	3.57±0.42[ab]

[a,b] – different letters in superscript represent significant differences ($p<0.05$) between light treatments for a concrete morphological variable of a concrete clone according to Tukey's HSD test results. Numbers after plus-minus signs represent 95% confidence intervals.

Murchie, 2017). Clone Med36 exhibited positive response to luminaires containing yellow and orange light – longer third internodes were observed under RGBYO and FL luminaires in comparison to RB. Results of Med36 agree with direct effect of light, where plants grown under RB luminaire formed significantly shorter third internode (Table 4).

Total leaf area and average leaf area was significantly smaller for plants grown under RB in comparison to other light treatments (Table 4). Clone 589-805 showed response similar to direct effect of light indicating that green, yellow and orange light affects leaf development (Table 1). Opposite clone-specific responses on total leaf area was observed on two clones – clone 589-353 had significantly higher total and average leaf area when grown under RGBYO, while clone 54-229 had the highest total leaf area when grown under FL (Table 3), indicating that, in addition to yellow and orange light effect, these clones have a specific response to red light as well. Clone 589-353 not only had significantly higher average leaf area, but total leaf area as well, when grown under RGBYO in comparison to other luminaires. This could be explained by clone-specific response to broad spectral composition emitted by RGBYO and related to light signals that plants are receiving when growing in full sunlight conditions. Similar results were observed in other studies where most effective leaf development occurred under broad spectral compositions (Baroli *et al*., 2008; Lake *et al*., 2001; Thomas, Woodwart, & Quick, 2003). Regarding average leaf area, clone 54-299 exhibited specific response to green light amount in luminaires – higher average leaf area was detected under FL and RGB treatments compared to other luminaires, indicating that leaf development of this clone was affected by B:G ratio, that signals about shade conditions (Jiang *et al*., 2011; Smith, McAusland, & Murchie, 2017). B:G ratio in RGBYO was 1, while in FL and RGB treatment it was 0.69 and 0.82, respectively.

In general, it can be concluded that the light spectrum containing blue, green, yellow, orange, red and far red spectra (RGBYO, FL) is important for birch growth *in vitro*. The specific reactions of birch clones (clone-light interaction effects) are related to the amount of red light, which means that an individual approach to determine the sensitivity of clones to red light is needed to optimize the propagation of each specific clone.

Conclusions

1. For silver birch clones in vitro, the main shoot length, total plantlet length, length of third internode, as well as average and total leaf area showed a clone-specific light-clone interaction response to the light spectrum.
2. The main shoot and total plant length of the birch clone responds specifically (two out of ten) to the amount of red light. Clones 54-229 and Med36 show the opposite reaction to the amount of red light, indicating the need for an individual approach to propagate these clones.
3. Silver birch clone in vitro cultures exhibited individual interaction effect of light and clone on length of third internode, average and total leaf area, where RB treatment underperformed. Clone-specific reactions, determined by interaction of light and clone, pointed out sensitivity to red light amount in combination with yellow and orange light.
4. LED luminaires with RGBYO spectral composition are an optimal solution to replace fluorescent lamps (FL) as primary illumination for silver birch propagation in vitro – spectral composition corresponds to silver birch sensitivity to red spectral region in combination with yellow and orange light. Knowledge of clone-specific responses to the spectral composition of light and the ability of LED luminaires to regulate the light spectrum can improve the propagation of birch clones.

Acknowledgements

The study was carried out in the European Regional Development Fund project 'Development of specially adapted LED luminaires for providing efficient and energy efficient tree propagation and rooting process' (No. 1.1.1.1/18/A/138).

References

Baroli, I., Price, G.D., Badger, M.R., & von Caemmerer, S. (2008). The contribution of photosynthesis to the red light response of stomatal conductance. *Plant Physiology*, 146, 737–747. DOI: 10.1104/pp.107.110924.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software,* 67, 1–48. DOI: 10.18637/jss.v067.i01.

Bourget, C.M. (2008). An introduction to light-emitting diodes. *HortScience*, 43(7), 1944–1946. DOI: 10.21273/HORTSCI.43.7.1944.

Brus, D., Hengeveld, G.M., Walvoort, D.J.J., Goedhart, P.W., Heidema, A.H., Nabuurs, G.J., & Gunia, K. (2012). Statistical mapping of tree species over Europe. *European Journal of Forest Research,* 131, 145–157. DOI: 10.1007/s10342-011-0513-5.

Chen, L., Zhang, K., Gong, X., Wang, H., Gao, Y., Wang, X., … Hu, Y. (2020). Effects of different LEDs light spectrum on the growth, leaf anatomy, and chloroplast ultrastructure of potato plantlets *in vitro* and minituber production after transplanting in the greenhouse. *Journal of Integrative Agriculture*, 19, 108–119. DOI: 10.1016/S2095-3119(19)62633-X.

Cioć, M., & Pawłowska, B. (2020). Leaf Response to Different Light Spectrum Compositions during Micropropagation of *Gerbera* Axillary Shoots. *Agronomy*, 10(11), 1832. DOI: 10.3390/agronomy10111832.

Distefano, G., Cirilli, M., Las Casas, G., La Malfa, S., Continella, A., Rugini, E., … Muleo, R. (2013). Ectopic expression of *Arabidopsis* phytochrome B in Troyer citrange affects photosynthesis and plant morphology. *Scientia Horticulturae*, 159, 1–7. DOI: 10.1016/j.scienta.2013.04.022.

Dougher, T.A.O., & Bugbee, B. (2001). Evidence for yellow light suppression of lettuce growth. *Photochem. Photobiology*, 73(2), 208–212. DOI: 10.1562/0031-8655(2001)073<0208:efylso>2.0.co;2.

Dubois, H., Verkasalo, E., & Claessens, H. (2020). Potential of birch (*Betula pendula* Roth. and *B. Pubescens* Ehrh.) for forestry and forest-based industry sector within the changing climatic and socio-economic context of western Europe. *Forests*, 11(3), 336. DOI: 10.3390/f11030336.

Forest Europe (2011). *State of Europe's Forests 2011 – status and trends in sustainable forest management in Europe*. Norway, Oslo: Forest Europe Liaison Unit.

Fu, Y., Liu, H., Shao, L., Wang, M., Berkovich, Y.A., Erokhin, A.N., & Liu, H. (2013). A high-performance ground-based prototype of horn-type sequential vegetable production facility for life support system in space. *Advances in Space Research*, 52(1), 97–104. DOI: 10.1016/j.asr.2013.03.020.

Gailis, A., Zeltiņš, P., Matisons, R., Purviņš, A., Augustovs, J., Vīndedzis, V., & Jansons, Ā. (2021). Local adaptation of phenotypic stem traits distinguishes two provenance regions of silver birch in Latvia. *Silva Fennica,* 55(2). DOI: 10.14214/sf.10524.

Gailis, A., Zeltiņš, P., Purviņš, A., Augustovs, J., Vīndedzis, V., Zariņa, I., & Jansons, Ā. (2020). Genetic parameters of growth and quality traits in open-pollinated silver birch progeny tests. *Silva Fennica*, 54(2). DOI: 10.14214/sf.10220.

George, E.F., & Davies, W. (2008). Effects of the Physical Environment. In George, E.F., Hall, M.A., De Klerk, G.J. (Eds.), *Plant propagation by tissue culture* (pp. 423–464). The Netherlands: Springer.

Grout, B.W.W., & Price, F. (1987). The establishment of photosynthetic independence in strawberry cultures prior to transplanting. In Ducote, G., Jacob, M., & Simeon, A. (Eds.), *Plant Micropropagation in Horticultural Industries* (pp. 55–61). Belgium, Arlon: Belgian Plant Tissue Group.

IEA. (2013). *Nordic energy technology perspectives – pathways to a carbon neutral energy future*. Paris and Oslo: International Energy Agency and Nordic Energy Research.

Jiang, C.D., Wang, X., Gao, H.Y., Shi, L., & Chow, W.S. (2011). Systemic regulation of leaf anatomical structure, photosynthetic performance, and high-light tolerance in sorghum. *Plant physiology*, 155, 1416–1424. DOI: 10.1104/pp.111.172213.

Kozai, T., Iwabuchi, K., Watanabe, K., & Watanabe, I. (1991). Photoautotrophic and photomixotrophic growth of strawberry plantlets *in vitro* and changes in nutrient composition of the medium. *Plant Cell Tissue and Organ Culture*, 25, 107–115. DOI: 10.1007/BF00042181.

Lake, J.A., Quick, W.P., Beerling, D.J., & Woodward, F.I. (2001). Plant development: signals from mature to new leaves. *Nature*, 411(6834). DOI: 10.1038/35075660.

Lenth, R.V. (2021). *Emmeans: estimated marginal means, aka least-squares means. R package version 1.6.0.* Retrieved March 8, 2022, from https://CRAN.R-project.org/package=emmeans.

Li, C.X., Xu, Z.G., Dong, R.Q., Chang, S.X., Wang, L.Z., Khalil-Ur-Rehman, M., & Tao, J.M. (2017). An RNA-Seq analysis of grape plantlets grown *in vitro* reveals different responses to blue, green, red led light, and white fluorescent light. *Frontiers in Plant Science,* 8(78). DOI: 10.3389/fpls.2017.00078.

Li-li, C., Zhang, K., Gong, X., Wang, H., Gao, Y., Wang, X., … Hu, Y. (2020). Effects of different LEDs light spectrum on the growth, leaf anatomy, and chloroplast ultrastructure of potato plantlets *in vitro* and minituber production after transplanting in the greenhouse. *Journal of Integrative Agriculture*, 19(1), 108–119. DOI: 10.1016/S2095-3119(19)62633-X.

Liu, H., Fu, Y., Hu, D., Yu, J., & Liu, H. (2018). Effect of green, yellow and purple radiation on biomass, photosynthesis, morphology and soluble sugar content of leafy lettuce via spectral wavebands 'knock out'. *Scientia Horticulturae*, 236, 10–17. DOI: 10.1016/j.scienta.2018.03.027.

Lloyd, G., & McCown, B. (1980). Commercially-feasible micropropagation of mountain laurel, *Kalmia latifolia*, by use of shoot-tip culture. *Combined Proceedings of International Plant Propagators Society*. 30, 421–427.

Massa, G.D., Kim, H.H., Wheeler, R.M., Mitchell, C.A., Cary, A. (2008). Plant productivity in response to LED lighting. *Hort. Sci.,* 43, 1951–1956. DOI: 10.21273/HORTSCI.43.7.1951.

Meier-Dinkel, A. (1992). Micropropagation of Birches (*Betula spp.*). In Bajaj, Y.P.S. (Ed.), *High-Tech and Micropropagation II* (pp. 40–81) Germany, Berlin: Springer-Verlag.

Morrow, R.C. (2008). LED lighting in horticulture. *HortScience*, 43(7), 1947–1950. DOI: 10.21273/HORTSCI.43.7.1947.

Nordiska Ministerrådet (2009). *Hållbar utvecklingen ny kurs för Norden* (Sustainable development – A new course for Nordics). Copenhagen, Denmark: Nordiska Ministerrådet. http://norden.diva-portal.org/smash/get/diva2:701331/FULLTEXT01.pdf. (in Danish).

R Core Team. (2018). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Retrieved March 8, 2022, from https://www.R-project.org/.

Rytter, L., Ingerslev, M., Kilpeläinen, A., Torssonen, P., Lazdina, D., Löf, M., Madsen, … Stener, L-G. (2016). Increased forest biomass production in the Nordic and Baltic countries – a review on current and future opportunities. *Silva Fennica*, 50(5). DOI: 10.14214/sf.1660.

Shao, L., Fu, Y., Liu, H., & Liu, H. (2015). Changes of the antioxidant capacity in *Gynura bicolor* DC under different light sources. *Scientia Horticulturea*, 184, 40–45. DOI: 10.1016/j.scienta.2014.12.010.

Silva, L.N., Freer-Smith, P.H., & Madsen, P. (2018). Production, Restoration, Mitigation: a new generation of plantations. *New Forests*, 50, 153–168. DOI: 10.1007/s11056-018-9644-6.

Smith, H.L., McAusland, L., & Murchie, E.H. (2017). Don't ignore the green light: exploring diverse roles in plant processes. *Journal of Experimental Botany*, 68(9), 2099–2110. DOI: 10.1093/jxb/erx098.

Taylor, R., Lyons, G., & Jeffries, B. (2012). *Living forests report: chapter 4 forests and wood products*. Switzerland, Gland: WWF International.

Thomas, W.P., Woodward, F.I., & Quick, W.P. (2003). Systemic irradiance signalling in tobacco. *New Phytologist*, 161, 193–198. DOI: 10.1046/j.1469-8137.2003.00954.x.

Wang, M., Xie, B., Fu, Y., Chen, D., Liu, H., Liu, G., & Liu, H. (2015). Effects of different elevated CO_2 concentrations on chlorophyll contents, gas exchange, water use efficiency, and PSII activity on C3 and C4 cereal crops in a closed artificial ecosystem. *Photosynthetic Research*., 126, 351–362. DOI: 10.1007/s11120-015-0134-9.

Yang, X., Xu, H., Shao, L., Li, Wang, Y., & Wang, R. (2018). Response of photosynthetic capacity of tomato leaves to different LED light wavelength, *Environ. Exp. Bot.,* 150, 161–171. DOI: 10.1016/j.envexpbot.2018.03.013.

 DOI: 10.22616/rrd.28.2022.010

SHORT-TERM IMPACT OF FERTILIZATION ON GROUND VEGETATION IN DECIDUOUS FOREST STANDS AND TREE PLANTATION

***Guna Petaja**, **Linards Krumsteds**, **Zaiga Zvaigzne**
Latvian State Forest Research Institute 'Silava', Latvia
*Corresponding author's email: guna.petaja@silava.lv

Abstract
This study examines the impact of fertilization with wood ash and ammonium nitrate on ground vegetation in Silver birch stands representing 4 forest types (*Hylocomiosa*, *Myrtilloso-sphagnosa*, *Myrtillosa mel*. and *Myrtillosa turf. mel*.), as well as in a deciduous tree (*Alnus glutinosa*, *Betula pendula, Cerasus avium*) plantation. Ground vegetation was assessed 2 years after application of fertilizers. The mean ground cover of individual species in moss, herb and shrub layer was determined. Species composition, species richness and species diversity were compared between fertilized and unfertilized plots. Shannon diversity index (H) was chosen as an indicator of species diversity. Results show that in Silver birch stands species composition in both control and fertilized plots is typical of the respective forest types. In the Ķeipene plantation, occurrence or increased abundance of several nitrophilous species was observed in the fertilized parcels. Statistically significant differences between H values of control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand in the moss layer, as well as in the herb layer of one of the *Hylocomiosa* stands and Sweet cherry parcel in Ķeipene plantation. Long-term observations are required in order to determine if the observed differences in ground vegetation between control and fertilized areas persist longer.
Key words: wood ash, ammonium nitrate, ground vegetation, deciduous trees, plantation.

Introduction

Over recent years, forest fertilization has been highlighted as a practice to improve tree growth, thus increasing biomass production. A shorter rotation period is another benefit of fertilizer application (Smethurst, 2010). Nitrogen (N), phosphorus (P) and potassium (K) are the nutrients that most commonly limit tree growth. Nitrogen containing fertilizers, such as ammonium nitrate (NH_4NO_3), are applied in forests on mineral soils, whereas fertilizers containing phosphorus (P) and potassium (K), such as wood ash, are mostly used in in peatland forests (Saarsalmi & Mälkönen, 2001). The dose of nitrogen applied with fertilizers in forests on mineral soils is 150 kg ha^{-1} and the subsequent tree growth response is 20-25 m^3 ha^{-1} (Pukkala, 2017). Ash is a solid, somewhat powdery residue of biomass combustion. It contains such essential mineral elements for tree growth as P, K, calcium (Ca), magnesium (Mg), and several trace elements. However, wood ash does not contain nitrogen as it is lost through burning. Wood ash has liming properties due to its high content of oxide CaO and hydroxide $Ca(OH)_2$ (Karltun *et al*., 2008). For peatland forests the recommended dose of K is 40-80 kg ha^{-1} and that of P is 40-50 kg ha^{-1}, which correspond to a wood ash amount of 2000-5000 kg dry weight (Sikström, Almqvist, & Jansson, 2010). Wood ash and ammonium nitrate can be applied simultaneously to supplement N, P and K, stocks as well as to prevent soil acidification.

Fertilizers are also frequently applied in tree plantations at some stage of development. The most frequently planted tree species in Latvia is Silver birch. Birch trees do not require heavy fertilizing if already growing in nutrient-rich soil. It is recommended to perform soil analyses before fertilization to determine nutrient deficiencies. The second most frequently planted deciduous tree species is Black alder (*Alnus glutinosa*). Black alder is tolerant of higher groundwater level, provided that tree roots are sufficiently supplied with oxygen. It has a capability to fix nitrogen; therefore, it can improve soil conditions and minimize the need for nitrogen containing fertilizers (European Forest Genetic Resources Programme, 2003). Fertilization also improves winter hardiness and fruit quality of sweet cherries (*Cerasus avium*) (Swarts *et al*., 2017).

Ground vegetation is an integral component of forest ecosystems although it is frequently overlooked. It has a role in water and nutrient cycling, soil stabilisation and biodiversity maintenance. Application of NH_4NO_3 and wood ash to forest soils has an impact on soil pH and nutrient availability, which may lead to changes in species composition, species richness, occurrence of cenrtain species and biodiversity of ground vegetation. These changes depend on several factors, such as light availability to herb and moss layers, initial nutrient status, moisture levels and forest site management. Loose ash is not suitable for fertilization, as it may cause a direct plant tissue damage; therefore, a pre-treatment is necessary. A number of studies on the impact of ground vegetation have been carried out in the Nordic countries and Canada, which can be approximated to the climatic conditions in Latvia. Studies show that changes caused by a small single dose would be most likely insignificant, whereas a repeated input may lead to changes in species composition and biodiversity loss (Olsson & Kellner, 2006). Application of fertilizers result in occurrence of species typical of more fertile site types (Kellner, 1993).

The aim of the study was to determine the impact of fertilization with NH_4NO_3 alone or supplemented

with wood ash on species composition, richness and diversity of ground vegetation in Silver birch stands and a deciduous tree plantation.

Materials and Methods

Research sites

The study was conducted in five forest stands all over Latvia, where the dominant tree species is Silver birch (*Betula pendula*), representing 4 forest types (*Hylocomio*sa, *Myrtilloso-sphagnosa*, *Myrtillosa mel*. and *Myrtillosa turf.mel.*), and in Keipene plantation, where deciduous tree seedlings have been planted in 2012 and 2013 on former agricultural land with mineral soil. The age of forest stands varied from 22 to 71 years. Stand characteristics are shown in Table 1. Ammonium nitrate (NH_4NO_3, dose 0.44 t ha^{-1}) was applied once in each stand from December 2016 till July 2017. In *Myrtillosa mel*. and *Myrtillosa turf.mel.*) stands, additionally wood ash was spread (dose 3 t ha^{-1}). Wood ash was obtained from Fortum and Latgran pellet factories.

The Keipene plantation is located in central Latvia, Ogre municipality, Keipene parish (56°55'59.3'N 25°08'15.4'E). In 2016, prior to fertilization, soil and leaf/needle analyses were carried out and P deficiency was detected. Fertilizers were spread manually in 2017 (dose 0.44 t NH_4NO_3 ha^{-1}) and in parcels, where decreased tree growth was observed, additionally wood ash was spread (dose 3 t ha^{-1}). Wood ash was obtained from SIA Graanul Pellets pellet factory. The element concentration of wood ash was 153.32 g kg^{-1} Ca, 25.96 g kg^{-1} K, 11.58 g kg^{-1} Mg and 9.6 g kg^{-1} P. The following tree species of the plantation were included in the study: Common alder (*Alnus glutinosa* (L.) Gaertn.) Silver birch (*Betula pendula* Roth.) and Sweet cherry (*Cerasus avium* (L.), Moench syn. *Prunus avium* L.).

Ground vegetation survey

Ground vegetation was surveyed 2 years after application of fertilizers. In both Ķeipene plantation and Silver birch-dominated forest stands, ground vegetation was surveyed in plots of 1 m^2 squares, grouped by two and arranged in an equilateral triangle, whose edges are oriented perpendicularly to a 30x30 m plot, where fertilizers were spread (Figure 1). The number of control and fertilized vegetation survey plots in each study site vary from 6 to 12. In each sample plot, the projective cover of each species in moss (mosses, liverworts, lichens), herb (vascular plants, shrubs and tree seedlings up to 0.5 m) and shrub (shrubs and trees 0.5-7.0 m in height) layer in both control and fertilized plots was determined. Along with visual estimation of the percentage cover of each plant species, species occurrence and species richness were determined and compared between control and fertilized plots. Changes in species composition and richness were analyzed for moss and herb layer separately. Shannon diversity index (H) was chosen as a measure to compare species diversity between control and fertilized plots. H was calculated separately for moss, herb and shrub layer using equation 1 (Magurran, 1988):

Table 1

Characteristics of the studied birch stands and amount of fertilizers used per stand

Forest type	Stand age	G, m^2 ha^{-1}	H, m	DBH, cm	Stand volume, m^3 ha^{-1}	NH_4NO_3, t	Wood ash, t
Hylocomiosa	68	31.5	23	20.5	369	0.247	-
Hylocomiosa	71	29	22	21.5	356.6	0.176	-
Myrtilloso-sphagnosa	22	20	18.5	15	192	0.079	-
Myrtillosa mel.	33	15	20	18	149.5	0.159	1.08
Myrtillosa turf.mel.	28	17	17	15	155.5	0.318	2.16

Table 2

Characteristics of the deciduous tree plantation in Keipene and the amount of fertilizers used per parcel

Tree species	Fertilized area, ha	NH_4NO_3, kg	Wood ash, kg	H, m	DBH, cm	Number of trees per ha
Alnus glutinosa	0.12	53	-	5.34	5.60	575
Betula pendula	0.12	53	-	4.12	5.40	576
Cerasus avium	0.09	40	270	3.86	4.11	1024

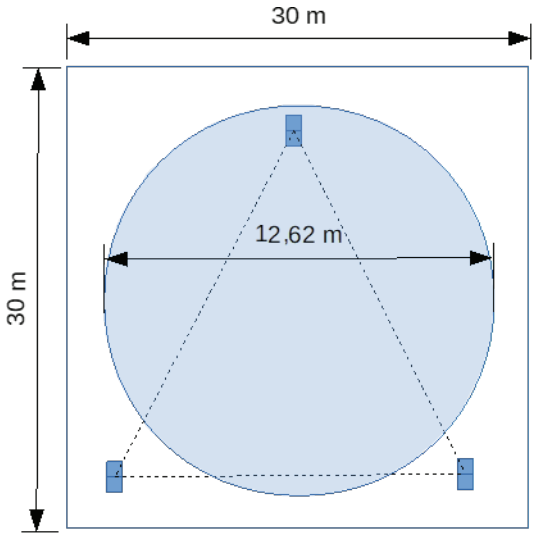

Figure 1. Vegetation survey plot design in relation to the fertilized area.

$$H = -\sum \left(\frac{n_i}{n}\right) log_2 \left(\frac{n_i}{n}\right) \quad (1),$$

where H – ground vegetation diversity; n – the total number of individuals; n_i – number of species per sample plot.

The ground cover of each species was used in calculations instead of the number of individuals (Vahdati *et al*., 2016).

Statistical analysis

Shannon diversity index was calculated and vegetation ground cover data were processed with Microsoft Excel. Statistical analyses were conducted, using software RStudio. Student's T-test and Wilcoxon rank sum test were performed to estimate differences between the control and fertilized areas. The test was chosen, depending on normality of data distribution.

Results and Discussion

In all the Silver birch stands species composition still correspond to the respective forest types. In *Hylocomiosa* stands in the moss layer *Hylocomium spledens, Pleurozium schreberi and Rhytidiadelphus triquestrus* predominate. In one of these stands, the total moss cover is larger in plots, where NH_4NO_3 has been added. In the herb layer, the dominant species are *Calamagrostis arundinacea, Carex sp., Vaccinium myrtillus.* The cover of dwarf shrubs does not decrease in a result of fertilization. The projective cover of mosses is slightly lower in the fertilized plots of *Myrtillosa mel.* forest stands. *Calliergonella cuspidata* and *Plagiomnium affine* are the most commonly observed moss species, whereas in the herb layer *Calamagrostis canescens* and *Deschampsia cespitosa* predominate. *Rubus idaeus* has a slightly larger projective cover in fertilized plots and nitrophilous *Lycopus europaeus* occurs only in the fertilized plots. In the *Myrtillosa turf. mel.* forest stands, the dominant moss species in both control and fertilized plots is *Calliergonella cuspidata*, whereas in the herb layer *Agrostis canina* and *Festuca sp.* predominate. In the *Myrtilloso-sphagnosa* stand, *Calliergon cordifolium* is the most commonly observed moss species, whereas in the herb layer the most commonly observed species is *Oxalis acetosella*.

The average H values in control plots in the moss layer range from 0.54±0.12 in the *Myrtilloso–sphagnosa* stand to 0.93±0.18 in one of the *Hylocomiosa* stands. In fertilized plots, the average values range from 0.22±0.10 in the *Myrtillosa turf. mel.* stand, where NH_4NO_3 has been applied together with wood ash, to 0.90±0.18 in *Hylocomiosa* stand, where NH_4NO_3 has been applied. In all the stands the average H value is lower in fertilized plots, except for one of the *Hylocomiosa* stands. Statistically significant differences between H values in control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand, where the average H value in the herb layer is higher but in the moss layer it is lower in fertilized plots, and in one of *Hylocomiosa* stands in the herb layer, where the average value in fertilized plots is lower. A comparison of the H values in control and fertilized plots, depending on site type is shown in Figure 2. The number of species in fertilized plots is higher in the herb layer in *Myrtillosa mel.* and *Myrtillosa turf.mel.* stands, but in the rest of stands it's lower, comparing with the control. The number of species is lower in the moss layer, except for one of the *Hylocomiosa* stands, where it is slightly higher. A comparison of the number of species in control and fertilized plots, depending on site type is shown in Figure 3.

Keipene plantation. Most of them are heliophiles with an Ellenberg value for light (L) in range from 7 to 9. Several nitrophilic species either occur only in the

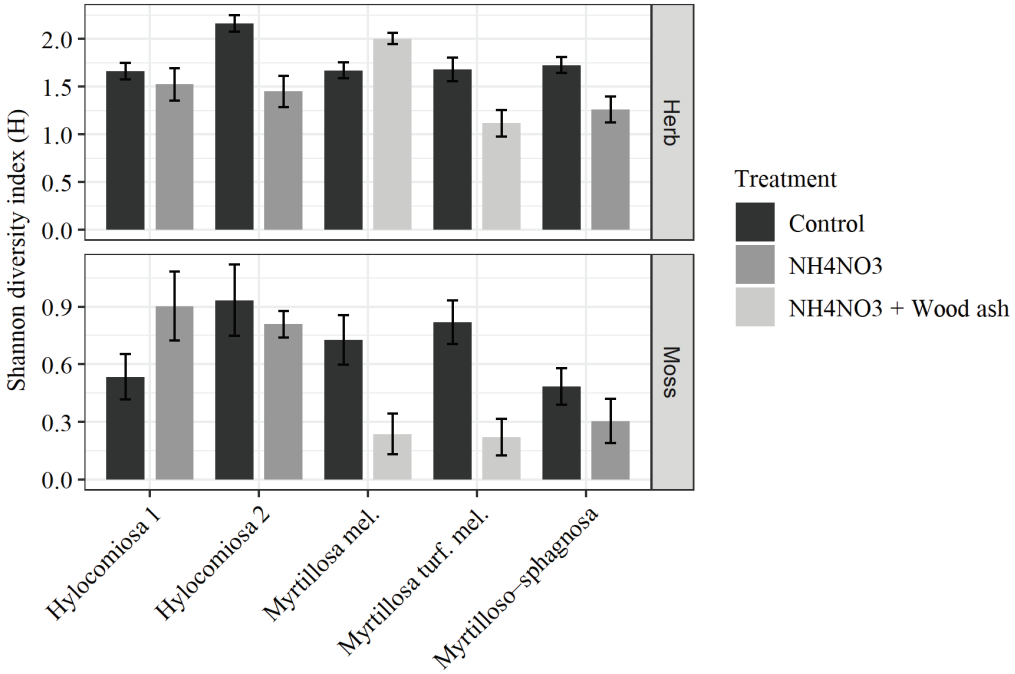

Figure 2. Shannon diversity index in herb and moss layer depending on forest type (mean values ± standard error of the mean (SEM)).

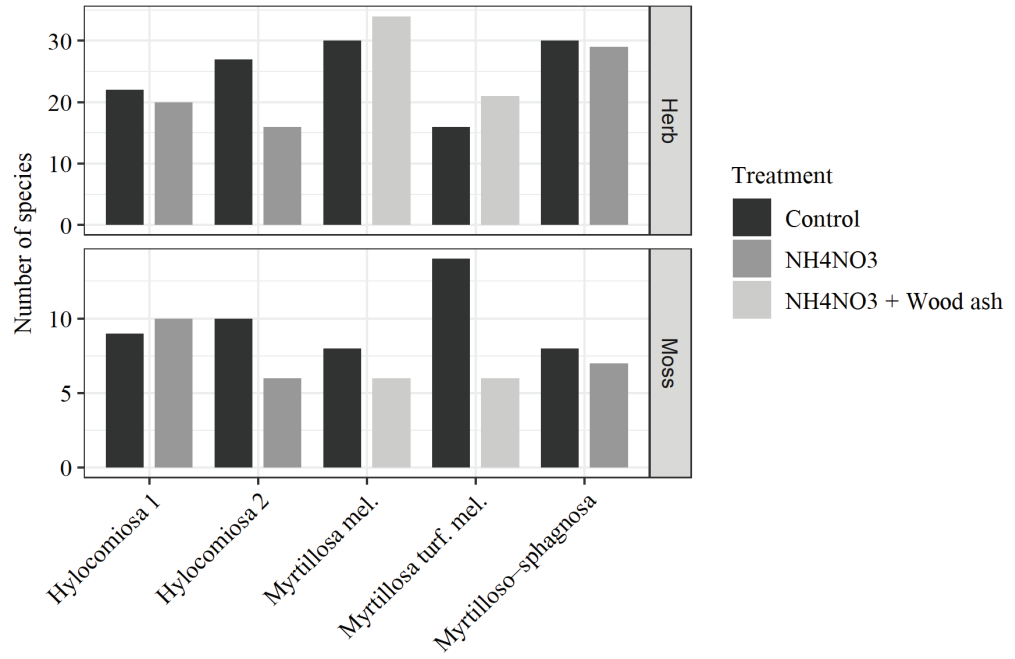

Figure 3. Number of species in herb and moss layer depending on forest type.

Species typical of meadows, pastures and wasty places predominate the ground vegetation of fertilized parcels or have a larger cover. In fertilized parcels, where Silver birch has been planted, larger projective cover and increased occurrence has been observed for *Aegopodium podagraria*. This species is also observed only in the fertilized areas, where Sweet cherry has been planted. Nitrophile *Anthriscus sylvestris* have slightly larger cover in the fertilized birch and alder parcels, whereas *Taraxacum officinale* has increased occurence in these plots. Only in fertilzed plots *Heracleum sibiricum* and *Lathyrus palustris* have been observed. In wild cherry-growing parcels a slighly larger cover has been observed for *Artemisia*

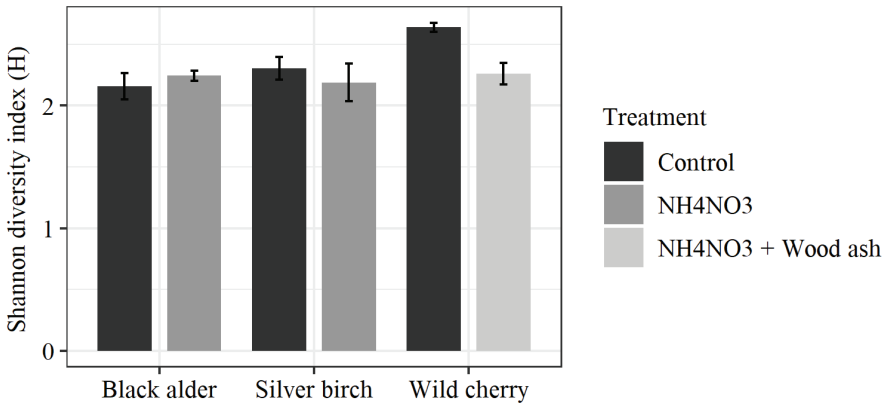

Figure 4. Shannon diversity index in *Ķeipene plantation* depending on tree species (mean values ± SEM).

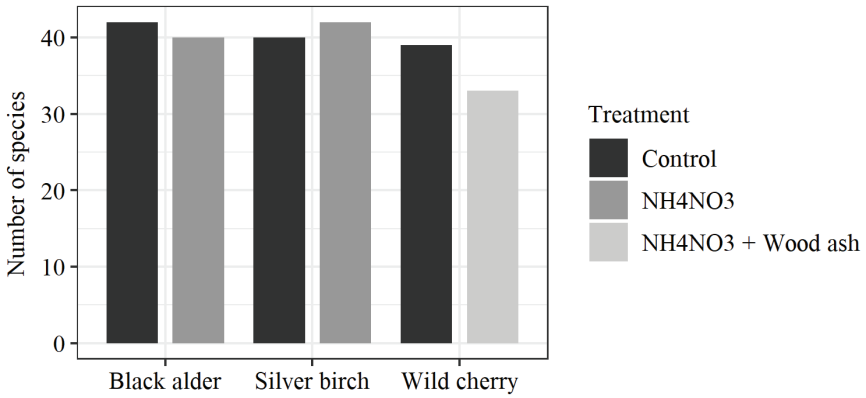

Figure 5. The number of ground vegetation species in Ķeipene plantation depending on tree species.

vulgaris. Only in fertilized parcels of both wild cherry and Black alder *Lolium perenne* has been observed. In Sweet cherry-growing parcels, individually growing plants of *Urtica dioica* have been observed as well as *Tussilago farfara* and *Lolium multiflorum*is occur more frequently than in control parcels. In all the fertilized parcels, *Phleum pratense* has been observed more frequently and had larger cover. Also, *Potentilla anserina* occured more frequently in fertilized parcels.

The average H value in fertilzed Black alder-growing parcel is 2.24±0.04, whereas in control it is 2.16±0.11. In fertilized birch-growing parcels the average H value is 2.19 ±0.15, whereas in control it is 2.30±0.08. In Sweet cherry-growing parcels, the average H value is 2.26±0.09, but in the control area, it is 2.64±0.04 (differeces were statistically significant, p=0.05). Overall, H values in fertilized parcels were lower in Black alder and Sweet cherry-growing parcels, whereas in birch-growing parcel it is slightly larger. A comparison of H values is shown in Figure 4.

The number of species in control parcels ranges from 39 in parcels, where Sweet cherry has been planted, to 42, where Black alder has been planted. In fertilized plots, the number ranges from 33 in Sweet cherry-growing to 42 in birch-growing parcels. No moss species have been observed in the Ķeipene plantation. The number of species in fertilized parcels is slightly lower in those of Sweet cherry and Black alder, comparing with the control, whereas in fertilized birch-growing parcels the number is slightly higher. Comparison of the number of species in control and fertilized parcels depending on tree species is shown in Figure 5.

Studies carried out in Sweden show that after application of N-containing fertilizers, species normally occuring in less fertile forest types – dwarf shrubs (blueberries, lingonberries, heathers), lichens, several mosses – decrease in abundance, whereas grasses (e.g. *Deschampsia flexuosa*) and nitrophilic forbs, e.g. *Rubus idaeus, Epilobium angustifolium* increase (Strengbom & Nordin, 2008). Silfverberg and Hotanen found that after addition of wood ash nitrophilic species (*Cirsium helenoides*, *Daphne mezereum*, *Paris quadrifolia*, *Prunus padus*, *Urtica dioica*) may become dominant over time in sites with peat soils. Similarly as when applying nitrogen fertilizers, also in case of wood ash heathers (*Calluna vulgaris*) are gradually replaced by grasses, such as *Deschampsia flexuosa* (Arvidsson *et al*., 2002). In our

study, occurrence of nitrophilic species in fertilized plots have also been observed, particularly in Ķeipene plantation.

The cover of mosses *Dicranum fuscescens, Dicranum polysetum, Hylocomium splendens* and *Pleurozium schreberi* decrease along with increasing N availability, whereas mosses of *Brachythecium* and *Plagiothecium* genera may increase in abundance (Olsson & Kellner, 2006; Press *et al*., 1998; Skrindo & Økland, 2002; van Dobben *et al*., 1999). Following addition of wood ash, moss cover may decrease dramatically and the impact increases along with ash dose (Ozolinčius *et al*., 2007). In our study, we did not obeserve a dramatic change in the moss cover. In one of the *Hylocomiosa* stands, a slightly larger cover was observed in fertilized plots. Two years is a relatively short period of time for assessment of ground vegetation development. Longer-term observations are required in order to draw the final conclusions about the impact of fertilization on ground vegetation.

The results of this study could be transferred to characterize the condition of plantations of shelter belts and to determine the potential of suitable species.

Conclusions

1. In birch-dominated forest stands, there are no significant differences in species composition between control and fertilized plots. In the *Myrtillosa mel.* stand, *Rubus idaeus* has a slightly larger projective cover in fertilized plots, and nitrophile *Lycopus europaeus* occurs only in the fertilized plots. In the Ķeipene plantation occurrence or increased abundance of several nitrophilic species was observed in the fertilized parcels. The impact is more pronounced in parcels, where Sweet cherry has been planted.
2. In general, results do not show a significant impact of fertilization on species diversity in Silver birch stands and Ķeipene plantation. Statistically significant differences between H values in control and fertilized plots have been found only in the *Myrtillosa mel.* forest stand, where the average H value in the herb layer is higher, but in the moss layer it is lower in fertilized plots, in one of *Hylocomiosa* stands in the herb layer, where the average value in fertilized plots is lower and in Sweet cherry-growing parcel of Ķeipene plantation, where the value is lower in fertilized plots.
3. Fertilization has no significant impact on the number of species. The number of species in fertilized plots is higher in the herb layer in *Myrtillosa mel.* and *Myrtillosa turf.mel.* stands, but in the rest of stands it is lower, compared to the control. The number of species is lower in the moss layer, except for one of the *Hylocomiosa* stands, where it is slightly higher. In the Ķeipene planation, the number of species in fertilized Sweet cherry and Black alder parcels is slightly lower comparing with the control, whereas in fertilized birch-growing parcels the number is slightly higher.

Acknowledgement

Climate change mitigation potential of trees in shelter belts of drainage ditches in cropland and grassland Agreement No 1.1.1.1/21/A/030

References

Arvidsson, H., Vestin, T., & Lundkvist, H. (2002). Effects of crushed wood ash application on ground vegetation in young Norway spruce stands. Forest Ecology and Management – FOREST ECOL MANAGE, 161, 75–87. DOI: 10.1016/S0378-1127(01)00482-0.

European Forest Genetic Resources Programme (2003). Alnus glutinosa. Retrieved March 7, 2022, from http://www.euforgen.org/species/alnus-glutinosa/.

Karltun, E., Saarsalmi, A., Ingerslev, M., Mandre, M., Andersson, S., Gaitnieks, T., Ozolinčius, R., & Varnagiryte-Kabasinskiene, I. (2008). Wood Ash Recycling – Possibilities and Risks. In D. Röser, A. Asikainen, K. Raulund-Rasmussen, I.Stupak (Eds.), Sustainable Use of Forest Biomass for Energy (pp. 79–108). Dordrecht, Springer. DOI: 10.1007/978-1-4020-5054-1_4.

Kellner, O. (1993). Effects on Associated Flora of Sylvicultural Nitrogen Fertilization Repeated at Long Intervals. *Journal of Applied Ecology*, 30(3), 563–574. DOI: 10.2307/2404195.

Magurran, A.E. (1988). Ecological diversity and its measurement. Princeton University Press.

Nohrstedt, H.-Ö. (1998). Residual effects of N fertilization on soil-water chemistry and ground vegetation in a Swedish Scots pine forest. Environmental Pollution, 102(1), 77–83. DOI: 10.1016/S0269-7491(98)80018-3.

Olsson, B.A., & Kellner, O. (2006). Long-term effects of nitrogen fertilization on ground vegetation in coniferous forests. Forest Ecology and Management, 237(1–3), 458–470. DOI: 10.1016/j.foreco.2006.09.068.

Ozolinčius, R., Buožytė, R., & Varnagirytė-Kabašinskienė, I. (2007). Wood ash and nitrogen influence on ground vegetation cover and chemical composition. Biomass and Bioenergy, 31(10), 710–716. DOI: 10.1016/j.biombioe.2007.06.015.

Pukkala, T. (2017). Optimal Nitrogen Fertilization of Boreal Conifer Forest. Forest Ecosystems.4(1), 3. DOI: 10.1186/s40663-017-0090-2 12.

Press, M.C., Potter, J.A., Burke, M.J.W., Callaghan, T.V., & Lee, J.A. (1998). Responses of a Subarctic Dwarf Shrub Heath Community to Simulated Environmental Change. *Journal of Ecology*, 86(2), 315–327. DOI: 10.1046/j.1365-2745.1998.00261.x.

Saarsalmi, A. & Mälkönen, E. (2001). Forest Fertilization Research in Finland: A Literature Review. Scandinavian *Journal of Forest Research*. 16(6), 514–535. DOI: 10.1080/02827580152699358.

Sikström, U., Almqvist, C., & Jansson, G. (2010). Growth of Pinus sylvestris after application of wood ash or P and K fertilizer to a peatland in southern Sweden. Silva Fennica. 44(3), 411–425. DOI: 10.14214/sf.139.

Skrindo, A., & Økland, R.H. (2002). Effects of fertilization on understorey vegetation in a Norwegian Pinus sylvestris forest. Applied Vegetation Science, 5(2), 167–172. DOI: 10.1111/j.1654-109X.2002.tb00546.x.

Smethurst, P. (2010). Forest fertilization: Trends in knowledge and practice compared to agriculture. Plant and Soil. 335(1), 83–100. DOI: 10.1007/s11104-010-0316-3.

Strengbom, J., & Nordin, A. (2008). Commercial forest fertilization causes long-term residual effects in ground vegetation of boreal forests. Forest Ecology and Management, 256(12), 2175–2181. DOI: 10.1016/j.foreco.2008.08.009.

Swarts, N., Mertes, E., & Close, D.C. (2017). Role of nitrogen fertigation in Sweet cherry fruit quality and consumer perception of quality: at and postharvest. Acta Horticulturae. 503–510. DOI: 10.17660/ActaHortic.2017.1161.80.

Vahdati, F.B., Mehrvarz, S.S., Dey, D.C., & Naqinezhad, A. (2017). Environmental factors–ecological species group relationships in the Surash lowland-mountain forests in northern Iran. *Nordic Journal of Botany*, 35: 240–250. DOI: 10.1111/njb.01221.

van Dobben, H.F., ter Braak, C.J.F., & Dirkse, G.M. (1999). Undergrowth as a biomonitor for deposition of nitrogen and acidity in pine forest. Forest Ecology and Management, 114(1), 83–95. DOI: 10.1016/S0378-1127(98)00383-1.

THE REACTION OF SCOTS PINE *PINUS SYLVESTRIS* L. FOREST GROUND COVER VEGETATION TO ORIENTEERING COMPETITIONS IN THE SEASIDE, LATVIA

***Inga Straupe**, **Ieva Ivbule**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: inga.straupe@llu.lv

Abstract
Orienteering is one of the most popular folk sports in Latvia, it involves a very large number of participants, and this number is growing every year. While participating in the competition and running through the forest, the competitors are trampling the forest floor. In Latvia, the impact of orienteering competitions has not been studied a lot; therefore, when organizing competitions, disagreements arise when choosing the competition area – there are groundless suspicions that orienteering sport has a significant negative long-term impact on the forest floor. The aim of research is to assess the impact of orienteering competitions on ground vegetation in pine forests at the seaside, Latvia. The research was carried out in the orienteering competition 'World Masters Orienteering Championships 2019' area, which was located in Scots pine forests in the seaside territory – in the vicinity of Bumbukalns and Garezeri. The study describes orienteering competitions and their process in forest lands; analyzes the vegetation at orienteering competition checkpoints before and after the competition; compares and evaluates vegetation changes in hilly areas on hill tops and in depressions. The study has found that orienteering competitions do not significantly affect the forest layers. It is concluded that as the distance from the control point increases, the trampling intensity decreases. The intensity of trampling does not depend only on the shape of the terrain. The effect of trampling is best seen on the moss layer.
Key words: Scots pine forests, forest layers, orienteering, trampling, projective coverage.

Introduction

Orienteering is very popular folk sport in Latvia. The number of participants increases year by year - from 50 to 700 participants, while international competitions gather more than one and a half thousand participants. Orienteering competitions take place all over Latvia, and in the year 2019 competitions gathered more than 16 thousand participants who took part in competitions 121.040 times (Orientēšanās sacensību rezultāti, 2020).

The origins of orienteering sport can be traced back to Scandinavia in the 19th century. Initially, orienteering was part of soldiers' military training. The first known public competition took place in 1897 in Norway, near Oslo. In 1918, cooperating with the Stockholm Amateur Athletics Association Ernst Killander organized a distance running competition, searching for and finding certain control points. After this event E. Killander developed rules for orienteering sport, relating to the choice of route, the creation of age groups and the organization of competitions. E. Killander in history is referred as the father of orienteering sport (History and Facts…, 2020).

In the 20th century, orienteering sport spread throughout the whole Europe (Orienteering, 2020). Orienteering sport also gained popularity in Latvia. Since 1933, orienteering competitions for beginners had been organized under the control of the Latvian Army Sports Club, and training had been organized under the guidance of specialists. In 1936, the first official orienteering competition took place (Senā vēsture, 2020).

Orienteering is a complex sport in which the athlete must be fast-thinking and at the same time physically strong in order to achieve the best results. In the orienteering distance, the athlete, using the orienteering map and compass, must find and check in the control points marked on the map and placed in the vicinity in the shortest time possible. When choosing a place where to organize orienteering competitions in Latvia, one must follow the guidelines of the organization process jointly prepared by the Nature Protection Board (DAP) and the Latvian Orienteering Federation (LOF) (DAP & LOF, 2014c).

The organization of orienteering competitions in one of the specially protected nature territories (SPNT) is regulated by several regulations of the Republic of Latvia (DAP & LOF, 2014a):

- Law On the Conservation of Species and Biotopes. Adopted on March 16, 2000;
- Cabinet Regulations No. 264 'General Regulations on Protection and Use of Specially Protected Nature Territories' adopted by the Cabinet of Ministers on March 16, 2010;
- Cabinet Regulations No. 940 'Regulations Regarding the Establishment and Management of Micro-reserves, Their Conservation, as well as Determination of Micro-reserves and Their Buffer Zones' adopted by the Cabinet of Ministers on 18 December 2012;
- Individual Regulations on Protection and Use of SPNT (for instance, Gauja National Park Law, Teiči Nature Reserve Law, etc.).

Any activity is prohibited, and residence is restricted or prohibited in the strict regime zone and regulated regime zone of nature reserves and specially protected nature territories. Without the written permission of the Nature Protection Board,

it is prohibited to organize public events in nature reserves and in nature reserves zone of specially protected nature territories in the open air, as well as camps with more than 60 people but in nature reserves zone of Gauja National Park and Ķemeri National Park no more than 50 people. In micro-reserves, it is prohibited to do any activity that is contrary to the objectives and tasks of the establishment of the micro-reserve, that destroys or disturbs the given specially protected species or habitat, including the organization and conduct of outdoor recreational and sports events.

The deliberate disturbance of animals of specially protected species, including birds, is prohibited. Individual protection and use regulations may be developed for each specially protected nature territory. They set out different requirements which must be followed while in them. In the nature park zone of Rāzna National Park, it is prohibited to organize public events in the open air with more than 100 people participating outside the designated or specially arranged places, without the written permission of the Nature Protection Board. In the nature reserve zone of Gauja National Park, it is prohibited to organize public events in nature from 15 March to 31 July, while from 1 August to 31 October it is allowed but no more than twice in the same territory (DAP & LOF, 2014a).

Orienteering has an impact on nature and its values. International Orienteering Federation has conducted various studies and produced reports on the impact of competitions. The results show that disturbance of mammals, wastewater and trampling of vegetation are considered to be very important factors during orienteering competitions. In relation to the ecological load, the most important factors are the trampling of vegetation and the disturbance of mammals. Laininen (2012) emphasizes that edaphic changes in the soil, such as changes in soil moisture, erosion and structure, can also occur in connection with trampling of vegetation. As a result of compaction, the soil pores are closed, interfering with the exchange of water and gases in the soil, resulting in a lack of water and oxygen, or the exact opposite process takes place – soil leaching. Similar processes are particularly sensitive in forest habitats, while in dunes edaphic changes in the soil are even necessary because they overgrow rapidly.

Orienteering competitions, with their positive impact on dune habitats, serve in the Braunton Burrow Nature Reserve in the south-west of England. This competition is a good example, because with the help of this competition the overgrowth of the dunes is prevented and the typical dunes plants return. After calculations it is concluded that 15,000 athletes, being in dune habitats for average 1.25 hours each, are equivalent to one cattle grazing in this type of habitat per year. With the competition the result is achieved much faster – overgrowth of the dunes is stopped and sand fields appear. It should be noted that an entire herd of, say, 200 cattle affects an area as much as 3 million athletes, leading to the conclusion that athletes are not the ones with the most significant impact on the environment (Parker, 2009).

Athletes are interested in getting from one control point to the next one trough the most efficient route, so their impact is linear, especially near control points where trails are particularly noticeable as vegetation is more trampled. Such trails are temporary and disappear during one to three vegetation seasons, depending on the nature of the vegetation affected (Mendoza, 2008).

In the south of England (The New Forest), an orienteering competition was held in 1988, with 1,200 participants in an area of 11 km^2. A study (Douglas, 1989) was conducted in connection with this event, in which it was found out that most of the surveyed sites recovered within two weeks. The most used as well as the most sensitive areas had not recovered at all after six months; however, they had fully recovered within a year, with the exception of two sample plots where moss and lichens grew on sandy soil. It is noted that trampling of vegetation depends on the intensity, duration and frequency of the disturbance, together with plant species, soil type and depth, slopes and moisture.

The main factors influencing the resilience of nature complexes in flat areas where the slope gradient does not exceed three degrees, are the bedrock, the degree of humidity, the main tree species in the forest stand and the origin of the forest. Nature complexes with light mechanical bedrock (sand, clay sand) are less resistant to recreational loads than natural complexes with heavy mechanical bedrock (loam, clay). As a result of trampling, the first mentioned will suffer more, mainly will suffer soil and biocenoses (Чижова, 1977).

In Finland (Sipoonkorpi National Park, near Helsinki) after the competition, monitoring started to assess the impact of the event on biodiversity. The greatest effect was observed in bog and wet forest habitats, as well as in the pioneering communities of dry and warm habitats. Dry habitats recover very slowly, especially those dominated by lichens, which can be explained by the fact that they were broken into smaller pieces and washed away during the rainy season. It will probably take decades for these habitats to fully recover. Vegetation damage in bogs and herbaceous plant covered forests recovered very quickly, but wet forests were still in very poor biological condition after one year (DAP & LOF, 2014b).

In Denmark, studies have been carried out (Andersen *et al*., 1986) in several forests with a

network of roads and trails about the proportions of trail running in the orienteering distance. It was concluded that, on average, 50% of the distance done by the participants is on forest roads, tracks or paths, and 50% is off-track, off-road, and only less than 0.5% of the distance passes through a very dense forest.

Dartmoor National Park in the south-west of England is a popular destination for a variety of activities, including orienteering sport. The number of bans in the park has been increasing on orienteering activities, so a comparative study of the environmental and ecological impacts on the national park was conducted, including 12 off-road activities (Parker, 2005a). It was found out that in comparison with other types of recreation in the mentioned park, the negative impact of orienteering on the park is very minimal. It has been studied that people spend many more hours off-tracks in other forms of recreation than in orienteering, which shows that they have a greater impact on the forest and forest floor. For instance, people spend one and a half million hours a year hiking off the trails, but for orienteering, it is only 800 hours a year. Of the mentioned activities in the study, hiking, bird watching and mountain biking can be referred to Latvia. Assuming that the number of hours is proportionally similar in Latvia as well, all three mentioned activities have a greater ecological impact than orienteering.

Among the Latvian researches related to the trampling of forest vegetation in recent years, the research of Laura Liepiņa (Vārpiņa) (2016) and Ralfs Čākurs (2019) can be mentioned. In her study, Liepiņa (2016) assessed the impact of orienteering competitions on the forest ground vegetation. The study confirms the hypothesis that the effect of trampling does not have a significant effect on the forest ground vegetation, except for the moss layer on the seaside. There it has also been observed that trampling has the greatest impact on vegetation on the hill tops and slopes of inland dunes and hills, and it has the least impact on micro-depressions and in *Vacciniosa*. Čākurs (2019) concluded that significant impact of trampling was observed only in a short period of time. Vegetation recovered very quickly - a month after the competition. The biggest impact of trampling was observed on the moss layer and on the slopes of dunes and hills. According to these studies, it can be concluded that the impact of orienteering competitions in the territory of Latvia is observed in the most sensitive places; however, the vegetation is restoring relatively quickly.

After analysis of several studies (Parker, 2005b), Parker believes that orienteering events with around 2,000 participants have very minimal impact on vegetation, while very large events require at least a season for vegetation to recover. Given that long-term damage is defined as lasting for at least ten years, it cannot be said that orienteering has a significant effect on vegetation, as no study has shown such a long-term damage, even in those with more than 10,000 participants.

Kardel (1974) considers that the biological damage to vegetation is mostly just theoretical. The main assumptions that vegetation is destroyed and erosion effects occur as a result of orienteering competitions and other forest recreational activities are often subjective and inconsistent. Vegetation damage can be observed immediately after orienteering competitions and may seem significant, but the resilience and capacity of different types of vegetation are so good that the damage is almost invisible after one or two seasons. Considering that, there is no significant reason to restrict or prohibit the organization of orienteering competitions.

The aim of the research is to assess the impact of orienteering competitions on ground vegetation at the seaside, Latvia. In order to achieve the aim, the following research tasks have been set: to analyse the vegetation around the orienteering control points before and after the competition and to compare and evaluate the changes of vegetation in the terrain on the hill tops and in depressions.

Materials and Methods

In order to assess the impact of orienteering competitions on ground vegetation, two research objects have been selected from orienteering competition 'World Masters Orienteering Championships 2019' or 'WMOC 2019' competition area which was situated in the seaside near Bumbukalns and Garezeri (Figure 1). The competition took place from July 5, 2019 to July 12, 2019 and gathered more than 3 thousand participants, which was the largest competition in Latvia that year. In these areas applies Cabinet Regulation No. 86. 'Methodology for determining the Coastal Protection Zone of the Baltic Sea and the Gulf of Riga' (adopted on 17 February, 2004).

Bumbukalns, where the competition in the middle distance took place, is located in the northwest of Riga near Buļļupe - the tributary of the old Lielupe in river Daugava. Bumbukalns is included in the green zone of Riga. Dunes covered with pine forests are typical for the competition area. It has a dune relief with various hill shapes. In some places the terrain is flat, but in other places dune ridges and hills reach a height of 20 meters. In several places, openings can be found as well as thick undergrowth. It is easy to run through the pine forests although the area is technically complex (LOF & IOF, 2019). In the competition area two forest types were recognized – *Cladinoso-callunosa* and *Vacciniosa*, where a small number of species and poor soils are common. The territory of

Figure 1. WMOC 2019 competition areas.

Bumbukalns is included in the SPNT 'Buļļu kāpas' and belongs to the nature reserve zone of this SPNT. In the competition area the European Union protected habitat *2180 Wooded seaside dunes* can be found (Dabas aizsardzības pārvalde, 2020).

Garezeri, where the competition in the long distance took place, is located northeast of Riga, on the Baltic Sea coast, near the village of Lilaste in Carnikava region. The competition area is characterized by sand dunes covered with pine forests. The area is filled with distinct hills and dune ridges of various sizes, but swampy places can also be found there. In the area, there is an extensive network of trails – both large and small trails run through the entire coastline. Garezeri is included in the Seaside Nature Park, most of it is the nature reserve area, but some areas are included in the nature park area as well (LOF & IOF, 2019). In this competition area two forest types were recognized too – *Cladinoso-callunosa* and *Vacciniosa*, which are characterized by a small number of species and poor soils. In the competition area, there is the European Union protected habitat *2180 Wooded seaside dunes* (Dabas aizsardzības pārvalde, 2020).

The collection of data required for the study took place in July 2019 before and after the competition. A total of 10 control point locations were selected at the sites (5 in Bumbukalns, 5 in Garezeri), of which 4 were located on hill tops, 4 in depressions and 2 were finish checkpoints. Vegetation was counted in each sample plot using the Braun-Blanquet method (Pakalne & Znotiņa, 1992). In each sample plot the total projected cover (%) of vegetation was determined in each layer at a distance of 7 m and 14 m from the control point. The intensity of the trampling depends on the number of participants crossing the sample plots to check in the required control point. Using the data published about 'WMOC 2019' concerning the results of the competition, the number of participants that have been at each control point has been calculated. Two-factor analysis of variance was used for mathematical data processing (Arhipova & Bāliņa, 1999).

Results and Discussion

The creation of control points is individual at each location of competition. Control points have been inspected both before and after the competition,

Table 1

The projective cover of forest stand layers in Bumbukalns sample plot before and after the competition

	Control points									
	1		2		3		4		5	
Relief	Depression				Hill top				Finish check-point	
Vegetation layer	Before	After	Before	After	Before	After	Before	After	Before	After
Tree layer	5.3	5.3	3.4	3.4	1.1	1.1	2.3	2.3	0.1	0.1
Scrub layer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Herb layer	0.0	0.0	0.0	0.0	17.7	17.7	17.7	17.7	20.2	20.2
Moss layer	94.3	92.6	95.3	90.2	61.1	57.8	82.9	80.2	41.1	40.0

and a photo has been taken of the sample plot. The repetition of data collection is possible using maps of competitions. The intensity of trampling varies in the sample plots. The projective cover of forest stand layers in Bumbukalns and Garezeri sample plots is shown in Table 1 and 2, respectively.

The first five sample plots – control points were located in Bumbukalns competition area (Table 1). Two of the control points were situated in depressions with the forest type – *Cladinoso-callunosa*. In the sample plot, the land in the centre is visibly trampled and the moss layer is flattened. In some places, both at a distance of 7 m and 14 m, some separate pieces of moss were trampled. This control point was visited by 335 participants. They went to the control point from different sides, hence there was a new path visible in the northern direction. The projective coverage of the moss layer has decreased by 1.7% ($p>0.05$).

A similar situation is observed in the second sample plot – the centre is trampled and several trajectories are visible from which the participants have come. At 7 m distance traces of trampling can still be seen - to the west the moss is trampled intensively, to the east the trampling is observed directly towards the centre, but not so intensively, while to the north the trampling volume is decreasing. At a distance of 14 m, no visual effect in the moss layer is observed. This control point was visited by twice as many participants as before – 742 in total. The projective coverage of the moss layer has decreased by 5.1% ($p>0.05$).

Two control points were located on the slopes, forest type *Cladinoso-callunosa*. In the first sample plot, open soil was already visible before the competition, there was not a lot of vegetation; however, after the competition it was recognized that the whole centre around the control point was trampled, only behind the tree in the northern direction the moss remained intact. This control point was visited by 848 participants. The influence of the participants can be seen in the centre; however, further away (at a distance of 7 m and 14 m) there are practically no visual changes. The projective coverage of the moss layer has decreased by 3.3% ($p>0.05$).

In the second sample plot, the control point is clearly visible from afar, and the participants came from the bottom of the hill, hence the slope to the control point is trampled; however, at the hill top the effect of trampling has not been observed. This control point was visited by 211 participants. A small impact is observed at a distance of 14 m in the northern direction, where the moss layer is trampled a little. The projective coverage of the moss layer has decreased by 2.7% ($p>0.05$).

At the finish, which was located at the crossroads of the trails, the terrain is flat, the forest type there is *Vacciniosa*, and 3,679 participants ran by this point. A flattened path has formed from the south direction. The projective coverage of the moss layer has decreased by 1.1% ($p>0.05$).

Five sample plots were located at Garezeri area competition control points (Table 2). The first two control points were located in depressions. In the first sample plot, the forest type is *Cladinoso-callunosa*. The ground vegetation has been trampled in the centre, the moss layer has been trampled a little at a distance of 7 m, but no other changes have been observed. This control point was visited by 603 participants. The projective coverage of the moss layer has decreased by 2.0% ($p>0.05$).

The second sample plot in the depression was with the forest type *Vacciniosa*. The centre there was slightly flattened, but further no visual changes were observed. This can be explained by the fact that the plot is dominated by herbaceous species which tolerate trampling better (Emsis, 1980). This control point was visited by 149 participants. The projective coverage of the moss layer has decreased by 0.1% ($p>0.05$).

Two control points were located on the hills, the forest type was *Vacciniosa*. After the competition, in the centre of the sample plot moss layer was trampled and a path had formed on the northern slope, which also stretches through 7 m sample plot and till 14 m from the centre. The control point was visited by 143 participants. The projective coverage of the moss layer has decreased by 3.2% ($p>0.05$).

Moss is trampled in a few places around centre of the second sample plot, visual changes further from the centre are minimal. It can be seen that the participants have visited the control point from the west - the moss has slightly flattened and is regaining its original shape. Only 28 participants visited this control point; therefore, the change is very small. The projective coverage of the moss layer has decreased by 0.6% ($p>0.05$).

The finish control point is located on a sandy road with flat terrain, the forest type is *Cladinoso-callunosa*. 1,412 people visited this place. No visual changes were observed in this sample plot, and the projective cover of the moss layer did not change.

It is characteristic of all control points that the ground is trampled in the centre. For the sample plots in the hills, the centre (average moss layer decreased by 2.5%) is more affected than in the depressions (average moss layer decreased by 2.2%), but the effect of trampling on flat terrain is small or practically non-existent (average moss layer decreased by 0.6%) and the differences are not significant ($p>0.05$) (Liepina, 2016). The participants visited the control points in the hills from one side of the hill - one slope of the hill is more trampled, but in the depressions, there are several trajectories from which the control was visited. The intensity of trampling varies depending on the

number of participants, but there are no regularities. The impact does not only depend on the number of participants - both the diversity of ground cover plants and the characteristics of the terrain and soil must be taken into account.

Conclusions

The effect of trampling is observed only in the moss layer. At control points, the projective coverage of the moss layer has decreased by 1.8% on average ($p>0.05$). On other layers of the forest stand there has been observed no impact of trampling. The most pronounced damage to the forest floor can be detected at the control point itself in the centre. As the distance from the control point increases, the trampling intensity decreases. There was no correlation among the terrain form at the checkpoint, the amount of participants and the intensity of the trampling. The impact depends on both the diversity of ground cover plants and the terrain as well as soil properties.

Acknowledgements

The study was supported by the grant of project of Latvia University of Life Sciences and Technologies 'Implementation of LLU research programme'.

References

Andersen, E.B., Børsting, B., Køhler, M., Neilsen, I., Rasmussen, J., & Sandgreen, F. (1986). *Vejvalgsundersøgelse af 3 orienteringsløb* (Route choice at 3 orienteering events). Danish Orienteering Federation. (in Danish).

Arhipova, I., & Bāliņa, S. (1999). *Statistika ar Microsoft Excel ikvienam* (Statistics with Microsoft Excel for everyone). Rīga: Datorzinību Centrs. (in Latvian).

Čākurs, R. (2019). *Orientēšanās sporta ietekme uz veģetāciju: bakalaura darbs* (The impact of orientieering sport to vegetation: Bachelour thesis). Rīga: LU Vides zinātnes nodaļa, 52 lpp. (in Latvian).

Dabas aizsardzības pārvalde (2020). *OZOLS – Dabas datu pārvaldības sistēma* (OZOLS – The system of nature data management). Retrieved March 31, 2020, from https://ozols.gov.lv/pub. (in Latvian).

DAP & LOF darba grupas rekomendācijas (The recommendations of DAP and LOF working group). (2014). *Kopsavilkums. Normatīvie akti orientēšanās sacensību organizēšanai ĪADT, sugu un biotopu dzīvotnēs* (Abstract. Normative acts of orienteering competitions in especially protected nature territories, species and habitat biotopes). Retrieved March 28, 2020, from https://lof.lv/uploads/Admin/DAP/Kopsavilkums_NA.DOCX. (in Latvian).

DAP & LOF darba grupas rekomendācijas (The recommendations of DAP and LOF working group). (2014). *Orientēšanās sacensību ietekme uz aizsargājamām dabas teritorijām* (The impact of orienteering competitions on especially protected nature territories). Retrieved March 28, 2020, from https://lof.lv/uploads/Admin/DAP/OS_ietekme_uz_vidi_apkopojums.doc. (in Latvian).

DAP & LOF darba grupas rekomendācijas (The recommendations of DAP and LOF working group). (2014). *Orientēšanās sporta sacensību organizēšanas PROCESS ietekmes uz vidi mazināšanai* (The process of organizing of orienteering sport competitions to reduce the impact on the environment). Retrieved March 28, 2020, from https://lof.lv/uploads/Admin/DAP/DAP_LOF_procedura_gala_20_05_2014.xlsx. (in Latvian).

Douglas, E.A. (1989). *Assessment of the impact of the November Classic Badge Event 1988 on the New Forest*. British Orienteering Federation, Matlock.

Emsis, I. (1980). Rīgas pilsētas mežu apsaimniekošana (The management of Riga city forests). Riga: LatZTIZPI. 63 lpp. (in Latvian).

History and Facts About Orienteering (2020). Retrieved April 4, 2020, from https://www.athleticscholarships.net/other-sports-orienteering.htm.

Kardell, L. (1974). *Vegetation damage in connection with orienteering events*. Research Notes 4. Royal College of Forestry, Stockholm.

Laininen, E. (2012). *IOF Survey – Orienteering and the Environment*. Retrieved March 31, 2020, from https://orienteering.sport/iof/environment-and-sustainability/.

Liepiņa, L. (2016). *Orientēšanās sacensību ietekme uz meža zemsedzi mainīgā reljefā*: *maģistra darbs* (The impact of Orienteering competitions on forest ground cover in variable relief: Master thesis). Jelgava: LLU Mežkopības katedra, 77 lpp. (in Latvian).

LOF & IOF. (2019). *WMOC_2019_Bulletin2*. Retrieved March 28, 2020, from https://www.wmoc2019.lv/augsuplades/files/WMOC_2019_Bulletin2.pdf.

Mendoza, A. (2008). Effects of an orienteering competition at Bow Valley Wildland Park, Alberta, 2002-2008, Alberta Orienteering Association.

Orienteering (2020). Encyclopaedia Britannica. Retrieved April 4, 2020, from https://www.britannica.com/sports/orienteering.

Orientēšanās sacensību rezultāti (The results of orienteering competitions). (2020). Latvijas Orientēšanās Federācija. Retrieved April 24, 2020, from https://lof.lv/seriali_rez/stati. (in Latvian).

Pakalne, M., & Znotiņa, V. (1992). *Veģetācijas klasifikācija: Brauna-Blankē metode* (The classification of vegetation: the method of Braun-Blanke). Rīga: Latvijas Universitāte, 36 lpp. (in Latvian).

Parker, B.H. (2005a). *Comparison of the environmental impact of orienteering and other off-track recreations in the Dartmoor National Park, UK*. IOF Environment Commission.

Parker, B.H. (2005b). Review of research into the ecological impact of orienteering. IOF Environment Commission.

Parker, B.H. (2009). *A physical model for comparing the trampling impact of large grazing mammals and off-track recreational activities*. Scientific Journal of Orienteering, Vol. 17, Issue 1, 21–24.

Senā vēsture (Old history). (2020). Retrieved April 4, 2020, from https://sites.google.com/view/os-karte/senie-laiki/senā-vēsture?authuser=0. (in Latvian).

Чижова, В.П.М. (1977). *Рекреационные нагрузки в зонах отдыха* (The recreational loads in recreational areas). Москва: Лесная промышленность, 48 с. (in Russian).

 DOI: 10.22616/rrd.28.2022.012

EVALUATION OF THE ATTENDANCE OF REFRESHER COURSES FOR FORESTRY MACHINE OPERATORS

*Aigars Strubergs[1], Andis Lazdins[2], Linards Sisenis[1]
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]Latvian State Forest Research Institute 'Silava', Latvia
*Corresponding author's email: aigars.strubergs@llu.lv

Abstract
The study finds out the forest machine operators' opinion about the need for refresher courses, the quality of the courses, the knowledge and skills gained as a result of attending the courses. As part of the research, a questionnaire was compiled and sent to forest machine operators who have attended courses at the Forest Machine Operator Training Center in the last 4 years to improve their professional skills. The questionnaire was prepared and sent electronically at the end of 2021. Within two months, the questionnaire was completed by 147 operators. The aim of the survey is to find out the operators' opinion about attending refresher courses, and whether operators acquire the necessary knowledge and skills in refresher courses, which would increase their productivity. Among the surveyed operators, operators in the age group up to 30 years with work experience on the respective machine under 5 years were more interested in refresher courses, while operators in the age group over 41 years of age having work experience over 5 years were less interested in the refresher courses. It was found that 30% of forwarders and 33% of CTL (Cut-To-Length) harvester operators attend refresher courses on their initiative, while all forwarders operators and 65% of harvester operators attend refresher courses on the initiative of the employer. 75% of forwarder operators and 66% of harvester operators stated that they had acquired additional new knowledge and skills as a result of their training, as a result of which their professional qualification level as well as productivity increased.
Key words: education, harvester, operator.

Introduction

In today's mechanized logging, harvester productivity is affected by several factors. Some of the influencing factors cannot be changed, such as tree species, diameter at breast height (DBH), type of felling, terrain, etc. There are several studies in this direction, where the influence of environmental factors is clarified (Olivera *et al*., 2016; Nurminen *et al*., 2006). However, some factors are subject to change and are largely related to the behavior of the operators, including psycho-emotional state, speed of reaction, speed of decision-making, and other factors (Purfürst, 2010; Purfürst & Erler, 2011). One such variable is the readiness of the operator of the logging machine (Alam *et al*., 2014). Periodic operator training plays a very important role in increasing productivity. Training can improve the skills of operators to perform certain activities. Training can take place in nature, in a logging machine, as well as the practical skills of operators can be developed with the help of a simulator (Eriksson & Lindroos, 2014). However, simulators differ in environmental factors, which sometimes cause problems for the operator in making decisions. Training operators in nature is an expensive process, because, firstly, the hourly cost of the logging machine itself is high and, secondly, a large part of the cost is fuel costs. Despite these costs, 8-16 hours of training is provided in Latvia, where the instructor follows the work of the operator in person and provides recommendations for more efficient work. This type of training produces results, but the result was largely determined by the professionalism of the instructor, from his ability to assess the situation and make recommendations. The aim of the research is to find out how forest machine operators working in Latvia use opportunities to increase their professional skills in professional development courses to increase productivity.

Materials and Methods

In this study, to find out the opinion of forest machine operators about the need for training and benefits from training, a survey of forest machine operators was created in electronic form (Geske & Grīnfelds, 2020). The survey consists of 3 blocks. The first block provides general information about the operator, the second block focuses on issues related to the in-service training process, and the third block provides questions related to the benefits of the training and recommendations. To be able to perform the mathematical processing of the survey, the variants of the answers to the questions of the second and third blocks of the survey are compiled according to the Likert scale in a six-point system from 'strongly disagree' to 'strongly agree'. Before the survey, the questionnaire was experimentally tested to ensure the clarity of the questions. The questionnaire was prepared electronically, emailed to the operators, and the questionnaire was filled online. The link to the survey was sent to the largest logging companies in Latvia, which have at least five logging machines and their forest machine operators participate in training organized by the Forest Machine Operator Training

Center. The master of logging companies distributed the questionnaire to forest machine operators. The results of the survey were collected and grouped with MS Excel. Harvester and forwarder operators were separated for analysis. Next, operators were grouped according to the level of education obtained: basic, secondary, secondary-professional and higher. In addition, operators were divided by age: up to 30 years, 31 to 40 years and over 41 years. To get a more complete picture of the impact of training on work productivity, operators were grouped by length of service on the relevant machine: up to 5 years and more than 5 years. The statistical processing of the survey data was performed using the R program by performing the chi-square test.

Results and Discussion

From 2018 to 2022, in-service training was conducted for 315 forest machine operators at the Forest Machinery Operators Center. 147 forest machine operators participated in the survey and filled in the questionnaires.

According to the survey data, the average age of operators is 33 years. During the survey, it was found that 18% of the surveyed operators had primary education, 20% had secondary education, 55% had secondary vocational education and 6% had higher education. 57% of the surveyed operators had obtained a diploma in forestry as a forest machine operator. The average total length of service of operators on logging machines is 7,6 years. Because two types of logging machine operators work in logging, the operators of harvesters and forwarders are separated. Initially, operators are sorted into separate groups. There are three groups according to the age of the operators: up to 30 years, 30-40 years, and more than 41 years, based on work experience in the last logging machine for up to 5 years and more than 5 years and education obtained accordingly.

Forwarder operators.

The average length of service on this machine of the surveyed forwarder operators was 6,4 years. To get a fuller picture, Table 1 shows the length of service and education of operators as a percentage of the total.

Of the surveyed forwarder operators, six operators in the age group up to 30 years have obtained a forest machine operator qualification diploma. The others have obtained a driver's license for the relevant category of tractors and further improved their professional qualification by working in a logging company and attending refresher courses.

Harvester operators.

The average length of service on this machine of the surveyed harvester operators was 4,7 years. To get a more complete picture, Table 2 shows the length of service and education of operators as a percentage of the total.

In the age group up to 30 years, 24 operators have obtained the qualification of a professional forest machine operator. In the age group 30-40, 4 operators have a professional qualification as a forest machine operator. Other operators have improved their professional skills by working in a logging company and attending refresher courses.

Table 1

Distribution of forwarders operators by age groups, the length of service in the respective machine, and level of education (as a percentage of the total number)

Age group (years)	Work experience (years)		Education			
	To 5	More than 5	basic	secondary	secondary – professional	higher
To 30	20	20	5	15	15	5
30-40	25	10	5	5	25	-
More than 41	10	15	10	10	-	5

Table 2

Distribution of harvester operators by age groups, the length of service in the respective machine, and level of education (as a percentage of the total number)

Age group (years)	Work experience (years)		Education			
	To 5	More than 5	basic	secondary	secondary – professional	higher
To 30	31	17	-	4	41	4
30-40	28	14	17	10	14	-
More than 41	3	7	-	-	10	-

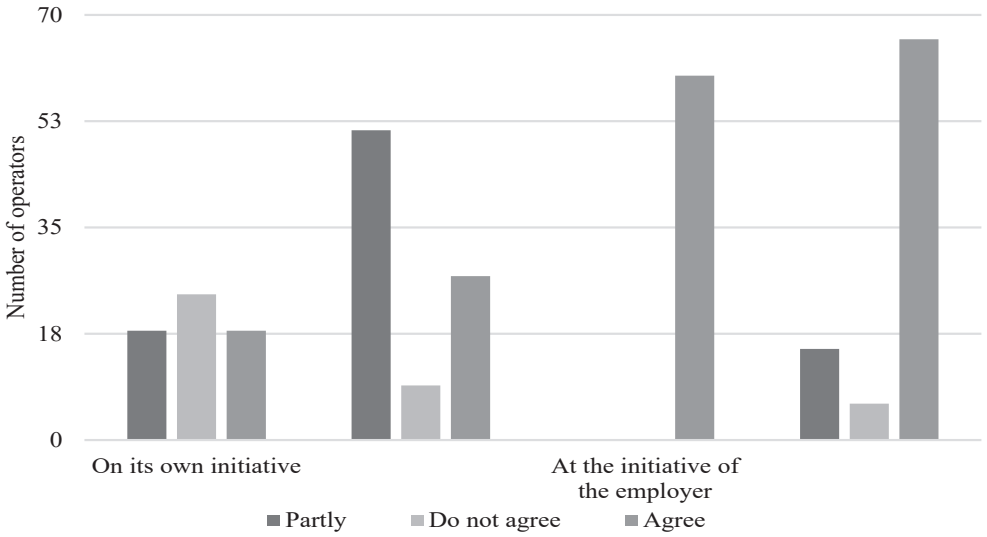

Figure 1. Attending refresher courses on your initiative or the employer's initiative.

The survey aimed to understand how attendance at qualification courses was assessed by the operators themselves. How useful were the knowledge and skills acquired under the guidance of professional instructors and how they affected productivity.

According to the information available at the Training Center for forest machine operators, it is understood that the operators of some logging companies have attended refresher courses several times. Consequently, operators were asked how often they attend refresher training.

According to the survey data, 42% of forwarder operators and 41% of harvester operators attend refresher courses one or more times a year. Of the forwarder operators who attended the refresher course once or more a year, 40% had less than 5 years of experience on the machine in question, and 60% had more than 5 years of experience, 67% and 33% for harvester operators, respectively.

According to the results of the survey, harvester operators, especially new operators with less than five years of experience with the machine, pay more attention to their professional development and productivity by improving their working methods.

Given that the response of the operators to the survey was relatively low, only 47% of the operators trained at the Forest Machinery Operators Training Center in the last 4 years answered the questionnaire, the answer groups of the following questions are merged. The Likert scale answers 'strongly agree' and 'partially agree' are combined as 'agree'. 'Partly agree' and 'partly disagree' are combined as 'partly'. The answers 'disagree' and are combined as 'strongly disagree' (Geske & Grīnfelds, 2020).

The purpose of the next two questions is to find out whether the operators attended the refresher courses on their own or on the employer's initiative (Figure 1). The diagram in Figure 1 shows that the initiative of harvester and forwarder operators to attend in-service training courses differs significantly $\chi^2 = 20.12$, $p = 4.275e^{-0.5} < 0.05$. 30% of forwarder operators answered that they attended the refresher courses on their initiative, 30% partially agreed with this statement, and the remaining 40% did not agree with the statement that they attended the refresher courses on their initiative. In turn, all surveyed forwarder operators indicated that they attended refresher courses at the initiative of the employer. On the other hand, 33% of harvesters agreed with the statement that they attended the training on their initiative, 57% partially agreed but 10% did not. 65% of the surveyed harvester operators fully agreed with the statement that the training was attended at the initiative of the employer, 28% partially agreed, but 7% did not agree with this statement. Comparing the answers of the harvesters by separating the operators according to the length of service, it was noticed that the answers of the operators differed significantly in this section $\chi^2 = 12.147$, $p = 0.002303 < 0.05$. Harvester operators with up to 5 years of experience attended more training on their initiative or in part, while harvester operators with more than 5 years of experience mostly attended refresher courses at the initiative of the employer.

One of the preconditions for the success of individual training is whether knowledge and skills are assessed before the training. According to the survey data, the evaluation of harvester and forwarder operators on the test of knowledge and skills before training did not differ significantly $\chi^2 = 0.47815$, $p = 0.7874 > 0.05$. 6 forwarder and 12 harvester operators denied that their knowledge and skills had been tested before the training; however (Figure 2), 90% of harvester operators and 86% of forwarder

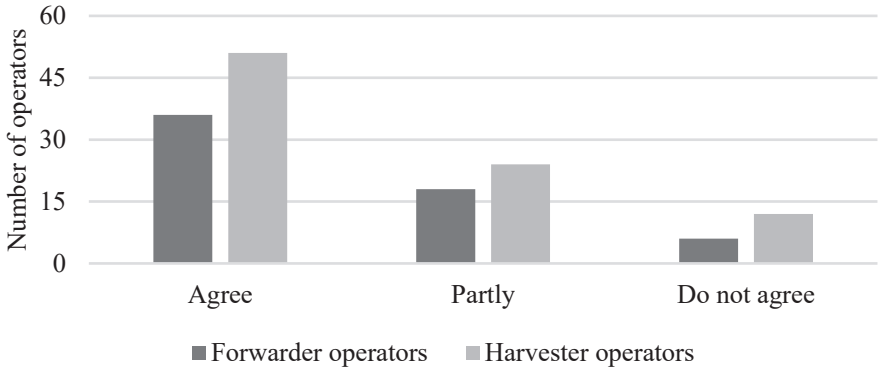

Figure 2. Test of operators' knowledge and skills before training.

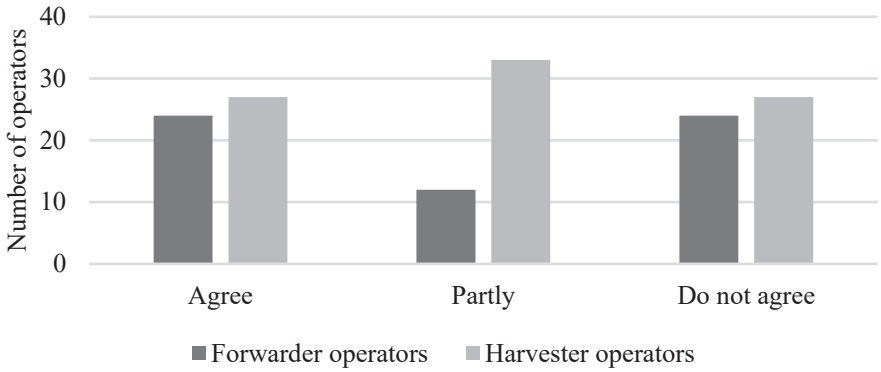

Figure 3. Analysis of the training process after completion.

operators confirmed or partially confirmed that their knowledge and skills were assessed by instructors. As a result, the instructor had an idea of the operator's skills and working methods. In the training process, the instructor paid increased attention to the skills that needed to be developed.

The survey of operators revealed that the instructor instructed the operator on more productive working methods. It was found that 80% of forwarder operators and 80% of harvester operators received training in the training process for mistakes made in the work process and for the benefits of using rational working methods, although 7% of harvester operators replied in the negative, the responses of forwarder and harvester operators did not differ significantly $\chi^2 = 1.8565$, $p = 0.3952 > 0.05$. As a result, operators were able to verify the effectiveness of these methods while continuing to work under the supervision of an instructor.

There was no significant difference between the responses of harvester and forwarder operators to the statement that after the training the instructor performed an analysis of the training process, $\chi^2 = 4.8366$, $p = 0.088907 > 0.05$ (Figure 3). 40% of forwarder operators and 31% of harvester operators agree with the statement that after the training, the analysis of the training process was carried out, as a result of which the operators realized the mistakes made. 20% of forwarder operators and 38% of harvester operators partially agreed with this statement, while 40% of forwarder operators and 31% of harvester operators disagreed with the statement. Therefore, it can be concluded that the operators who did not agree with the statement that the analysis of the results was done after receiving the training, the operators did not take the training process seriously or that the instructor has formally addressed the training process.

The training process was generally positively assessed by 75% of forwarder operators and 66% of harvester operators, partially by 25% of forwarder operators and 31% of harvester operators. One harvester operator considered that training was irrelevant. Analyzing the survey data, it was found that a partially negative and negative evaluation of training can be found in the responses of operators over the age of 41 and length of service over 5 years. The most positive attitude towards periodic training is found among operators under the age of 30 and the length of service up to 5 years.

Conclusions

1. The qualification course is most actively attended by harvester operators younger than 30 years

and with up to 5 years of work experience on the relevant machine and forwarder operators in the age group of 30 to 40 years with up to 5 years of work experience, respectively 31% and 25%. Less active training courses are attended by harvester operators older than 41 years and with less than 5 years of work experience on the relevant machine and forwarder operators in the age group from 30 to 40 years, with more than 5 years of work experience and in the age group over 41 years, with work experience up to 5 years, respectively 3% and 10%.

2. The research found that the majority of operators have attended the training courses several times. Among those who attended training courses: 30% of harvester operators and 33% of forwarder operators attended the courses on their own initiative, while all forwarder operators and 65% of harvester operators mentioned that they attended training courses on the initiative of the employer.
3. The majority (75%) of forwarder operators and 66% of harvester operators positively evaluated the training process and confirmed that they had acquired new knowledge and skills during the training.

References

Alam, M., Walsh, D., Strandgard, M., & Brown, M. (2014). A log-by-log productivity analysis of two Valmet 475EX harvesters. *International Journal of Forest Engineering*, 25(1), 14–22. DOI: 10.1080/14942119.2014.891668.

Eriksson, M., & Lindroos, O. (2014). Productivity of harvesters and forwarders in CTL operations in northern Sweden based on large follow-up datasets. *International Journal of Forest Engineering*, 25(3), 179–200. DOI: 10.1080/14942119.2014.974309.

Geske, A., & Grīnfelds, A. (2020). *Izglītības pētījumu aptaujas – no izveidošanas līdz datu apstrādei (Educational research surveys – from creation to data processing).* Rīga: LU Akadēmiskais apgāds. (in Latvian).

Nurminen, T., Korpunen, H., & Uusitalo, J. (2006). Time Consumption Analysis of the Mechanized Cut-to-length Harvesting System. *Silva Fennica* 40(2), 335–363. DOI: 10.14214/sf.346.

Olivera, A., Visser, R., Acuna, M., & Morgenroth, J. (2016). Automatic GNSS-enabled harvester data collection as a tool to evaluate factors affecting harvester productivity in a Eucalyptus spp. harvesting operation in Uruguay. *International Journal of Forest Engineering*, 27(1). 15–28. DOI: 10.1080/14942119.2015.1099775.

Purfürst, F.T. (2010). Learning curves of harvester operators. *Croatian Journal of Forest Engineering*, 32(2), 89–97. ID: 63720

Purfürst, F.T., & Erler, J. (2011). The Human Influence on Productivity in Harvester Operations. *International Journal of Forest Engineering,* 22(2), 15–22. DOI: 10.1080/14942119.2011.10702606.

 DOI: 10.22616/rrd.28.2022.013

A REVIEW: DAIRY PHOSPHOLIPIDS IN HUMAN NUTRITION

***Svetlana Aleksejeva[1], Inga Ciprovica[1], Laila Meija[2]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]Rīga Stradiņš University, Latvia
*Corresponding author's email: s.aleksejeva@gmail.com

Abstract
More than six billion people worldwide consume dairy products every day. Dairy products and their constituents contain hundreds of different components, but milk fat globule membrane (MFGM) polar lipids are still underestimated from a nutritional point of view. The unique composition of phospholipids (PLs) – the main MFGM component – provides high nutraceutical properties. Therefore, the research of bioactive dairy components and their impact has promising potential in human health by various mechanisms. The positive effects of MFGM PLs are mainly based on animal studies, but there are a small number of *in vivo* studies with volunteers. The present study aimed to review the research findings of dairy PLs in human nutrition and their functional properties. Dairy PLs effectively impact intestinal integrity and gut microbiota, lipid profile and risk lowering of cardiovascular diseases (CVDs), cognitive performance during stress, and neonatal brain development.
Key words: phospholipids, dairy products, MFGM.

Introduction

The essential components of the milk fat globule membrane are – phospholipids (PLs) and sphingolipids (SLs). PLs and SLs are amphiphilic molecules consisting of a hydrophobic tail, given by fatty acids, and a hydrophilic head, given by a concrete polar group. Glycerophospholipids and phosphosphingolipids represent PLs, but sphingomyelin and ceramides – SLs (Anto *et al*., 2020).

The essential part of a balanced and healthy diet is dairy products. The intake of dietary PLs from dairy products varies – approximately 2-8 g per day or 1-10% of the total daily fat intake (Cohn *et al*., 2010). Primary dietary PLs sources are eggs, cereal grains, oilseeds, fish, beef, and dairy products. Dairy products represent a significant source of nutritional PLs in the human diet. Dairy products consumption in Europe corresponds to 9% of dietary energy supply (OECD/FAO, 2019).

Different dairy products provide different amounts of PLs: whole milk 0.2-0.3 g 100 g^{-1} dry matter (DM), cream 0.2-0.4 g 100 g^{-1} DM, butter 0.3 g 100 g^{-1} DM, skimmed milk yogurt 0.2 g 100 g^{-1} DM, buttermilk 1.1-2.0 g 100 g^{-1} DM (Anto *et al*., 2020). The production processes explain those differences. Additionally, the chemical composition of milk depends on environmental factors, feed composition, animal health status, lactation period, season, etc. (Pereira, 2014; Liu *et al*., 2017; Timlin *et al*., 2021; Conway *et al*., 2013).

The research of bioactive dairy components has considerable potential in human health by various mechanisms. The number of studies of dairy PLs positive health effects on human health is still growing. Clinical researches suggest that dietary PLs effectively impact intestinal integrity and gut microbiota, inflammation, lipid profile and heart and circulatory system, brain development, and cognitive improvements (Anderson *et al*., 2011; Salcedo *et al*., 2013; Lee *et al*., 2014; Anderson *et al*., 2018; Kosmerl *et al*., 2021; Baumgartner *et al*., 2013; Boyle *et al*., 2019; Okuda, 2019; Hernell *et al*., 2016).

The present study aimed to review the research findings of dairy PLs in human nutrition and their functional properties.

Materials and Methods

Scientific databases Web of Science, Scopus, Wiley Online Journal (2000-2022) were studied to review the latest available data on dairy phospholipids in human nutrition and their functional properties. Full-text papers were included in this review. The monographic method was used in this study. The following keywords were used to select scientific literature: 'dairy phospholipids', 'milk fat globule membrane', 'buttermilk phospholipids', 'buttermilk', 'milk consumption', 'intake of phospholipids', 'dairy phospholipids'.

Results and Discussion

The study titles and abstracts were screened (n = 3621), full-texts assessed (n = 96). Twenty-three studies were included in a review. The main research areas were: the content of dietary PLs and SLs in different types of dairy products, PLs impact on lowering the CVDs risk and lipid profile changes, changes in gut microbiota and intestinal barrier functions, changes of cognitive performance during the stress, PLs effect on structural and functional development of the neonatal brain.

Everyday consumption of dairy products is high, especially in Western countries. Dairy products contain hundreds of components, but MFGM polar lipids are underestimated from a nutritional perspective. The structure of milk fat is specific, consisting of the fat and the membrane surrounding it, but the membrane

composition and bioactive role are insufficiently studied. The membrane contains polar lipids, sterols, proteins, nucleic acids, vitamins, and minerals. Polar lipids are richly present in the membrane and are therefore extracted from membranes for a wide use in food supplements and pharmaceutical purposes. A wide diversity of PLs provides complex metabolic pathways and thus influences different health conditions and organ systems. One of the most significant polar lipids is sphingomyelin (more than 25% of polar lipids), which is particularly important in preventing CVDs risks compared to polar lipids of other animal origins (less than 5% of polar lipids) or polar lipids of plant origin products (Bruno *et al*., 2021).

Intestinal integrity and gut microbiota

The knowledge of intestinal permeability and barrier function regulating mechanisms has grown widely over the past years. Correct maturation of the intestinal barrier is significant for health during all life. Milk lipid fractions support the proper development and stability of the intestinal barrier by enhancing the integrity of intracellular tight junctions that control permeability. There are two leading roles of the human intestine – absorption of macro- and micronutrients and prevention of potentially harmful agents. The evolution and growth of the human intestinal immune system and microbial colonization development take approximately two years (Anderson *et al*., 2011).

Dairy lipid fractions improved the integrity of the small intestinal epithelial barrier. Gangliosides represent glycosphingolipids in cellular membranes that can modulate membrane functions and the activity of membrane proteins. Gangliosides have two positive health-promoting mechanisms – the ability to decrease pathogenic bacteria adhesion and advance the growth of infant gut-associated bifidobacteria (Salcedo *et al*., 2013; Lee *et al*., 2014). In addition, the presence of gangliosides may cause the improvement in barrier integrity in response to dairy lipid fractions (Anderson *et al*., 2018). However, more studies are required to understand further the relationship between phospholipids intake and the intestinal barrier and intestinal microbial integrity.

PLs directly interacts with bifidobacteria and lactic acid bacteria. This interaction with probiotic bacteria goes through interactions with bacterial surface proteins. Therefore, there are synergistic effects between MFGM and probiotics for positive human health outcomes at all ages. Furthermore, PLs enhance the efficiency of probiotics in the gut by promoting probiotic survival and boosting mucosal immune development (Kosmerl *et al*., 2021). Unfortunately, the exact mechanism of the relationship between probiotics and PLs has yet to be thoroughly studied.

Lipid profile and CVDs

According to World Health Organisation data (WHO, 2021), CVDs – cerebrovascular disease, rheumatic heart disease, coronary heart disease – are the leading cause of death globally. CVDs are the most common cause of death in Latvia – 54.6% of all deaths in 2019 (Latvijas Universitātes Kardioloģijas un reģeneratīvās medicīnas zinātniskais institūts, 2020). In addition, a significant correlation is present between increases in triglyceride (TG), total cholesterol (TC) levels, and the risk of CVDs (Zhao *et al*., 2021). The role of low-density lipoprotein cholesterol (LDL) in the pathogenesis of CVDs and the clinical benefit of lowering LDL cholesterol in high-risk patients has been demonstrated in many studies. Therefore, as part of the most important behavioral risk factors, diet plays a significant role in CVD risk lowering and prevention.

In plasma and cholesterol homeostasis, LDL concentration is supported by intestinal cholesterol absorption, endogenous cholesterol synthesis, and cholesterol withdrawal (Ros, 2000). The diet's impact on reducing intestinal cholesterol absorption has a remarkable effect on plasma cholesterol and LDL concentrations. *In vitro* studies have shown that buttermilk contains a high concentration of PLs, inhibiting cholesterol micellar solubility. Short-term consumption of buttermilk significantly reduced TC and TG concentrations in men and women. The reduction was even noticeable among individuals with higher LDL concentrations (Conway *et al*., 2013).

Buttermilk is an excellent dietary source of sphingolipids and contains 17.9-34.5% of the total PLs (Conway *et al*., 2014). Buttermilk sphingolipids and lactic acid bacteria influence the metabolism of cholesterol. At the same time, eggs are a concentrated source of dietary cholesterol and dietary PLs. Dietary cholesterol increases TC and LDL. 12-week egg consumption significantly raised TC and LDL concentrations in women, but the consumption of eggs with buttermilk increased TC and LDL moderately (non-significant). Buttermilk components influence the bioavailability of dietary egg cholesterol absorption and thus have beneficial effects on health (Baumgartner *et al*., 2013).

Animal studies show that SLs lower cholesterol. Therefore, intake of dairy PLs may lower plasma cholesterol level by inhibiting the intestinal bioavailability of cholesterol (Conway *et al*., 2013).

Cognitive performance during stress

Stress has become an integral part of everyday life, but in the case of high-stress levels or chronic states, it may cause different somatic and mental disorders. Stress reduces cognitive performance cognition and often underlies cognitive deficits (Nagy *et al*., 2020). PLs have a lowering effect on the activity and reactivity of the hypothalamic-pituitary-adrenal axis (HPAA).

Supplementation with PLs has a positive lowering impact on the stress response and protects cognitive performance sensitive to stress initiation. Intake of milk PLs has shown the improvement of cognitive performance under conditions of psychosocial stress. A six-week daily intake of 2.7 g of PLs positively affects neuroendocrine and subjective stress reactions to an acute psychosocial stressor in individuals with a raised predisposition toward high-cortisol responsivity (Boyle *et al*., 2019).

PLs most likely increase the availability of cortisol in chronically stressed men and may downgrade stress-induced memory analogs. PLs intake lowers morning salivary cortisol levels, which may conform to the prolonged availability of free cortisol. An increase of PLs on 0.5% provided a higher morning cortisol level. At the same time, no differences were noticed after a rise in PLs of 1%. Additionally, elderly participants with higher PLs intake showed better memory performance than the placebo and low PLs intake group (Schubert *et al*., 2011).

Neonatal brain development

The first years after birth are a crucial period of structural and functional development of the brain and its complex underlying microstructural changes (Li *et al*., 2019). Gangliosides play an essential role in neuronal growth and are involved in migration and maturation, neuritogenesis, synaptogenesis, and myelination during early life (McJarrow *et al*., 2009). Atypical expression and metabolism of gangliosides can lead to neurologic diseases. Dairy gangliosides are not directly absorbed into tissues *in vivo*. Firstly, they are broken down in the intestinal tract and absorbed. Thus, it affects ganglioside expression in the tissues. An adequate level of ganglioside expression is necessary for maintaining overall membrane integrity. Therefore, the diet can indirectly control the expression of ganglioside metabolism-related genes (Okuda, 2019).

MFGM as a dietary source of PLs can supplement infant formulas to narrow the difference in performance between formula-fed and breastfed infants. In addition, such supplementation is safe from the first week of life in infants without serious side effects (Hernell *et al*., 2016).

Conclusions

Dairy products are a valuable source of PLs and an essential part of a human healthy and balanced diet. The unique composition of PLs provides high nutraceutical properties. Intake of PLs positively impacts the number of health states – intestinal integrity and gut microbiota, lipid profile and heart and circulatory system, neonatal neurodevelopment, and cognitive performance during stress. The positive effects of MFGM PLs are mainly based on animal studies, but there are few *in vivo* studies with volunteers.

References

Anto, L., Warykas, S.W., Torres-Gonzalez, M., & Blesso, C.N. (2020). Milk Polar Lipids: Underappreciated Lipids with Emerging Health Benefits. *Nutrients*, 12(4), 1001; DOI: 10.3390/nu12041001.

Anderson, R.C., Dalziel, J.E., Gopal, P.K., Bassett, S., Ellis, A., & Roy, N.C. (2011). The role of intestinal barrier function in early life in the development of colitis. In: Fukata M, editor. *Colitis*: INTECH. pp. 3–30. DOI: 10.5772/25753.

Anderson, R.C., MacGibbon, A.K.H., Haggarty, N., Armstrong, K.M., & Roy, N.C. (2018). Bovine dairy complex lipids improve in vitro measures of small intestinal epithelial barrier integrity. *PLOS ONE* 13(1): e0190839. DOI: 10.1371/journal.pone.0190839.

Baumgartner, S., Kelly, E.R., van der Made, S., Berendschot, TJM. T., Husche, C., Lütjohann, D., & Plat, J. (2013). The influence of consuming an egg or an egg-yolk buttermilk drink for 12 wk on serum lipids, inflammation, and liver function markers in human volunteers, *Nutrition*, Vol. 29, Issue 10, Pages 1237–1244. DOI: 10.1016/j.nut.2013.03.020.

Boyle, N.B., Dye, L., Arkbåge, K., Thorell, L., Frederiksen, P., Croden, F., & Lawton, C. (2019). Effects of milk-based phospholipids on cognitive performance and subjective responses to psychosocial stress: A randomized, double-blind, placebo-controlled trial in high-perfectionist men. *Nutrition*.; 57:183–193. DOI: 10.1016/j.nut.2018.05.002.

Bruno, R.S., Pokala, A., Torres-Gonzalez, M., & Blesso, C.N. (2021). Cardiometabolic health benefits of dairy-milk polar lipids. *Nutrition reviews*, *79*(Supplement_2), 16–35. DOI: 10.1093/nutrit/nuab085.

Cohn, S.J., Kamili, A., Wat, E., Chung, R.W.S., & Tandy, S. (2010). Dietary Phospholipids and Intestinal Cholesterol Absorption. *Nutrients*. Volume 2, 116–127. DOI: 10.3390/nu2020116.

Conway, V., Couture, P.C., Richard, S.F., Gauthier, Y., Pouliot, & Lamarche, B. (2013). Impact of buttermilk consumption on plasma lipids and surrogate markers of cholesterol homeostasis in men and women. *Nutrition, Metabolism & Cardiovascular Diseases* 23, 1255–1262.

Conway, V., Gauthier, S.F., & Pouliot, Y. (2014). Buttermilk: Much more than a source of milk phospholipids. *Animal Frontiers*, Vol. 4, Issue 2, Pages 44–51. DOI: 10.2527/af.2014-0014.

Hernell, O., Timby, N., Domellof, M., & Lonnerdal, B. (2016). Clinical Benefits of Milk Fat Globule Membranes for Infants and Children. *The Journal of Pediatrics*, Vol. 173, S60–S65, DOI: 10.1016/j.jpeds.2016.02.077.

Kosmerl, E., Rocha-Mendoza, D., Ortega-Anaya, J., Jiménez-Flores, R., García-Cano, I. (2021). Improving Human Health with Milk Fat Globule Membrane, Lactic Acid Bacteria, and Bifidobacteria. *Microorganisms*;9(2):341. Published 2021 Feb 9. DOI: 10.3390/microorganisms9020341.

The Institute of Cardiology and Regenerative Medicine of the University of Latvia (2020). A cross-sectional study of risk factors for cardiovascular and other non-communicable diseases of the population of Latvia within the framework of the ESF project 'Complex health promotion and disease prevention measures'.

Lee, H., Garrido, D., Mills, D.A., & Barile, D. (2014). Hydrolysis of milk gangliosides by infant-gut-associated bifidobacteria determined by microfluidic chips and high-resolution mass spectrometry. *Electrophoresis* 35: 1742–1750. DOI: 10.1002/elps.201300653 24519724.

Li, G., Wang, L., Yap, P. T., Wang, F., Wu, Z., Meng, Y., Dong, P., Kim, J., Shi, F., Rekik, I., Lin, W., & Shen, D. (2019). Computational neuroanatomy of baby brains: A review. *NeuroImage*, *185*, 906–925. DOI: 10.1016/j.neuroimage.2018.03.042.

Liu, Z., Logan, A., Cocks, B.G., & Rochfort, S. (2017). Seasonal variation of polar lipid content in bovine milk. *Food Chem.*; 237:865–869. DOI: 10.1016/j.foodchem.2017.06.038.

McJarrow, P., Schnell, N., Jumpsen, J., & Clandinin, T. (2009). Influence of dietary gangliosides on neonatal brain development. *Nutrition Reviews*, Vol. 67, Issue 8, Pages 451–463, DOI: 10.1111/j.1753-4887.2009.00211.x.

Nagy, S.A., Vranesics, A., Varga, Z., Csabai, D., Bruszt, N., Bali, Z. K., Perlaki, G., Hernádi, I., Berente, Z., Miseta, A., Dóczi, T., & Czéh, B. (2020). Stress-Induced Microstructural Alterations Correlate with the Cognitive Performance of Rats: A Longitudinal *in vivo* Diffusion Tensor Imaging Study. *Frontiers in neuroscience*, *14*, 474. DOI: 10.3389/fnins.2020.00474.

OECD/FAO (2019). Dairy and dairy products. OECD-FAO Agricultural Outlook 2019-2028, *OECD Publishing*, Paris, DOI: 10.1787/7ccc11c6-en.

Okuda, T. (2019). Dietary Control of Ganglioside Expression in Mammalian Tissues. *Int J Mol Sci*. 2019;21(1):177. DOI: 10.3390/ijms21010177.

Pereira, P.C. (2014). Milk nutritional composition and its role in human health. *Nutrition*.; 30(6):619–627. DOI: 10.1016/j.nut.2013.10.011.

Ros, E. (2000). Intestinal absorption of triglyceride and cholesterol. Dietary and pharmacological inhibition to reduce cardiovascular risk. *Atherosclerosis*; 151:357e79.

Salcedo, J., Barbera, R., Matencio, E., Alegria, A., & Lagarda, M.J. (2013). Gangliosides and sialic acid effects upon newborn pathogenic bacteria adhesion: an in vitro study. *Food Chem* 136:726–734. DOI: 10.1016/j.foodchem.2012.08.078 23122120.

Schubert, M., Contreras, C., Franz, N., & Hellhammer, J. (2011). Milk-based phospholipids increase morning cortisol availability and improve memory in chronically stressed men. *Nutr Res*.; 31(6):413–420. DOI: 10.1016/j.nutres.2011.05.012.

Timlin, M., Tobin, J.T., Brodkorb, A., Murphy, E.G., Dillon, P., Hennessy, D., O'Donovan, M., Pierce, K.M., & O'Callaghan, T.F. (2021). The Impact of Seasonality in Pasture-Based Production Systems on Milk Composition and Functionality. *Foods*; 10(3):607. DOI: 10.3390/foods10030607.

World Health Organization (2021, June). Retrieved March 1, 2022, from https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).

Zhao, X., Wang, D., & Qin, L. (2021). Lipid profile and prognosis in patients with coronary heart disease: a meta-analysis of prospective cohort studies. *BMC Cardiovasc Disord* 21, 69. DOI: 10.1186/s12872-020-01835-0.

 DOI: 10.22616/rrd.28.2022.014

USE OF PEAS (*PISUM SATIVUM* L.) AND BEANS (*PHASEOLUS VULGARIS* L.) IN HIGH-MOISTURE FOOD EXTRUSION: A REVIEW

***Elizabete Andersone-Trezina, Tatjana Kince**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: elizabete-andersone@inbox.lv

Abstract
Demands for plant-based food in the European Union are growing especially nowadays. Pulses are common and regional; they have an excellent nutritive value but its consumption in food industry is still low. In last decades extrusion technology has become extremely popular in food development. The aim of this study was to investigate the latest findings about pea *Pisum sativum* L. and beans *Phaseolus vulgaris* L. flour suitability for high-moisture food extrusion. Monographic method was used to analyse pulse seeds chemical content, possible pre-treatment methods, functional properties, covering the latest information about high-moisture extrusion, raw materials and technical parameters used. Pulses are a good source of protein, carbohydrates, minerals and vitamins. Chemical content, functional properties of yellow peas and different varieties of beans, except grey peas are well described in scientific literature. Germination can be promising pre-treatment for pulse seeds, it increases folic acid content, water absorption capacity and reduces the amount of antinutrients. Extrusion technology increases ready product protein digestibility and induces changes in antinutrient activity. High-moisture food extrusion characterises with moisture of raw materials above 40.00% where mostly protein concentrate and isolates from pulses are used.
Key words: pulses, germination, functional properties, high-moisture extrusion.

Introduction

Pulses are edible seeds of legume plant. They are well known and grown all over the world and are used as food and feed especially nowadays (Rawal *et al*., 2019).

Pulses consumption pattern is affected by several factors such as socio-cultural, economical and historical. The consumption of legumes in Europe is about 7.50 g per capita per day, but for the comparison, in the world − about 21.00 g per day (Rawal *et al.*, 2019). Improving pulses production, consumption and usage are important for prevention of malnutrition, micronutrient deficiencies and overweight (Calles, Xipsiti, & del Castello, 2019).

Low glycaemic index characterizes pulses, they reduce blood glucose level, which is very important factor in diabetes prevention (Calles, Xipsiti, & del Castello, 2019).

Pulses are source of protein with its variation from 17.00 to 30.00%, that is two times higher than in cereals, where globulins, salt-soluble proteins (leguminous (11S) and vicilin (7S) families) make up 70.00% of total protein (Cotacallapa-Sucapuca *et al*., 2021; Djoullah *et al.*, 2015).

Peas (*Pisum Sativum L.*) and beans (*Phaseolus vulgaris L.*) are rich with essential amino acids such as leucine and lysine (Krumina-Zemture, Beitane, & Gramatina, 2016; Nosworthy *et al*., 2017).

In 2018, European Parliament accepted European strategy for the promotion of protein crops in the European Union to meet growing consumer interest especially in demands for plant-based foods (European Parliament, 2018).

Current trend in plant-based foods is meat analogues, sports foods, instant soups, breakfast cereals, bakery and dairy substitutes. Most of plant-based products are made from pea, faba bean, soy (*Glycine max*) protein powder, protein isolates and protein concentrate using food extrusion (Kołodziejczak *et al*., 2021).

In the last decade, there has been scientific interest in extrusion cooking process; it seems to be appropriate for ready-to-eat pulse and cereals-based products. Extrusion cooking is usually carried out at a temperature up to 200 °C and a pressure of 20 MPa. The degree of grinding of the raw material and the moisture content are prerequisites for the mass to move further into the heated barrel using one or two screws (Pasqualone *et al*., 2020). However, in 2014 experiments have been realised in Latvia by developing of new type beans products using single screw extruder (Strauta *et al*., 2014).

Extrusion can be low-moisture and high-moisture. The latest trend in food extrusion is high-moisture extrusion, when moisture content of raw material is more than 40.00%, and it seems to have products with better texture and with lower energy input than using extrusion cooking (Zhang *et al*., 2019).

The aim of the present review was to investigate the latest findings about peas and beans flour suitability for high-moisture food extrusion.

Materials and Methods

Monographic method was used for this study. Available literature (monographs, journals) was reviewed in the period from 1998 to 2022. The review includes articles on the cultivation and use of pulses in the production of food products in Latvia, Europe, North and South America, as well as in Asia. As key-words used: peas (*Pisum sativum L.*), beans (*Phaseolus vulgaris L.*), extrusion and antinutrients. 40 most suitable sources from Scientific databases as

Scopus, ScienceDirect, Web of Science were studied. The main aim was to summarise and compile recent findings about peas and beans chemical composition, functional properties and possibility of pulse flour blend using in high-moisture food extrusion.

Results and Discussion

Pulses chemical composition and functional properties

Chemical composition of whole pea (*Pisum sativum* L.) seeds in dry matter is as follow: protein content 16.00-30.00%, fibre 6.00-10.00%, total lipids 1.00-3.00%, resistant starch 1.00-7.00% (Santos *et al.*, 2019). Whole beans (*Phaseolus vulgaris* L.*)* seed contains (in dry matter): protein 17.70-27.90%, starch 41.80-45.60%, total dietary fibre 27.20-38.20% (including insoluble dietary fibre 13.90-32.80% and soluble dietary fibre 2.90-8.30%), soluble sugars 6.29 and 9.09%, total lipids 0.70-2.70%, ash 3.80-5.70% (Los *et al*., 2018; Da Silva Fialho *et al*., 2006).

Pulse protein content can be influenced by genetics, climate, soil type and harvesting practises (Mohammed *et al.*, 2018).

In 2020, results from the study carried out in Latvia where the main goal was to gather 5-year investigation results of total protein content, amino acid profile and total lipids content in different pea varieties and to estimate their usage for food production have been published (Sterna *et al*., 2020). Results of those experiments demonstrate that the peas grown in conventional and organic systems result with different total protein content as 25.30±2.00% and 21.90±2.20% respectively (Sterna *et al.,* 2020). Whereas, the total amount of essential amino acids in peas in the conventional system shows greater variation over years and varieties, 79.60±10.20 g kg^{-1} compared to organic system 77.20±5.3 g kg^{-1} with highlights leucine, lysine, phenylalanine and valine content, 14.10 g kg^{-1}, 13.00 g kg^{-1}, 9.50 g kg^{-1} and 9.10 g kg^{-1} respectively. In this experiment extruded pea flakes were made using high-temperature short time extrusion. Results of experiments demonstrate no significant differences in nutritional value of raw and extruded pea flakes (Sterna *et al.*, 2020). Krumina-Zemture, Beitane, & Gramatina, (2016) determined total amino acid content in organic pea flour (Latvia). The results showed that total amount of amino acids was 19.30 g 100 g^{-1} of which 6.89 g 100 g^{-1} were essential amino acids. Essential amino acids accounted for 35.00% from total amino acid amount. Lysine content was roughly 22.00% and 1.58 g 100 g^{-1} in absolute values.

Canadian scientists determined protein content, amino acid profile, protein digestibility-corrected amino acid score (PDCAAS), protein efficiency ratio (PER) and digestible indispensable amino acid score (DIAAS) in cooked four varieties of *Phaseolus vulgaris* (kidney, navy, pinto, black beans) and one variety of yellow peas (Nosworthy *et al*., 2017). In 1991, FAO made the lowest ratio observation model, as the reference pattern (FAO/WHO, 1991). This model was used for sulphur containing amino acids – methionine, cysteine, tryptophan evaluation. The scientist declares that amino acid score for methionine and cysteine were limiting for red kidney beans and black beans 0.70 mg g^{-1} and 0.76 mg g^{-1}, respectively. The tryptophan was limiting for navy beans, split yellow peas, and pinto beans, 0.83 mg g^{-1}, 0.73 mg g^{-1}, 0.77 mg g^{-1}, respectively. As a reference, casein is used in Canada (Nosworthy *et al*., 2017). Black beans showed the lowest results in true protein digestibility (TDP %) almost 70.00% compared with pinto beans 76.00%, navy beans 80.00%, kidney beans 79.00%, yellow peas 87.00%. The PDCAAS is protein evaluation method combining amino acid requirements of human and the ability to digest it (the maximum is 100%). The results showed the highest value observed for navy beans, 67.00%, kidney beans 55.00%, black beans 53.00%, pinto beans 59.00%, spilt peas 64.00% (Nosworthy *et al.*, 2017). It seems that navy beans and yellow peas are easier to digest but the starch content is also very important factor for pulse used in food production.

The relatively low degree of digestibility of starch in legumes is attributed to the unavailability of starch granule amylases embedded in intact cell wall structures (Dahl, Foster, & Tyler, 2012). Ferawati, Hefni, & Witthöft (2019) studied how boiling, roasting and germination affect starch in pulses. After processing, the resistant starch content was twofold higher in yellow pea flour and almost threefold higher in faba bean (*Vicia faba* variety 'Alexia') flour, but decreased by 18.00–54.00% in grey pea flour and by 80.00–90.00% in white bean flour in comparison with unprocessed pulse flour. Microscopic examination of cooked whole legumes (green, yellow peas, navy beans and pinto beans) explained that a large part of the starch was partially gelatinized and located in the walls of intact cells, while cooked flour pastas contained few gelatinized granules. After *in vitro* digestion in the upper intestine, starch was unavailable to digestive enzymes (Brummer, Kaviani, & Tosh, 2015). Studies have been conducted to the dietary intake of dried peas in patients with type 2 diabetes and the results showed that peas, as carbohydrate source in a mixed meal, cause significantly minor glycaemic and insulin reactions than potatoes (*Solanum tuberosum*) (Schäfer *et al*., 2003).

Pulse biological component are antinutritional factors. They are worthwhile as prebiotics, but at the same time, they are heat resistant, cause flatulence and inhibit absorption of trace elements as Ca, Zn, Fe (Dahl, Foster, & Taylor, 2012; Da Silva Fialho *et*

al., 2006). Trypsin inhibitors (class of proteins) can reduce specific amino acid availability, e.g. they can bind with lysine and arginine (Kumar *et al*., 2021; Ramireddy & Radhakrishna, 2021).

Antinutritional factor reducing methods are germination, boiling, soaking and extrusion (Ramireddy & Radhakrishnan, 2021). High treatment temperature as 148 °C and short extrusion time, however 25.00% moisture content of raw material and 100 rpm (screw speed rotation) were the most effective circumstances for tannin, trypsin, α-amylase inhibitors reduction in peas without effecting protein content,– how it eventuate by germination, dehulling and soaking (Alonso, Orúe, & Marzo, 1998).

Pulses contain sugar complexes such as galactooligosaccharides (GO), raffinose, stachyose and verbascose. Study results showed that the GO contents varied from 3.12 to 5.71% in ten different varieties of beans in Brazil (Da Silva Fialho *et al.,* 2006). Canadian researchers have found that peas contain oligosaccharides (3.73% of total dry matter), raffinose 0.48±0.07%, stachyose 2.36±0.39% and verbascose 0.89±1.17% (Tosh *et al*., 2013).

In Harmankaya *et al.* (2010) study, 19 genotypes of peas were investigated; obtained results showed average mineral content for potassium 757.94±1.81 mg 100 g^{-1}, for phosphorus 302.90±0.72 mg 100 g^{-1}, for magnesium 84.06±0.56 mg 100 g^{-1}, and calcium 82.53±0.37 mg 100 g^{-1}. Researchers find out a strong positive correlation between potassium and phosphorus, potassium and sulphur and zinc ($p<0.01$) (Harmankaya *et al.*, 2010). Scientists Dahl, Foster & Taylor (2012) reviewed iron content in peas 9.70 mg 100 g^{-1} selenium 4.20 mg 100 g^{-1}, zinc 4.10 mg 100 g^{-1}, molybdenum 1.20 mg 100 g^{-1}, manganese 1.10 mg 100 g^{-1} and cuprum 0.90 mg 100 g^{-1} (Dahl, Foster, & Taylor, 2012). Iron, zinc and phytate concentration in beans traditionally is in range of 38.40–93.70 µg 100 g^{-1}, 18.90–43.60 µg 100 g^{-1}, 4.80–19.90 µg 100 g^{-1}, respectively (Caproni *et al*., 2020). The amount of trace minerals in beans varieties can be in range 10.10–109.00 µg 100 g^{-1} of zinc, 2.80–10.90 µg 100 g^{-1} of copper, 15.80–64.60 µg 100 g^{-1} of phosphorus, and 6.70–14.40 µg 100 g^{-1} of aluminium (Hayat *et al*., 2014).

A study in Latvia shows that pea flour in comparison to wheat flour can be a good source or B group vitamins. Thiamine content in pea flour was 1.11 mg 100 g^{-1} and riboflavin 0.71 mg 100 g^{-1} (Beitane & Krumina-Zemture, 2017). Peas also contains folate within 23.70 µg 100 g^{-1} to 101.00 µg 100 g^{-1} (Dahl, Foster, & Taylor, 2012). Results from study in Sweden showed that total choline content in raw yellow pea (DM) was 136.00±4.90 mg 100 g^{-1}, grey pea (unknown Latvian variety) 141.00±4.70 mg 100 g^{-1}, but after roasting total choline content was higher in yellow and grey peas 143.00±3.50 mg 100 g^{-1} and 142.00±3.80 mg 100 g^{-1} respectively. After 48 h germination total folic acid content increased from 73.00±2.90 mg 100 g^{-1} to 254.00±11.50 mg 100 g^{-1} in yellow peas and from 90.00±0.50 mg 100 g^{-1} to 256.00±6.50 mg 100 g^{-1} in grey peas (Ferawati, Hefni, & Witthöft, 2019).

Beans are a good source of folate 0.15-0.68 mg 100 g^{-1}, thiamine 0.81-1.32 mg 100 g^{-1}, riboflavin 0.11-0.41 mg 100 g^{-1}, niacin 0.85–3.21 mg 100 g^{-1} and pyridoxine 0.30-0.66 mg 100 g^{-1} (Hayat *et al*., 2014). In Spain, using randomized block design 255 lines of beans (*Phaseolus vulgaris*) in different colours – white, white with speckle, yellow, cream, brown, red, pink, grey and black were grown (Madrera *et al*., 2021). All samples were analysed for phenol antioxidant index (PAOXI), which is an indicator to sum up antioxidant phenols concentration and their effectiveness. The highest PAOXI had beans in cream colour 18.90±4.20, red coloured beans 18.70±3.20, black coloured beans 18.10±2.70, brown coloured beans 17.40±3.20 and pink coloured beans 15.90±2.50 (Madrera *et al*., 2021). In other study, researchers found out that the antiradical activity of pulse varieties closely correlated with the colour of the seed coat (Dahl, Foster, & Taylor, 2012).

Physicochemical and functional properties of pulses

In the study, the physicochemical and functional properties of raw, unshelled pulse flour were investigated. Results showed that raw beans bulk density (BD) differs between bean varieties; pinto 0.68 g mL^{-1}, lima 0.78 g mL^{-1}, small red 0.68 g mL^{-1}, red kidney 0.68 g mL^{-1}, black bean 0.54 g mL^{-1}, navy 0.69 g mL^{-1}, black eyed 0.76 g mL^{-1} and mung beans 0.80 g mL^{-1} (Du *et al.*, 2014). Water absorption capacity (WAC) in raw yellow peas was 0.80±0.03 g_{water} g^{-1}_{DM} but in grey peas 1.10±0.04 g_{water} g^{-1}_{DM}. Raw white bean WAC was 1.20±0.02 g_{water} g^{-1}_{DM}. Boiling, roasting and germination were used as flour treatment methods. All methods increased ($p<0.001$) WAC among 1.50 and 3.00 times comparing with untreated pulses (Ferawati, Hefni, & Witthöft, 2019).

The raw materials in Ferawati, Hefni & Witthöft (2019) research were investigated on water and oil absorption capacity (OAC). It is necessary to indicate that the OAC is very important for enhancing the mouthfeel and retaining products flavour. The OACs of pinto, lima, small red, red kidney, black bean, navy, black eyed and mung beans were in scale from 0.93 g 100 g^{-1} to 1.38 g 100 g^{-1}, where the differences were statistically significant (Du *et al*., 2014). However, soaking and boiling reduced emulsion activity (EA) in white bean flour ($p<0.001$) by 17.00% and emulsion stability (ES) by 25.00% ($p<0.001$), but did not change ($p>0.41$) the emulsion properties of grey, yellow peas and faba bean flours (Ferawati, Hefni,

& Witthöft, 2019). Scientists in China have revealed that the emulsion activity of pulse flours contrasted, small red bean flour had the highest value 92.20% and lima bean flour the lowest value 63.77%. Emulsion stability in pinto bean flour was 84.15%, but in navy bean flour 96.90%. These are the extreme minimum and maximum absolute values. Protein content, starch, lipids and sitosterols are linked with emulsion stability and emulsion activity in pulse flour. Proteins in their tertiary structure have hydrophobic polar side chains and thus impact emulsion properties and solubility (Du *et al*., 2014). The sprouting decreased ($p<0.007$) EA by 15.00-33.00% in grey pea flour and ES by 14.00-48.00% in grey pea, faba, and white bean flours, in comparison with untreated flours. Boiling and roasting influenced foaming stability (FS) in grey and yellow peas and white and faba bean, approximately in range 21.00-48.00% ($p<0.001$). Roasting and germination highlighted grey pea results in emulsion properties as the lowest ($p<0.004$) and the FS was lower ($p<0.001$) than in other tested samples. Thus, they could be used in the production of coatings for egg custard, sausages, pastries and baked goods. However, processed grey pea flour usage in sauces and meat substitutes can be restricted (Ferawati, Hefni, & Witthöft, 2019).

Viscosity is one of the most important quality factors in food products. It describes by pasting temperatures. In the study of Maninder, Sandhu, & Singh (2007) different bean flour pasting temperatures were tested. The highest results at 83.0 °C showed lima beans, the lowest at 73.2 °C mung beans. Higher treatment temperature pronounces starch more resistant to swelling and tearing. As measurement unit for viscosity, Rapid-Visco Analyser units (RVU) are used. The highest peak viscosity had black eye bean flour − 216.80 RVU, but the lowest value had small red bean 103.30 RVU (Du *et al*., 2014). Mean gelatinization temperature of field pea flour was 59 °C in onset, 66 °C on peak and 74 °C on conclusion. Peak height index was 0.68. Pasting temperature was moderate to be 73.9-75.4 °C (Maninder, Sandhu, & Singh, 2007).

Pulses in high moisture extrusion

Extrusion at high moisture level above 40.00%, is also known as 'wet extrusion'. Generally, for wet extrusion technology, twin-screw extruders (TSE) in large-capacity manufacturing enterprises are used (Akdogan, 1999).

High-moisture extrusion is a process where in combination of moisture, pressure, shear stress conditions and temperature, raw materials are forced through the heating barrel, mixed between screws, shaped, cooled and sheared. All these factors influence proteins, cause their denaturation, starch gelatinization and degradation, lipid oxidation, antinutrient, trace minerals and vitamins degradation (Zhang *et al*., 2022). The literature review shows that extrusion increases the protein digestibility *in vitro* by approximately 13.00-18.00% (Pasqualone *et al*., 2020).

Current trend in high moisture extrusion is meat analogues, usually made from pea and bean protein powders and isolates, soy protein isolates, maize (*Zea mays*) and wheat (*Triticum*) starch, microalgae, peanut (*Arachis hypogaea*) protein and isolates. Cornet *et al.,* (2021) an overview article described high moisture food extrusion process using a single screw extruder, twin extruder or shear cell. Moisture content of raw materials was 55.00-72.00% and the maximum extrusion temperature was 95-170 °C depending on nature of raw material (Cornet *et al.*, 2021). In another study, certain conditions for successful high-moisture food extrusion process were mentioned. The product after processing had fibrous meat-like structure, moisture content was more than 30.00% and was ready-to-eat. Weaknesses of technology is high-cost equipment. Inflexible restrictions on raw materials were more than 60.00% of protein, moisture content was in range 40.00−80.00%. Researchers indicate problems with short time storage conditions and modification with product palatability. Most important aspect of high-moisture extrusion is the future development direction (Zhang *et al*., 2022).

Screw speed and length, moisture content, different temperatures in barrels − all these aspects can make structural and chemical changes in products, e.g. lower antinutrient activity, shorter cooking time, changes in carbohydrates concentration complex and denaturation of protein structures (Berrios, Ascheri, & Losso, 2012; Cotacallapa-Sucapuca *et al*., 2021).

Yoshimoto *et al.* (2020) studied suitability of dehulled yellow pea, unshelled yellow pea, chickpea (*Cicer arietinum*), and lentil (*Lens culinaris*) in noodles obtaining. Prepared noodles analysed with *in vitro* digestion and studied the opportunity to use them as functional staple food with an aim to control blood glucose. However, nutrition with low glycaemic index can be used as prevention for type 2 diabetes, gastrointestinal cancers and obesity. In the experiment, water was added approximately 50% to the legume flour, dough was mixed, extruded at 120 °C, and then air dried. Results showed that rapidly available glucose (RAG) in dehulled yellow pea noodles were (YP) 8.34±1.07% and unshelled yellow pea noodles (YP-U) 8.20±0.88% it was less than both control samples commercial gluten-free pastas (made from steamed rice) 9.91±1.56% and 9.71±1.42% respectively, but there was no significant difference. In sensory evaluation (9-point scale), the highest overall acceptance had YP noodles 5.30±1.32 and, also, they had highest result in appearance, taste, aroma and stickiness 6.23±1.07, 5.60±1.25, 4.70±1.39 and 5.67±1.40, respectively. Sensory evaluation results

were statistically significant. Results from physical properties tests such as breaking stress, breaking strain and bulk density showed that dehulled yellow pea noodles and unshelled yellow pea noodles were the hardest and panellist must use more force to chew noodle string. Experiments showed that noodles obtained from yellow peas are possible to use as novel staple food with the glycaemic control function, but the physical properties must be advanced (Yoshimoto *et al*., 2020).

In scientific literature, the main research data is available regarding to soy protein isolate extrusion at ~56.00% moisture using twin screw extruder or yellow pea protein isolate/concentrate at moisture content in range 66.00-70.00% using co-rotating twin screw extruder or both combinations at moisture content 50.00-70.00% (Ferawati *et al*., 2021; Maung & Ryu, 2020; Wittek, Karbstein, & Emin, 2021).

Conclusions

Pulse flour is practically not used in the high-moisture food extrusion. Peas and beans protein powders and isolates are most often used as raw materials due to their protein content more than 60% and hydrophilic nature.

Raw navy beans, black beans, small red beans can be used in high-moisture extrusion; they had lower bulk density comparing with other bean samples. Significantly higher oil absorption capacity (OAC) had raw black bean flour comparing with other bean samples. Data in literature shows that pulses with higher OAC contain more available non-polar side chains in their protein molecules.

Roasting and germination reduce foaming capacity in yellow pea flour. Boling and roasting reduce foaming stability in grey pea flour. Water absorption capacity and emulsion activity can be increased by germination, it can be used as pre-treatment method before extrusion process to solve problems with end-product palatability and hardness.

Results from experiments with yellow peas flour high-moisture extrusion with 50% moisture content using twin screw extruder seem promising in pasta obtaining.

Further research is needed to clarify the possibilities of peas and beans flour blend in high moisture extrusion.

Acknowledgement

This study was carried out in the framework of the project ‘Legumes as alternative for extruded pasta obtaining’ funded and implemented by the program ‘Strengthening of scientific capacity at LLU’.

References

Akdogan, H. (1999). Review High Moisture Food Extrusion. *International Journal of Food Science and Technology* 34:195–207.

Alonso, R., Orúe, E., & Marzo, F. (1998). Effects of Extrusion and Conventional Processing Methods on Protein and Antinutritional Factor Contents in Pea Seeds. *Food Chemistry* 63(4):505–12. DOI: 10.1016/S0308-8146(98)00037-5.

A European Strategy for the Promotion of Protein Crops – Tuesday, (17 April 2018). *Strasbourg*. Retrieved March 7, 2022, from https://www.europarl.europa.eu/doceo/document/TA-8-2018-0095_EN.html.

Beitane, I., & Krumina-Zemture, G. (2017). Dietary micronutrient content in pea (*Pisum Sativum* L.) and buckwheat (*Fagopyrum Esculentum* M.) flour. In E. Straumite (Ed.), 11th Baltic Conference on Food Science and Technology ‘Food science and technology in a changing world’ (Vol. 700, pp. 56–60). DOI: 10.22616/foodbalt.2017.007.

Berrios, J., De J., Ascheri, J.L.R., & Losso, J.N. (2012). Extrusion Processing of Dry Beans and Pulses. pp. 185–203 in *Dry Beans and Pulses Production, Processing and Nutrition*. John Wiley & Sons, Ltd.

Brummer, Y., Kaviani, M., & Tosh, S.M. (2015). Structural and Functional Characteristics of Dietary Fibre in Beans, Lentils, Peas and Chickpeas. *Food Research International* 67:117–25. DOI: 10.1016/J.FOODRES.2014.11.009.

Calles, T., Xipsiti M., & del Castello, R. (2019). Legacy of the International Year of Pulses. *Environmental Earth Sciences* 78(5):1–8. DOI: 10.1007/s12665-019-8106-6.

Caproni, L., Raggi, L., Talsma, E.F., Wenzl, P., & Negri, V. (2020). European Landrace Diversity for Common Bean Biofortification: A Genome-Wide Association Study. *Scientific Reports* 10(1):1–13. DOI: 10.1038/s41598-020-76417-3.

Cornet, S.H.V., Snel, S.J.E., Schreuders, F.K.G., van der Sman, R.G.M., Beyrer, M., & van der Goot, A.J. (2021). Thermo-Mechanical Processing of Plant Proteins Using Shear Cell and High-Moisture Extrusion Cooking. *Critical Reviews in Food Science and Nutrition*. DOI: 10.1080/10408398.2020.1864618.

Cotacallapa-Sucapuca, M., Vega, E.N., Maieves, H.A., José, De J., Berrios, J., De J., Morales, P., Fernández-Ruiz, V., & Cámara, M. (2021). Extrusion Process as an Alternative to Improve Pulses Products Consumption. A Review. *Foods* 10(5):1096. DOI: 10.3390/FOODS10051096.

Da Silva Fialho, L., Guimarães, V.M., De Barros, E.G., Moreira, M.A., Dos Santos Dias, L.A., De Almeida Oliveira, M.G., José, I.C., & De Rezende, S.T. (2006). Biochemical composition and indigestible oligosaccharides in Phaseolus vulgaris L. seeds. *Plant Foods for Human Nutrition.* 61(2), 87–89. DOI: 10.1007/S11130-006-0019-3.

Dahl, W.J., Foster, L.M., & Tyler, R.T. (2012). Review of the Health Benefits of Peas (*Pisum Sativum* L.). *British Journal of Nutrition* 108(S1):S3–10. DOI: 10.1017/S0007114512000852.

Djoullah, A., Djemaoune, Y., Husson, F., & Saurel, R. (2015). Native-State Pea Albumin and Globulin Behavior upon Transglutaminase Treatment. *Process Biochemistry* 50(8):1284–92. DOI: 10.1016/J.PROCBIO.2015.04.021.

Du, S., Jiang, H., Yu, X., & Jane, J.lin. (2014). Physicochemical and functional properties of whole legume flour. *LWT – Food Science and Technology*. 55(1), 308–313. DOI: 10.1016/J.LWT.2013.06.001.

FAO/WHO. 1991. *FAO/WHO.* (1991). *Protein Quality Evaluation. Report of the Joint FAO/WHO Expert Consultation. Food and Nutrition Paper No. 51.*

Ferawati, F., Hefni, M., & Witthöft, C. (2019). The development of novel foods from Swedish pulses. *Food Science & Nutrition*. 7(12), 4116–4126. DOI: 10.1002/fsn3.1280.

Ferawati, F., Zahari, I., Barman, M., Hefni, M., Ahlström, C., Witthöft, C., & Östbring, K. (2021). High-Moisture Meat Analogues Produced from Yellow Pea and Faba Bean Protein Isolates/Concentrate: Effect of Raw Material Composition and Extrusion Parameters on Texture Properties. *Foods.* 10(4), 843. DOI: 10.3390/foods10040843.

Harmankaya, M., Musa Özcan, M., Karadaş, S., & Ceyhan, E. (2010). Protein and mineral contents of pea (Pisum sativum L.) genotypes grown in Central Anatolian region of Turkey. *South Western Journal*. 1(2), 159–165. E-Issn: 2068–7958.

Hayat, I., Ahmad, A., Masud, T., Ahmed, A., & Bashir, S. (2014). Nutritional and Health Perspectives of Beans (Phaseolus vulgaris L.): An Overview. *Critical Reviews in Food Science and Nutrition*. 54(5), 580–592. DOI: 10.1080/10408398.2011.

Kołodziejczak, K., Onopiuk, A., Szpicer, A., & Poltorak, A. (2022). Meat Analogues in the Perspective of Recent Scientific Research: A Review. *Foods*. 11(1), 105. DOI: 10.3390/foods11010105.

Krumina-Zemture, G., Beitane, I., & Gramatina, I. (2016). Amino acid and dietary fibre content of pea and buckwheat flours. In *Research for Rural Development*, 18-20 May 2016 (pp. 84–90). Jelgava, Latvia University of Agriculture.

Kumar, Y., Basu, S., Goswami D., Devi, M., Uma, S.S., & Vishwakarma, R.K. (2021). Anti-nutritional compounds in pulses: Implications and alleviation methods. *Legume Science.* e111. DOI: 10.1002/leg3.111.

Los, F.G.B., Zielinski, A.A.F., Wojeicchowski, J.P., Nogueiera, A., & Demiate, I.M. (2018). Beans (*Phaseolus vulgaris* L.): whole seeds with complex chemical composition. *Current Opinion in Food Science.* 19, 63–71. DOI: 10.1016/j.cofs.2018.01.010.

Madrera, R.R., Negrillo, A.C., Valles, B.S., & Fernández, J.J.F. (2021). Phenolic Content and Antioxidant Activity in Seeds of Common Bean (*Phaseolus vulgaris* L.). *Foods.* 10(4), 864. DOI: 10.3390/foods10040864.

Maninder, K., Sandhu, K.S., & Singh, N. (2007). Comparative study of the functional, thermal and pasting properties of flours from different field pea (*Pisum sativum* L.) and pigeon pea (*Cajanus cajan* L.) cultivars. *Food Chemistry.* 104(1), 259–267. DOI: 10.1016/j.foodchem.2006.11.037.

Maung, T.T., & Ryu, G.H. (2020). Asian Perspective on High-Moisture Extrusion. *Cereal Foods World.* 65(4). DOI: 10.1094/cfw-65-4-0039.

Mohammed, Y.A., Chen, C., Walia, M.K., Torrion, J.A., McVay, K., Lamb, P., Miller, P., Eckhoff, J., Miller, J., & Khan, Q. (2018). Dry pea (*Pisum sativum* L.) protein, starch, and ash concentrations as affected by cultivar and environment. *Canadian Journal of Plant Science.* 98(5), 1188–1198. DOI: 10.1139/cjps-2017-0338.

Nosworthy, M.G., Neufeld, J., Frohlich, P., Young, G., Malcolmson, L., & House, J.D. (2017). Determination of the protein quality of cooked Canadian pulses. *Food Science & Nutrition*. 5(4), 896–903. DOI: 10.1002/fsn3.473.

Pasqualone, A., Costantini, M., Coldea, T.E., & Summo, C. (2020). Use of Legumes in Extrusion Cooking: A Review. *Foods.* 9(7), 958. DOI: 10.3390/foods9070958.

Ramireddy, L., & Radhakrishnan, M. (2021). Cold plasma applications on pulse processing. In Tiwari, B.K., Gowen, A., & Mc Kenna B. (Eds.), Pulse Foods: Processing, Quality and Nutraceutical Applications, Second Edition (pp. 295–307). London, Elsevier.

Rawal, V., Charrondiere, R., Xipsiti, M., & Grande, F. (2019). Pulses: Nutritional Benefits and Consumption Patterns. In Rawal, V. & Navarro D.K. (Eds.), The Global Economy of Pulses. pp. 9–19. Rome:FAO.

Santos, C.S., Carbas, B., Castanho, A., Vasconcelos, M.W., Vaz Patto, M.C., Domoney, C., & Brites, C. (2019). Variation in Pea (*Pisum sativum* L.) Seed Quality Traits Defined by Physicochemical Functional Properties. *Foods*. 8(11), 570. DOI: 10.3390/foods8110570.

Schäfer, G., Schenk, U., Ritzel, U., Ramadori, G., & Leonhardt, U. (2003). Comparison of the effects of dried peas with those of potatoes in mixed meals on postprandial glucose and insulin concentrations in patients with type 2 diabetes. *The American Journal of Clinical Nutrition*. 78(1), 99–103. DOI: 10.1093/ajcn/78.1.99.

Sterna, V., Zute, S., Jansone, I., Ence, E., & Strausa, E. (2020). Evaluation of various legume species and varieties grown in Latvia as a raw material of plant-based protein products. *Agronomy Research*. 18(4), 2602–2612. DOI: 10.15159/ar.20.215.

Strauta, L., Muizniece-Brasava, S., Alsina, I., & Rakcejeva, T. (2014). Extruded Bean Product Quality Evaluation. In 9th Baltic Conference on Food Science and Technology 'Food for Consumer Well-Being', 8-9 May 2014. (pp. 144–149). Jelgava Latvia: Latvia University of Agriculture Faculty of Food Technology. ISSN 2255-9817.

Tosh, S.M., Farnworth, E.R., Brummer, Y., Duncan, A.M., Wright, A.J., Boye, J.I., Marcotte, M., & Benali, M. (2013). Nutritional Profile and Carbohydrate Characterization of Spray-Dried Lentil, Pea and Chickpea Ingredients. *Foods*. 2(3), 338. DOI: 10.3390/foods2030338.

Wittek, P., Karbstein, H.P., & Emin, M.A. (2021). Blending Proteins in High Moisture Extrusion to Design Meat Analogues: Rheological Properties, Morphology Development and Product Properties. *Foods.* 10(7), 1509. DOI: 10.3390/foods10071509.

Yoshimoto, J., Kato, Y., Ban, M., Kishi, M., Horie, H., Yamada, C., & Nishizaki, Y. (2020). Palatable noodles as a functional staple food made exclusively from yellow peas suppressed rapid postprandial glucose increase. *Nutrients.* 12(6), 1–13. DOI: 10.3390/nu12061839.

Zhang, J., Liu, L., Liu, H., Yoon, A., Rizvi, S.S.H., & Wang, Q. (2019). Changes in conformation and quality of vegetable protein during texturization process by extrusion. *Critical Reviews in Food Science and Nutrition.* 59(20), 3267–3280. DOI: 10.1080/10408398.2018.1487383.

Zhang, Z., Zhang, L., He, S., Li, X., Jin, R., Liu, Q., Chen, S., & Sun, H. (2022). High-moisture Extrusion Technology Application in the Processing of Textured Plant Protein Meat Analogues: A Review. *Food Reviews International.* 1–36. DOI: 10.1080/87559129.2021.2024223.

OLIGOSACCHARIDES IN HUMAN MILK, ACHIEVEMENTS IN ANALYSIS: A REVIEW

***Alina Belusko, Liva Aumeistere, Inga Ciprovica**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding authors email: alinapolipartova@gmail.com

Abstract
Human milk oligosaccharides (HMOs) comprise about 20% of the total carbohydrates of human milk. There is currently a growing interest in HMOs as many researchers have recognized the importance of their benefits to infant health. Accumulated evidence suggests that HMOs are anti-adhesive antimicrobials that serve as soluble bait receptors, prevent pathogens from attaching to infant mucous membranes, and reduce the risk of viral, bacterial, and protozoan parasites. It also provides functionality including anti-adhesion and immunomodulators. Even though the composition of human milk in Latvia has been studied in detail, there are no studies on oligosaccharides in human milk. The aim of the study is to find out recent advances in the analysis of HMOs. Semi-systematic method was used to analyze the latest information about the recent advances in the analysis of HMOs by liquid phase separation methods, to investigate any known associations between HMOs composition and maternal nutrition and nutritional factors during lactation and the effect of HMOs on the infant's development and health. The analysis of HMOs is considered very complex because of heterogeneity and different isomeric/anomeric structures of compounds. The proposed methods for analysing HMOs are largely based on liquid chromatography.
Key words: human milk, oligosaccharides, analysis, infant's development.

Introduction

Human milk is recognized as an ideal and unique nutrient base for infants (Ballard & Morrow, 2013). Human milk contains a lot of biologically active compounds such as nucleotides, vitamins, proteins including immunoglobulins, oligosaccharides, and minerals. It was recognized as the first functional food in the life of an infant (Aly *et al*., 2018).

Human milk oligosaccharides (HMOs) comprise about 20% of total carbohydrates, being the third largest solid component presented in human milk at concentrations greater than 20 g L^{-1} (Urashima, Asakuma, & Leo, 2012). A wide variety of oligosaccharides is synthesized in the mammary gland under the influence of specific glycosyltransferases, which sequentially attach N-acetylglucosamine, galactose, fucose, and N-acetylneuramic acid to the main acceptor molecule − lactose (Thurl *et al*., 2017). HMOs consist of a complex mixture of more than 200 non-food and non-digestible carbohydrates (Porfirio *et al*., 2020), varies in size from 3 –22 monosaccharide units, in most cases containing fucose, N-acetylglucosamine (GlcNAc), galactose, sialic acid and glucose. All HMOs have a reducing lactose moiety that can be extended by various numbers of lacto-N-biose (Galβ1,3GlcNAc, LacNAc) or N-acetyllactosamine (Galβ1,4GlcNAc, LacNAc) motifs. Branched HMOs are formed by the action of N-acetyllactosaminide β1,6-N-acetylglucosaminyltransferase (GCNT2), which installs a β1,6-linked N-acetyl-glucosamine (GlcNAc) at an internal galactosyl moiety that can be further extended by structures (Prudden *et al*., 2017). Even though the composition of human milk varies from person to person, HMOs is recognized as one of the most important nutritional components that affects the growth and development of the infant (Thurl *et al*., 2017). In the middle of the twentieth century increased interest in HMOs, the importance of HMOs potential benefits to infant health was recognized (Bode, 2012). HMOs have a wide range of activity, preventing pathogenic organisms from contacting the intestinal epithelium and using them as nutrients in selected beneficial bacteria of the same class (Wu *et al*., 2011). Prebiotic activity of HMOs can be observed in various studies, they reveal that HMOs work on bifidogenic molecules, thereby improving the growth of bifidoflora. In addition, prebiotic contributes functionality including anti-adhesion and immunomodulatory (Euler *et al*., 2005). Research by Smilowitz *et al.* (2014) suggests on how other factors interact with each other with the composition of the HMOs, including mode of delivery parity, environmental factors such as seasonality and geographical location, and maternal factors as dietary quality and age. Nursing mothers' health conditions (obesity, malnutrition or hyperglycemia) have a significant effect on HMOs production and structural diversity (Smilowitz *et al*., 2014).

The aim of the study is to find out recent advances in the analysis of HMOs.

Materials and Methods

The databases of scientific papers Web of Science and Scopus were examined in order to find out data from the latest achievements related to analyses of human milk oligosaccharides; scientific papers in English were used for review, which were published from 2011 to 2021. The search was based on combining two key terms: human milk oligosaccharides and human milk oligosaccharide analysis. In the review, 42 full text articles were collected. When searching

for their menologies, the author used a wide range of synonyms to search for the corresponding literature. Semi-systematic method was used in the study.

Results and Discussion

According to statistics, for about 20% of children under six months of age, human milk is the only source of nutrients (Slimību profilakses un …, 2020), its diverse nutrient composition promotes protection against pathogenic bacteria or viruses (El-Hawiet, Kitova, & Klassen, 2015), prevents intestinal inflammation, and constructive modulation of immune system response in infant development (He, Lawlor, & Newburg 2016).

HMOs bioactive factors

During lactation, the composition and amount of HMOs in women varies. It is recognized that the concentration of HMOs in the first lactation stage is higher and gradually begins to decrease during the first trimester of lactation. HMOs are recognized as one of the most important bioactive factors that change the outgrowth of genes in immune cells as microbiota modifiers or immune modulators in the gastrointestinal tract work as prebiotics and counting this affects the immune potential of infants (Ray *et al*., 2019). HMOs are resistant to low stomach pH and pancreatic brush enzymes (Bode, 2012). Therefore, they penetrate the colons, and they are substrates of bacterial metabolism. An important role is played by the defense mechanism, thanks to which HMOs divert gastrointestinal infections, being the bait receptor. The gastrointestinal tract is a functional barrier that diverts pathogenic invasion that provides elements of active lymphoid cell lines, which is the main value for infant immunity (Morozov *et al*., 2018). Derivatives from HMOs work as a binding for cells, for example for Dendritic Cell-Specific Intercellular adhesion molecule-3-Grabbing Non-integrin (DC-SIGN), respectively, they block reactions between viruses or pathogens as well as their receptors, they work as a bait for receptors. Scientific work has shown that HMOs, or rather their branched chains, block viral infections (Gao *et al*., 2020).

Breastfeeding as a source of early life nutrients and especially non-digestible HMOs among the various bioactive components of human milk are considered critical for healthy microbial colonization of infants, fine-tuning of inflammatory processes, and immune defense and maturation in the early years of life (Ayechu-Muruzabal, Stigt, & Mank, 2018). Many diseases with infectious and immune components in their etiology, including diarrhea, respiratory and urinary tract infections, otitis media, bacteremia, and necrotizing enterocolitis occur less often in breast-than formula-fed infants (Donovan & Comstock, 2016).

Relationship between the mother's diet and the HMOs

Studies show that the mother's breast activation diet alters milk components, they are involved in structuring the gut microbiome, potentially affecting the state of metabolism throughout life (Horta & Mola, 2015). Few scientists have investigated the effects of maternal diet on the bioactive components of HMOs (Maxim *et al*., 2020). HMOs and the milk microbiome are particularly interesting components, because they are associated with changes in the microchip microbiome of newborns and older children (Pannaraj, 2017).

As a result of studies of human milk of different populations during lactation, it turned out that several HMOs are reduced during breastfeeding over time and synthesized oligosaccharides differ in different nursing women (Samuel *et al*., 2019). Studies show significantly different concentrations of HMOs in the milk of exclusively breast infants with excessive weight gain (Larsson *et al*., 2019).

Quin *et al.* (2020) in their work analyzed studies on dietary nutrition during the breastfeeding period, which is insufficient basis, to assess the quality of nutrition. Their work focused only on dietary components, but as a result, it turned out that there was a relationship between diet (total sugar, dietary fiber) and fucose/galactose in HMOs. Their assumption that maternal nutrition is important for HMOs biosynthesis is most likely correct, since the biosynthesis pathway is initiated from activated monosaccharides (Quin *et al.*, 2020). These findings may be pointed out in the most recent work by Seferovic *et al.* (2020), which found that changes in maternal nutrition, mainly, replacement of carbohydrate sources, leads to changes in some major components of HMOs. And all this happens in a short time (Seferovic *et al*., 2020). Kristen *et al.* (2017) found in their work that, the milk microbiome is changing if you follow a high fat and carbohydrates diet. High fat content reduces the concentration of sialylated HMOs compared to galactose, glucose significantly alters the concentration of fucosylated HMOs. Interestingly, as it turned out, the concentration of sialylated HMOs has a relationship with the composition of the microbiome. Presumably, these HMOs play a major role in structuring the milk microbiome (Kristen *et al*., 2017).

Probiotic supplements consumed in the last stages of pregnancy have been found to alter the relative composition of HMOs, probably in the formation of the maternal gut microbiome (Seppo *et al*., 2019). It is likely that this, in turn, forms the milk microbiome (through the entero-mammalian pathway) and successively a common dairy environment of which HMO is a part (Moossavi *et al*., 2019). High fiber diets can also be used, where foods such as fruits and whole grains are consumed. This will be a high fiber diet, which is also a mechanism for the formation of

the maternal microbiome. In the works of Azad *et al.* (2018) and Quin *et al.* (2020) there was evidence of a connection between the composition of HMOs and the nutritional composition, and, possibly, the education system is the relationship between the maternal diet, the intestinal microbiome, the milk microbiome and the composition of HMOs in it.

Analytical methods for HMOs analysis

Human milk research began in the early 1900s (Bode, 2012), and various approaches to HMOs analysis have been developed. Elucidating the structures of these oligosaccharides are very important in order to detect their biological functions. Research into methods to separate oligosaccharides from human milk samples is still ongoing. The great heterogeneity and complexity of their monosaccharide compositions and bonds is one reason, which complicates their study. The low concentration of HMOs in the presence of high levels of lactose further exacerbates this problem. In addition, oligosaccharides do not have chromophores or fluorophores, which also prevents their optical detection (Auer, Jarvas, & Guttman, 2021).

Sample Preparation – Methods

Prior to starting the analysis, HMOs need to be isolated from other components that are found in human milk, such as lipid, protein and lactose (Balogh, Jankovics, & Beni, 2015). Currently, methods for preparing HMOs samples comprise similar steps, typically starting with the removal of lipid and protein. The degreasing step is often carried out by centrifugation or solvent extraction. Protein precipitates tend to complement organic solvents such as ethanol, chloroform/methanol, acetone or acetonitrile (Tonon *et al*., 2019). For quantitative characterization of oligosaccharides and their further structural clarification, for example by mass spectrometer (MS), it is very important to choose an effective separation method. This must be the way, which is suitable for separating many polar and branched isomeric structures.

High Performance Liquid Chromatography (HPLC) Analysis of HMOs

At the moment, a large number of HPLC methods have been identified, which are used for the analysis of HMOs. HPLC can be used with label-free detection modes such as charged aerosol, refractive index, pulsed amperometry, evaporative light scattering and MS. Alas, without the release of HMOs, the most used optical recognition techniques cannot be identified due to their insufficient absorption of ultraviolet (UV) radiation and lack of fluorescent characteristics. In any case, several UV-active labels or fluorescent ones can be detected, which contribute to increased detection sensitivity. The most widely used are 2-aminobenzamide (2-AB), 2-aminoacridone (2-AMAC), 2-aminobenzoic acid (2-AA), perbenzoylation and 1-phenyl-3-methyl-5-pyranosolone (PMP) (Leeuwen, 2019).

Other studies compared centrifugation and ultrafiltration methods in 15 acidic and neutral HMOs using ultra-high performance liquid chromatography (UHPLC) and fluorescence detection assay (FLD) for this (Huang *et al*., 2019). The method of obtaining a sample for this analysis required only dilution, ultrafiltration or centrifugation, and the derivatization processes contributed to high sensitivity. At the time when in ultrafiltration the reduction process of disiailacto-N-tetraose (DSLNT) took less than 50 minutes. The greatest drawback of methods that are based on liquid chromatography (LC) is the need to use oligosaccharide standards to identify structural refinement of retention times due to similar public glycan libraries. Despite this, standards are often not presented in commercial access, if they have been purchased for commercial purposes, they are very expensive (Austin *et al*., 2018).

HMOs analysis by capillary electrophoresis

In addition to chromatography methods, capillary electrophoresis (CE) is also often used as a strong glycoanalytic tool due to low sample volume requirements, reduced buffer use, high and fast. CE provides several separation modes that are easy to change during operation. In working with CE, derivatization is needed primarily for uncharged carbohydrates in order to provide them with the necessary electromigration (Sarkozy *et al*., 2020). A team of scientists led by Volpi developed a CE method with conventional 254 nm UV detection to identify HMOs standards and human milk oligosaccharides derived from mothers (Galeotti *et al*., 2014). They applied simple steps of pretreating and derivatizing oligosaccharides with a 2- aminoacridone (AMAC), uncharged and hydrophobic fluorescent label. After removal, the labeled oligosaccharides were separated into a borate buffer containing 20% methanol. This CE approach was able to separate basic neutral and acidic oligosaccharides from human milk in the presence of lactose and other high concentration impurities such as excess fluorophores, proteins and salts (Auer, Jarvas, & Guttman, 2021).

Mass spectrometry (MS) HMOs separation methods (related to liquid phase)

MS is often used in the field of glycan analysis and is also successfully used to analyze milk oligosaccharides for structural characteristics. Electrospray ionization (ESI) and matrix laser desorption/ionization (MALDI) are widely used soft ionization modes for the analysis of sugars based on MS. During MALDI ionization, the sample is mixed or coated with an energy-absorbing standard carbohydrate separation matrix and ionized with a laser beam. This method generates single protonated

ions from assays (Lai & Wang, 2017). In contrast, ESI genifies multicharged ions by using an electric field to transform the phase assays of solutions in gas phase ions (Zhong *et al*., 2017). A commonly used method is the permethylation of glycan derivatization, which is used to detect multiple sclerosis, since it contributes to the enhancement and improvement of ionization and makes labile sialic acids stable. During the MS analysis period, reinstallation helps to eliminate fucose overheating and guarantee the diagnosis of fragment ions (Zhou *et al*., 2017). MS associated with chromatographic or electromigratic separation techniques facilitates structural.

The use of biosynthetic routes to generate HMOs has not yet been fully resolved, but complex bioanalytic methods can bring us closer to doing this work (Auer, Jarvas, & Guttman, 2021).

Conclusions

Human milk is the first functional food in an infant life. Human milk oligosaccharides account for about 20% of total carbohydrates, and it is the third largest solid component in human milk. HMOs helps to develop many beneficial properties in the infant body. As prebiotics, they are considered metabolic substrates for beneficial bacteria, which gives them an advantage in growth, when compared with pathogens. As anti-plaque antimicrobials, they act as soluble bait of glycan receptors that help prevent contact with pathogens and the intestinal mucosa.

All the time, the tested data indicate how the HMOs has a beneficial effect on breastfeeding, the formation of the intestinal flora, the modulation of immune responses and the protection of the infant body from infections and diseases. These positive properties directly depend on the structure of the HMOs, which allows us to conclude, that a comprehensive approach to data synthesis is very important for understanding the situation. In turn, the analysis of HMOs is considered very complex that heterogeneity and different isomeric/anomeric structures. The lack of simply chromophore/fluorophore or ionizable oligosaccharide groups that make the analysis difficult to achieve. The proposed methods for analysing HMOs are largely based on liquid chromatography. In addition, a wide range of HPLC methods have been identified, they are often performed to identify the composition of HMOs. HPLC is used in the case of detection, for example as refractive index or light scattering − charged aerosol, pulsed MS and amperometry. Alas, without the release of HMOs, the most common optical detection analyses used are not visible due to insufficient absorption of ultraviolet radiation and lack of fluorescent characteristics.

References

Aly, E., Darwish, A., Lopez-Nicolas, R., Frontela-Saseta, C., & Ros-Berruezo, G. (2018). Bioactive Components of Human Milk: Similarities and Differences between Human Milk and Infant Formula, *Selected Topics in Breastfeeding*. DOI: 10.5772/intechopen.73074.

Auer, F., Jarvas, G., & Guttman, A. (2021). Recent advances in the analysis of human milk oligosaccharides by liquid phase separation methods. Elsevier. 1162. DOI: 10.1016/j.jchromb.2020.122497.

Austin, S., Cuany, D., Michaud, J., Diehl, B., & Casado, B. (2018). Determination of 2'-Fucosyllactose and Lacto-N-neotetraose in Infant Formula Molecules, 23. DOI: 10.3390/molecules23102650.

Ayechu-Muruzabal, V., Stigt, A.H., & Mank, M. (2018). Diversity of human milk oligosaccharides and effects on early life immune development. Front Pediatr. 6:239. DOI: 10.3389/fped.2018.00239.

Azad, M.B., Robertson, B., Atakora, F., Becker, A.B., Subbarao, P., Moraes, T.J., Mandhane, P.J., Turvey, S.E., Lefebvre, D.L., Sears, M.R., Bode L. (2018). Human Milk Oligosaccharide Concentrations Are Associated with Multiple Fixed and Modifiable Maternal Characteristics, Environmental Factors, and Feeding Practices. J. Nutr. 148:1733–1742. DOI: 10.1093/jn/nxy175.

Ballard, O., & Morrow, A.L. (2013). Human milk composition: Nutrients and bioactive factors. Pediatric Clinics of North America, 60 (1), 49−74. DOI: 10.1016/j.pcl.2012.10.002

Balogh, L., Jankovics, P., & Beni, S. (2015). Qualitative and quantitative analysis of N-acetyllactosamine and lacto-N-biose, the two major building blocks of human milk oligosaccharides in human milk samples by high-performance liquid chromatography-tandem mass spectrometry using a porous graphitic carbon column J. Chromatogr. A, 1422 140−146. DOI: 10.1016/j.chroma.2015.10.006.

Bode, L. (2012). Human milk oligosaccharides: every baby needs a sugar mama *Glycobiology*, 22(9), 1147–1162. DOI: 10.1093/glycob/cws074.

Donovan, S.M., & Comstock, S.S. (2016). Human milk oligosaccharides influence neonatal mucosal and systemic immunity. Ann Nutr Metab. 69:42–51. DOI: 10.1159/000452818.

El-Hawiet, A., Kitova, N.E., & Klassen, J.S. (2015). Recognition of human milk oligosaccharides by bacterial exotoxins. Glycobiology. 25(8):845–54. DOI: 10.1093/glycob/cwv025.

Euler, A., Mitchell, D., Kline, R., & Pickering, L. (2005). Prebiotic effect of fructooligosaccharide supplemented term infant formula at two concentrations compared with un-supplemented formula and human milk.

Journal of Pediatric Gastroenterology and Nutrition. 40:157−164. DOI: 10.1097/00005176-200502000-00014.

Galeotti, F., Coppa, G.V., Zampini, L., Maccari, F., Galeazzi, T., Padella, L., Santoro, L., Gabrielli, O., & Volpi, N. (2014). Capillary electrophoresis separation of human milk neutral and acidic oligosaccharides derivatized with 2-aminoacridone. Electrophoresis, 35. 811−818. DOI: 10.1002/elps.201300490.

Gao, X., Wu, D., Wen, Y., Gao, L., Liu, D., & Zhong, R. (2020). Antiviral effects of human milk oligosaccharides: A review. *International Dairy Journal*, 104784. DOI: 10.1016/j.idairyj.2020.104784.

He, Y., Lawlor, N.T., & Newburg, D.S. (2016). Human milk components modulate toll-like receptor-mediated inflammation. Adv Nutr. 7(1):102–11. DOI: 10.3945/an.115.010090.

Horta, B.L., & Mola, L. (2015). Long-term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure, and type-2 diabetes: Systematic review and meta-analysis. Acta Paediatrics 104, 30–7. DOI: 10.1111/apa.13133.

Huang, X., Zhu, B., Jiang, T., Yang, C., Qiao, W., Hou, J., Han, Y., Xiao, H., & Chen, L. (2019). Improved simple sample pretreatment method for quantitation of major human milk oligosaccharides using ultrahigh pressure liquid chromatography with fluorescence detection. *J. Agric. Food Chem*., 67. 12237−12244. DOI: 10.1021/acs.jafc.9b03445.

Kristen, M., Mahmoud, M., Bode, L., Derrick, M., Ma, J., Haymond, M., & Aagaard, K. (2017). Maternal diet structures the breast milk microbiome in association with human milk oligosaccharides and gut-associated bacteria. *Basic science. Oral concurrent Session 2.*

Lai, Y.H., & Wang, Y.S. (2017). Matrix-assisted laser desorption/ionization mass spectrometry: mechanistic studies and methods for improving the structural identification of carbohydrates Mass spectrometry *Tokyo, Japan* 6. S0072.

Larsson, M.W., Lind, M.V., Laursen, R.P., Yonemitsu, C., Larnkjær, A., Mølgaard, C., Michaelsen, K.F., & Bode, L. (2019). Human Milk Oligosaccharide Composition Is Associated with Excessive Weight Gain During Exclusive Breastfeeding − An Explorative Study. Front. Pediatr. 7:297. DOI: 10.3389/fped.2019.00297.

Leeuwen, S.S. (2019). Challenges and pitfalls in human milk oligosaccharide analysis Nutrients, 11. DOI: 10.3390/nu11112684.

Maxim, D., Mahmoud, M., Ryan, M., Melinda, E., Versalovic, J., Bode, L., Morey, H., & Kjersti, M. (2020). Maternal diet alters human milk oligosaccharide composition with implications for the milk metagenome. Scientific Reports. 22092. DOI: 10.1038/s41598-020-79022-6.

Moossavi, S., Sepehri, S., Robertson, B., Bode, L., Goruk, S., Field, C.J., Lix, L.M., de Souza, R.J., Becker, A.B., & Mandhane, P.J. (2019). Composition and Variation of the Human Milk Microbiota Are Influenced by Maternal and Early-Life Factors. Cell Host Microbe. 25:324–335. DOI: 10.1016/j.chom.2019.01.011.

Morozov, V., Hansman, G., Hanisch, F.G., Schroten, H., & Kunz, C. (2018). Human milk oligosaccharides as promising antivirals Molecular Nutrition & Food Research, 62. 1700679. DOI: 10.1002/mnfr.201700679.

Pannaraj, P.S. (2017). Association between breast milk bacterial communities and establishment and development of the infant gut microbiome. JAMA Pediatr. 171, 647–654. DOI: 10.1001/jamapediatrics.2017.0378.

Porfirio, S., Archer-Hartmann, S., Moreau, G.B., Ramakrishnan, G., Haque, R., Kirkpatrick, B.D., Petri, P.W.A., & Azadi (2020). New strategies for profiling and characterization of human milk oligosaccharides Glycobiology, 30 (10), 774−786. DOI: 10.1093/glycob/cwaa028.

Prudden, A.R., Liu, L., Capicciotti, C.J., Wolfert, M.A., Wang, S., Gao, Z., Meng, L., Moremen, K.W., & Boons, G.J. (2017). Synthesis of asymmetrical multiantennary human milk oligosaccharides Proceedings of the National Academy of Sciences of the United States of America, 114 (27), 6954−6959. DOI: 10.1073/pnas.1701785114.

Quin, C., Vicaretti, S.D., Mohtarudin, N.A., Garner, A.M., Vollman, D.M., Gibson, D.L., & Zandberg, W.F. (2020). Influence of sulfonated and diet-derived human milk oligosaccharides on the infant microbiome and immune markers. Biol Chem. 295:4035–4048. DOI: 10.1074/jbc.RA119.011351.

Ray, C., Kerketta, J.A., Rao, S., Patel, S., & Dutt, S. (2019). Human milk oligosaccharides: The journey ahead *International Journal of Pediatrics*, 2390240. DOI: 10.1155/2019/2390240.

Samuel, T.M., Binia, A., de Castro, C.A., Thakkar, S.K., Billeaud, C., Agosti, M., Al-Jashi, I., Costeira, M.J., Marchini, G., & Martinez-Costa, C. (2019). Impact of maternal characteristics on human milk oligosaccharide composition over the first 4 months of lactation in a cohort of healthy European mothers. Sci Rep. 9:1–10.

Sarkozy, D., Borza, B., Domokos, A., Varadi, E., Szigeti, M., Meszaros-Matwiejuk, A., Molnar-Gabor, D., & Guttman, A. (2020). Ultrafast high-resolution analysis of human milk oligosaccharides by multicapillary gel electrophoresis. Food Chem., 341, 128200. DOI: 10.1016/j.foodchem.2020.128200.

Seferovic, M.D., Mohammad, M., Pace, R.M., Engevik, M., Versalovic, J., Bode, L., Haymond, M., & Aagaard, K.M. (2020). Maternal diet alters human milk oligosaccharide composition with implications for the milk metagenome. Sci. Rep.10:1–18. DOI: 10.1038/s41598-020-79022-6.

Seppo, A.E., Kukkonen, A.K., Kuitunen, M., Savilahti, E., Yonemitsu, C., Bode, L., & Järvinen, K.M. (2019). Association of Maternal Probiotic Supplementation with Human Milk Oligosaccharide Composition. JAMA Pediatr. 173:286–288. DOI: 10.1001/jamapediatrics.2018.4835.

Slimību profilakses un kontroles centrs. (Breastfeeding statistics data in Latvia since). (2000). Retrieved March 9, 2022, from https://statistika.spkc.gov.lv/pxweb/lv/Health/Health__Mates_berna_veseliba/MCH100_kruts_barosana.px/table/tableViewLayout2/. (in Latvian).

Smilowitz, J.T., Lebrilla, D.A., Mills, C.B., German, J.B., & Freeman, S.L. (2014). Breast milk oligosaccharides: Structure-function relationships in the neonate Annual Review of Nutrition, 34, 143−169. DOI: 10.1146/annurev-nutr-071813-105721.

Thurl, S., Munzert, M., Boehm, G., Matthews, C., & Stahl, B. (2017). Systematic review of the concentrations of oligosaccharides in human milk. Nutr Rev. 75(11):920–33. DOI: 10.1093/nutrit/nux044.

Tonon, K.M., Miranda, A., Abrao, A., de Morais, M.B., & Morais, T.B. (2019). Validation and application of a method for the simultaneous absolute quantification of 16 neutral and acidic human milk oligosaccharides by graphitized carbon liquid chromatography − electrospray ionization − mass spectrometry Food Chem. 274, 691−697. DOI: 10.1016/j.foodchem.2018.09.036.

Urashima, T., Asakuma, S., & Leo, F. (2012). The predominance of type I oligosaccharides is a feature specific to human breast milk. Adv Nutr, 3:473S–482S. DOI: 10.3945/an.111.001412.

Wu, S., Grimm, R., German, J.B., & Lebrilla, C.B. (2011). Annotation and structural analysis of sialylated human milk oligosaccharides. *Journal of Proteome Research*. 10:856−868. DOI: 10.1021/pr101006u.

Zhong, X., Zhang, Z., Jiang, S., & Li, L. (2014). Recent advances in coupling capillary electrophoresis-based separation techniques to ESI and MALDI-MS. Electrophoresis, 35. 1214−1225. DOI: 10.1002/elps.201300451.

Zhou, S., Dong, X., Veillon, L., Huang, Y., & Mechref, Y. (2017). LC-MS/MS analysis of permethylated N-glycans facilitating isomeric characterization Anal. Bioanal. Chem. 409, 453−466. DOI: 10.1007/s00216-016-9996-8.

 DOI: 10.22616/rrd.28.2022.016

EXTRACTION OF BIOACTIVES FROM PUMPKIN BY-PRODUCTS AND DETERMINATION OF THEIR ANTIOXIDANT ACTIVITY

***Daiga Konrade**, **Kriss Spalvins**
Riga Technical University, Latvia
*Corresponding author's email: daiga.konrade@rtu.lv

Abstract
Agro-industrial and food processing from pumpkins (*Cucurbitaceae*) produces a large number of by-products: bark, pomace, seeds still rich in bioactive compounds, especially carotenoids and green pigments (proto chlorophyll (a and b) and proto pheophytin (a and b)), which exhibit a broad spectrum of health-promoting effects and can be used as ingredients in functional food and cosmetics. For extraction of bioactive compounds from dried pumpkin by-products different methods were used: supercritical CO_2, Soxhlet extraction with n- hexane, ethanol. Vegetable oils (rapeseed, coconut, grapeseed and olive oil) were used as green solvent alternatives to conventional organic solvents for carotenoid extraction. Detection and analyses of chlorophylls and carotenoids was done with hexane/acetone, cyclohexane, ethanol as solvents. The aim of this study was to use pumpkin by-products for extraction of high-value bioactive compounds with different methods, to determine antioxidant´s content and profile – carotenoids (ß-carotene, lutein, lycopene, zeaxanthin), pigments (chlorophylls a, chlorophylls b) with different solvents and to find out what solvent can be used for detection of pigments and carotenoids; to determine antiradical scavenging activity of biologically active compounds in extracts from pumpkin by-products (peel and hulled seeds).
Key words: antiradical activity, carotenoids, chlorophylls, oil, supercritical CO_2.

Introduction

Family of *Cucurbitaceae* is rich in approximately 825 species including 26 species of pumpkins that are grown as vegetables and used for food production (Mala, 2016). 760 000 tonnes of pumpkin were harvested in the EU countries in 2020 (Eurostat, 2021). Production process generates large amount of by-products – seeds, peel, pomace that are rich in bioactive compounds such as – phenolic compounds and their derivatives, provitamins, pigments and carotenoids, pyrazine, squalene, saponins, phytosterols, triterpenoids, unsaturated fatty acids, flavonoids (Černiauskiene *et al*., 2014;coronary heart and other diseases. Dietary fiber (DF Konrade *et al.*, 2016; Fruhwirth *et al*., 2003; Sook *et al*., 2005). Carotenoids in pumpkin are lutein, α- and β-carotene, violaxanthin, neoxanthin and xanthophylls (Soengas *et al*., 2011). Pumpkin seed oil is rich in vitamin E – important antioxidant, including both ɣ-tocopherol and α-tocopherol. Pumpkin seed oil is rich in unsaturated fatty acids, such as linolic acid, oleic acid and saturated as palmitic acid and stearic acid (Konrade *et al*., 2016; Seo *et al*., 2005; Henriques, Guiné, & Barroca, 2012; Secil & Berrin, 2011; Rawson *et al*., 2013).

There is an increasing interest in natural antioxidants from plant origin instead of synthetic antioxidants – carotenoids as their radical scavenging potential is well-documented and their extracts can be used in food, cosmetic, and pharmaceutical industries (Jian *et al*., 2005). Therefore, extraction methods should be observed to obtain the highest recovery and quality (Soengas *et al*., 2011; Salami, Asefi, & Esmaeilzadeh, 2021).

Carotenoid content in dried pumpkin by-products was 91.28 mg 100 g^{-1} (Konrade *et al*., 2019) and ranged from 0.06 to 7.4 mg 100 g^{-1} for β-carotene, from 0 to 7.5 mg 100 g^{-1} for α-carotene and from 0 to 17 mg 100 g^{-1} for lutein (Murkovic & Mu, 2002). Carotenoids are free radical quenchers and liquid antioxidants, they can interact with reactive oxygen species and as singlet oxygen scavengers (Lu & Yeap Foo, 2000). Carotenoids and green pigments, chlorophylls, their derivatives are important health promoters as their role is important in reduction of risks of some types of cancer, diabetes, cardiovascular diseases; they are antimutagenic and with anti-inflammatory activities (Hsu *et al*., 2013; Gebregziabher *et al*., 2021).

Various physical and chemical barriers in the food matrixes can occur during carotenoid extraction; therefore, attention should be paid to methods and solvents polarity (Gebregziabher *et al*., 2021). Edible vegetable oils are used as green solvent alternatives to conventional organic solvents for carotenoid extraction (Borguini *et al*., 2020). Supercritical CO_2 extraction technology has been widely used as an alternative to conventional solvent extraction for the extraction of natural products, because it gives extracts free of organic solvents (Durante, Lenucci, & Mita, 2014).

The aim of this study was to use pumpkin by-products for extraction of high-value bioactive compounds with different methods – supercritical CO_2 ($SCCO_2$), Soxhlet extraction with n- hexane, ethanol and edible oils; to determine antioxidant´s content and profile – carotenoids (ß-carotene, lutein, lycopene, zeaxanthin), pigments (chlorophylls a, chlorophylls b) with different solvents, and antiradical scavenging activity of biologically active compounds in extracts from pumpkin by-products (peel and hulled seeds).

Materials and Methods

Materials

Pumpkin (*Cucurbita pepo* L, Pink Banana Jumbo and *Cucurbita* Moshata, Muscade de Provence) by-products peel and seeds were obtained from Lat Eko Food Ltd. and local farmers in Latvia, 2021.

By-products were washed, peels were ground with a single speed food processor – Robot-Coupe Blixer3, France. Ground peels and hulled seeds were dried with a conventional air dryer Essiccatori professionali B.Master, SR19390 *(*Italy), temperature +40 ℃, 36-48 h to moisture content 5-8%. Afterwords, seeds were ground. Drying, washing and grinding was done at the Institute of Horticulture, Latvia. Dried seed and peel samples were kept in dark plastic boxes in a dark place at temperature 20±2 ℃ till extraction and analyses.

Extraction

1) Supercritical CO_2 extraction of pumpkin by-products was performed with SFE 1000 FANEKS extractor with some modifications (Saini & Keum, 2017). Operating parameters: 252 bar pressure in extractor zone, 60.6-67.4 bar in Separator 1 and Separator 2 zones, CO_2 heater – +33.9 ℃, temperature control in separators 36.6 ℃ and 40.2 ℃, CO_2 flow rate was 8 kg h^{-1}. For extraction of peels, rapeseed oil was added to ground pumpkin by-products (28.4%) to obtain better mass flow in extractor. Seeds of two cultivars (*Cucurbita pepo* L, Pink Banana Jumbo and *Cucurbita* Moshata, Muscade de Provence) were extracted for obtaining the pumpkin seed oil.

2) Soxhlet extraction of pumpkin seeds at 60 ℃ was done with ethanol or hexane to determine the oil content in samples (Mustafa, Trevino, & Turner, 2012)about 25% of the annual production is regarded as by-products due to strict market policies. The aim of this study was to extract carotenoids from those by-products. Conventional carotenoid extraction methods require the use of organic solvents, which are costly, environmentally hazardous, and require expensive disposal procedures. Pressurized liquid extraction (PLE. Dried ground pumpkin seeds (PS) with coat/ hulled were pressed for oil recovery with Oil press Täby Press Type *20* (Sweden) (working conditions – hot single screw extruder type) (Navale, Swami, & Thakor, 2015; Jain, Devi, & Thakur, 2013) banana.

3) Extractions with some modifications with edible vegetable oils – rapeseed, coconut oil, olive oil, grapeseed oil (1:10 (w/v), w – weigh of the sample, v – volume of the oil), were carried out using pumpkin seeds (PS) and peel (PP)): dried and ground samples were sieved (1.2 mm) and extraction was done in a hot water bath at t = 45 ℃±5 ℃ for 60 min, samples were centrifuged at speed 5000 rpm^{-1}, 20 min, temperature +20 ℃ (Sigma 4-16KS*,* Germany) (Seo *et al*., 2005; Fikselová *et al.*, 2008).

Analyses of sample material

Extracted supernatants were analysed for total content of carotenoids (TCC), ß-carotene, lycopene, lutein, zeaxanthin and pigments – chlorophyll a (Chl a) and chlorophyll b (Chl b) and antiradical scavenging activity (AA, %) (DPPH assay) with M501 Single beam Scanning UV/Visible Spectrophotometer (Camspec UV, United Kingdom).

Extracts from by-products were analysed to identify components – pigments and carotenoids with acetone/ hexane (2:3), acetone, cyclohexane and ethanol (Merk, Sigma Aldrich®, Germany) with methods described (Braniša *et al*., 2014*;* Kļava *et al*., 2018; Kampuse & Ozola, 2015; Delia, 2004).

1±0.01g of each sample was separately homogenized with 10 mL of solvent acetone; hexane/ acetone (2:3); cyclohexane or ethanol for 2 minutes, the samples were sonicated for 3 minutes (Ultrasound processor *Hielscher Ultrasound Technology, Ultrasonic Processor UP200S*), vortexed. The spectrum of absorbance for each supernatant was measured and the absorption maxima at different wavelength was read.

The absorption coefficients ($A_{1cm}^{1\%}$) of common food carotenoids were used for calculations.

1) For determination of carotenoids and chlorophyll's acetone/ hexane mixture (2:3) was used and absorption was read at λ = 453; 505; 663 and 645 nm (Braniša *et al*., 2014).

Chl a, Chl b, β-carotene and lycopene content was calculated according to measurements using the following equations (1-4):

$$\text{Chl a } (\mu g\ mL^{-1}) = C\ (0.999A_{663} - 0.0989\ A_{645}) \quad (1)$$

$$\text{Chl b } (\mu g\ mL^{-1}) = C\ (-0.328\ A_{663} + 1.77\ A_{645}) \quad (2)$$

$$\text{Lycopene } (\mu g\ mL^{-1}) = C\ (-0.0485A_{663} + 0.204\ A_{645} + 0.372\ A_{505} - 0.0806\ A_{453}) \quad (3)$$

$$\text{ß- carotene } (\mu g\ mL^{-1}) = C\ (0.216\ A_{663} - 1.22\ A_{645} - 0.304\ A_{505} + 0.452\ A_{453}) \quad (4)$$

where C = concentration of sample, mg mL^{-1}, A= absorbance, nm (Braniša *et al*., 2014).

After that, calculation results were expressed as μg mL^{-1} to be compared.

2) The acetone was used as a solvent to describe content of chlorophylls a and b (Chl a; Chl b) and total carotenoids (TCC).

The absorbance maxima was read at λ = 663.6 nm for Chl a; λ = at 646.6 nm for Chl b; λ = 470.0 nm for TCC (Braniša *et al*., 2014).

Total content of carotenoids (TCC), green pigments (Chl a and Chl b) were calculated (equitation 5-7):

$$\text{Chl a } (\mu g\ mL^{-1}) = C\ (122.5\ A_{663.6} - 22.5\ A_{646.6}) \quad (5)$$

Chl b ($\mu g\ mL^{-1}$) = C (203.1 $A_{646.6}$ – 49.1 $A_{663.6}$) (6)

TCC ($\mu g\ mL^{-1}$) = C ((10000 A_{470} – 2.27* Chl a – – 81.4* Chl b) 270^{-1}) (7)

3) Cyclohexane was used as solvent to determine total content of carotenoids (TCC) at the absorbance λ = 456 nm. TCC was calculated from formulation (8).

TCC= , $\mu g\ mL^{-1}$ (8)

TCC – Total content of carotenoids
2505 – coefficient of extinction ($E^{1\%}$)
A – absorbance at 456 nm
C – Concentration of sample solution, mg mL^{-1}.

4) Ethanol was used for determination of lutein at λ = 445 nm, ß-carotene and zeaxanthin at λ = 450 nm,
$A_{1cm}^{1\%}$ = 2620 for ß-carotene
$A_{1cm}^{1\%}$ = 2480 for zeaxanthin (Mustafa, Trevino, & Turner, 2012)about 25% of the annual production is regarded as by-products due to strict market policies. The aim of this study was to extract carotenoids from those by-products. Conventional carotenoid extraction methods require the use of organic solvents, which are costly, environmentally hazardous, and require expensive disposal procedures. Pressurized liquid extraction (PLE.

5) The antiradical activity of the samples was determined with 2,2-diphenyl-1-picrylhydrazyl radical (DPPH·) solution in ethanol (0.1 mM DPPH) (Merk, Sigma Aldrich®, Germany). The results were expressed as the percentage of antiradical activity (AA, %) (Eskicioglu, Kamiloglu, & Nilufer-Erdil, 2015; Yavuz & Emen, 2008). The extract of sample was diluted with ethanol (0.1g mL^{-1}), 2 mL of sample solution and 2 mL of DPPH ethanol solution (0.1 mM) was added, 30 min of reaction in a dark place was allowed, and the absorbance at 517 nm was measured (Priecina & Karklina, 2014; Tirzitis & Bartosz, 2010; Soengas *et al*., 2011).

The antioxidant activity calculation according to the following formula (9):

AA, %= 100, (9)

where A1 – the absorbance before reaction, A2 – the absorbance after reaction has taken place, AA – antiradical activity of samples (%) was done.

All measurements were carried out for three independent samples (n=3), and the results were expressed as mean values ± standard deviation (SD). A mathematical analysis of the data has been performed using MS Excel Data Analysis, ANOVA, a Single-factor, correlation and regression analysis were used. The protruding hypotheses have been tested with a p-value method and the factors have been evaluated as relevant if $p<\alpha=0.05$. In the analysis of variance, the Tukey and Friedman test was used to justify the differences in the results between the studied samples.

Results and Discussion

Oils were extracted from pumpkin by-products with subcritical CO_2 ($SCCO_2$) and Soxhlet (with n-hexane or ethanol) extraction. The yield of recovered oils from two different varieties of *Cucurbita spp* is attached in Figure 1.

The data are presented as mean values (n=3)

Oil content varied from 25.95±2.2% to 32.23±1.18% in pumpkin by-products – hulled seeds with $SCCO_2$ and Soxhlet extraction (Figure 1), the differences were not significant ($p>0.05$) in the yield of oil from pumpkin seeds with such extractions. Typically, the industrial production of pumpkin seed oil takes place from special pumpkin varieties

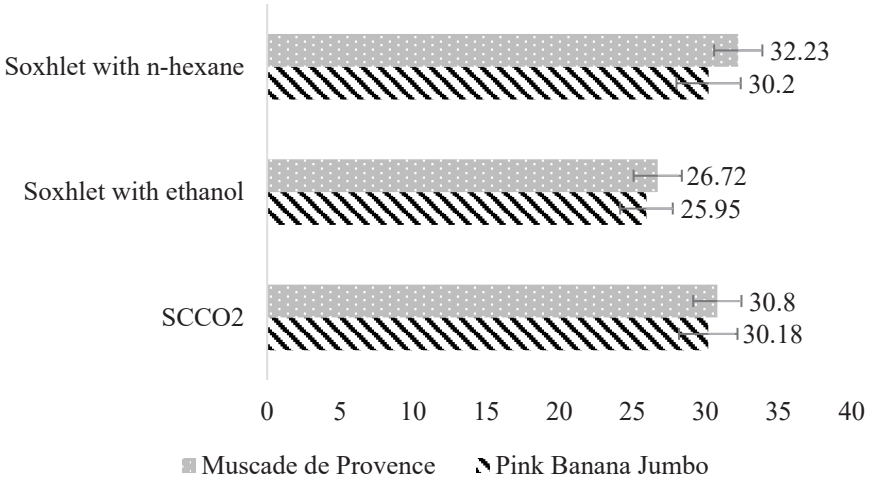

Figure 1. Oil yield (%) of pumpkin (*Cucurbita pepo* L, Pink Banana Jumbo and *Cucurbita* Moshata, Muscade de Provence) by-products with different extractions.

Table 1

Carotenoid content in edible oils used for extraction of pumpkin by-products

Oil	Solvent acetone	Solvent cyclohexane	Carotenes, µg mL^{-1}			
	TCC, µg mL^{-1}		Lycopene	ß carotene	Lutein	Zeaxanthin
Coconut oil	0.09±0.01	0.65±0.01	n.d	1.06±0.01	n.d.	1.13±0.01
Grapeseed oil	3.67±0.04	3.20±0.03	1.21±0.01	2.3±0.01	0.74±0.01	2.1±0.01
Rapeseed oil	3.45±0.08	4.17±1.08	0.24±0.01	1.5±0.01	2.91±0.09	0.16±0.01
Olive oil	6.84±0.07	8.48±0.09	1.01±0.01	5.15±0.04	2.48±0.03	5.48±0.03

n.d. – not detected, the data reported as average (n=3); ± Standard Deviation.

Table 2

Chlorophylls in edible oils for extraction of pumpkin by-products

Oil	With acetone		With acetone/hexane (2:3)	
	Chl a, µg mL^{-1}	Chl b, µg mL^{-1}	Chl a, µg mL^{-1}	Chl b, µg mL^{-1}
Coconut oil	n.d.	n.d.	n.d.	n.d.
Grapeseed oil	0.57±0.02	0.38±0.01	0.51±0.01	2.01±0.02
Rapeseed oil	0.38±0.01	0.47±0.04	0.18±0.01	1.39±0.01
Olive oil	1.75±0.03	0.43±0.03	n.d.	1.63±0.01

n.d. – not detected, the data reported as average (n=3); ± Standard Deviation.

(*Cucurbita* pepo subsp. pepo var *Styriaca*) that are already botanical naked or hull-less seeds, the content of lignin and cellulose is very low and outer hull is very thin (Fruhwirth *et al*., 2003). Studies of twelve pumpkin (*Cucurbita* maxima D) cultivars showed that the oil content ranged from 10.9 to 30.9% (Stevenson *et al*., 2007). Differences of oil content in two different cultivars in research should be of harvest time, variety, and ratio between seed kernel and shell (Redrouthu, Sundramurthy, & Zergu, 2020).

Main carotenoids in vegetables and plants are α- and β-carotene, lutein, neoxanthin, violaxanthin, and they have been studied very widely because of the beneficial effects on human health. The stability of carotenoids is very sensitive, and they can form isomers (Murković *et al*., 1996). Extraction of carotenoids and pigments were carried with $SCCO_2$ and edible vegetable oils. Carotenoid and chlorophyll profile of oils for further by-products extraction with different solvents was analysed (Table 1, Table 2). Highest content of total carotenoids (TCC) was determined in olive oil 6.84-8.48 µg mL^{-1}, TCC in coconut oil was determined 0.652 µg mL^{-1}, (Table 1). Different results were obtained with cyclohexane and acetone as solvents. Acetone as solvent for detection of chlorophylls showed better results in comparison with hexane/ acetone. TCC determination with cyclohexane gave higher extractions for analyses.

The main pigments-four carotenoids (lycopene, lutein, β-carotene, zeaxanthin) and two chlorophyll derivatives (a and b) were quantified by the near UV-visible spectrum.

For determination of chlorophyll's acetone/ hexane gave higher contents of Chl b, while acetone was better for detection of Chl a in edible oil samples.

The choice for solvent is necessary to find out what solvent can be used for detection of pigments and carotenes as some solvents gave negative data in determination of chlorophylls, lutein and lycopene (Niewiadomski, Bratkowska, & Mossakowska, 1965). It is described that vegetable oil refining also affect the carotenoid content in oils; therefore, it should be considered for further experiments for using oils as solvents for extraction (Kuncewicz, 2008).

Two varieties of pumpkin hulled seeds were analysed for pigments profile (Table 4). Solvents for analyses also are important for prediction of bioactive compounds as, for example, ethanol gave negative results for ß-carotene while lycopene was detected in all extracted samples of pumpkin seed oil. In oils extracted with ethanol and hexane ß-carotene, lutein and zeaxanthin were not detected, though (Juknevi, Judita, & Kulaitien, 2013) lutein in seeds from pumpkin cultivars Golosemiannaja, Herakles and Miranda from 25.26 to 162.70 µg g^{-1} and ß-carotene about 5.15 µg g^{-1} was detected.

Pumpkin seed extracts have high content of carotenoids (Table 3), the highest amount with $SCCO_2$ extraction. Higher carotene profile (Table 3, 4) of oils from two varieties of PS is in oil from Pink Banana

Table 3

Composition of oils from two varieties of pumpkin (Cv Muscade de Provence and Cv Pink Banana Jumbo) hulled seeds by different extraction methods

Samples	ß-carotene, µg ^{mL}-1	Lutein, µg mL^{-1}	Zeaxanthin, µg mL^{-1}	Lycopene, µg mL^{-1}	TCC, µg mL^{-1}
$_{OKET}$OH	4.28±0.02	11.22±1.01	1.12±0.09	n.d.	24.04±1.18
O_{Khe}x	7.25±0.03	11.81±2.02	0.77±0.02	0.69±0.21	13.75±2.06
O_{KCO}2	4.36±0.01	12.26±1.02	0.46±0.11	0.75±0.03	23.98±2.45
OR_{ETOH}	n.d.	n.d.	n.d.	0.48±0.06	n.d.
OR_{hex}	n.d.	n.d.	n.d.	0.37±0.08	33.30±3.18
OR_{CO2}	2.27± 0.04	18.25±1.18	0.24±0.05	0.7±0.01	47.67±2.09
O_{Rf}r	5.30±0.01	17.74±2.04	0.56±0.03	0.76±0.20	32.62±1.44

n.d. – not detected, the data reported as average (n=3); ± Standard Deviation, sample abbreviations: OK – oil from pumpkin seeds (PS) (variety Muscade de Provence), (OK_{ETOH} – oil from pumpkin seeds with ethanol; OK_{hex} – oil from PS with n-hexane; OK_{CO2} – oil from PS with ScCO2; OK_{CO2} – oil from PS with ethanol); OR – oil from PS (variety Pink Banana Jumbo), OR_{ETOH} – oil from pumpkin seeds with ethanol; OR_{hex} – oil from PS with n-hexane;OR_{CO2} – oil from PS with $SCCO_2$; OR_{fr} – oil from PS with oil press/ extruder.

Jumbo – the highest TCC was determined in oils with $SCCO_2$ extraction – 47.67±2.09 µg mL^{-1}. Temperature of extraction is decisive factor for carotenoids and bioactives that explains lower results for extracts with ethanol (TCC=24.04±1.18 µg mL^{-1}) as the temperature for Soxhlet extraction with ethanol was +70 °C. Lutein was predominantly present, its content determined from 11.22±1.01 to 18.25±1.18 µg mL^{-1}. There was a significant difference (p>0.05) between samples with different extractions in carotene profile, highest results of lutein were in $SCCO_2$ extracts of oils. There was no significant difference (p>0.05) in determination of chlorophylls with acetone and acetone/ hexane ($F>F_{crit}$, p=5.28). Predominantly chlorophylls were Chl b (1.59-13.0 µg mL^{-1}).

$SCCO_2$ and edible oils were used as solvent for recovering bioactive compounds – carotenoids (Table 6). From previous studies TCC content in dried pumpkin by-products was 91.28 mg 100 g^{-1} (Konrade *et al*., 2016). ß-carotene 0.06 to 7.4 mg 100 g^{-1}, from 0 to 7.5 mg 100 g^{-1} for α-carotene and from 0 to 17 mg 100 g^{-1} for lutein (Murkovic & Mu, 2002).Therefore, it can be considered that the highest extractions of carotenes are obtained with coconut oil as the content of TCC in oil as solvent was determined 0.09-0.65 µg mL^{-1} after recovering of carotenoids with solvents. It was observed that extraction with coconut oil with PP TCC reached 17.95 µg mL^{-1}. Coconut oil is a promising solvent for the recovery of bioactive compounds, flavours and vitamins as coconut oil is the highest natural source of lauric acid and its derivative monolaurin (Papadaki, Kyriakopoulou, & Krokida, 2017).

Under the influence of sunlight, temperature, extraction temperatures and oxidation, the pigments can be destroyed (Soengas *et al*., 2011). Studies and

Table 4

Chlorophylls in oils from pumpkin cultivars Cv Muscade de Provence and Cv Pink Banana Jumbo

Sample	With acetone		With acetone/hexane (2:3)	
	Chl a, µg mL^{-1}	Chl b, µg mL^{-1}	Chl a, µg mL^{-1}	Chl b, µg mL^{-1}
OK_{ETOH}	2.09±0.12	5.30±1.2	1.61±0.13	1.59±0.02
OK_{hex}	3.54±0.18	7.09±0.90	2.23±0.07	8.3±0.007
OK_{CO2}	0.45±0.01	2.58±0.02	2.52±0.01	0.9±0.002
OR_{ETOH}	2.68±0.02	5.05±0.08	6.50±0.01	3.89±0.14
OR_{hex}	4.96±0.01	7.95±0.09	0.80±0.01	13.0±0.02
OR_{CO2}	2.84±0.01	6.74±1.12	4.0±0.020	6.4±0.013

The data reported as average (n=3); ± Standard Deviation; Sample abbreviations: OK_{ETOH} – oil from pumpkin seeds with ethanol; OK_{hex} – oil from pumpkin seeds with n-hexane; OK_{CO2} – oil from pumpkin seeds with SCCO2; OK_{ETOH} – oil from pumpkin seeds with ethanol; OR_{hex} – oil from pumpkin seeds with n-hexane; OR_{CO2} – oil from pumpkin seeds with $SCCO_2$.

Table 5

Assay of chlorophylls, carotenoids in extracts of pumpkin peel (variety Muscade de Provence)

	Acetone			Hexane		Lutein µg mL^{-1}	ß-carotene, µg ^{mL}-1	Zeaxanthin, µg mL^{-1}
	Chl a, µg mL^{-1}	Chl b, µg mL^{-1}	TCC, µg mL^{-1}	Chl a, µg mL^{-1}	Chl b µg mL^{-1}			
$Kscco_2$	1.53±0.02	1.17±0.01	32.43±2.09	2.08±0.01	2.4±0.01	6.72±0.01	5.37±1.12	5.72±0.08
KR1	1.01±0.01	0.36±0.02	27.17±1.18	1.81±0.02	1.6±0.02	8.85±0.02	6.81±0.02	7.25±0.06
KC1	0.91±0.04	1.71±0.05	26.03±2.09	1.01±0.01	1.2±0.01	7.71±0.01	8.48±0.09	9.03±0.03
KO1	1.84±0.01	1.66±0.02	17.95±1.14	n.d.	1.44±0.04	6.0±0.06	3.79±0.03	6.61±0.01
KG1	1.00±0.03	1.09±0.01	16.32±1.11	1.4±0.01	0.08±0.02	7.01±0.02	5.37±0.03	5.72±0.04

The data reported as average (n=3); ± Standard Deviation, n.d.-not detected, Sample abbreviations: K_{SCCo2} – extracts from pumpkin by-products peel (PP) with $SCCO_2$ extraction, KR1 – extracts from PP with rapeseed oil, KC1 – extracts from PP with coconut oil, KO1 – extracts from PP with olive oil, KG1 – extracts from PP with grapeseed oil.

Table 6

Carotenoids in edible vegetable oil extracts with pumpkin by-products (hulled seeds)

	SG1	SR2	SC1	SO1
TCC, µg mL^{-1}	32.08±1.18	29.63±1.16	18.38±1.14	22.55±0.37
Lutein, µg mL^{-1}	20.71±0.23	7.87±0.18	n.d.	8.04±0.12
ß-carotene, µg m^{L-}1	7.67±0.31	12.61±0.13	7.57±2.08	4.08±1.18
Lycopene, µg mL^{-1}	n.d.	n.d.	1.04±0.01	n.d.
Chl a µg mL^{-1}	2.30±0.2	2.02±0.06	0.2±0.01	2.4±0.02
Chl b µg mL^{-1}	1.21±0.11	1.24±0.02	1.12±0.01	3.23±0.01

The data reported as average (n=3); ± Standard Deviation, n.d.-not detected. Sample abbreviations: SG1 – pumpkin seed (PS) extracts with grapeseed oil; SR2 – PS extracts with rapeseed oil; SC1 – PS extracts with coconut oil; SO1 – PS extracts with olive oil;

experiments, analyses should be done immediately after extractions.

Although the mixture of acetone-hexane is considered to be effective in the extraction of carotenoids, our results (Table 1), obtained in some extracts, appear to be problematic in determining the lycopene, chlorophyll content, as regards some determination which gives negative values (added as not detected – n.d.)

Antiradical scavenging activity (AA, %) in coconut oil – 41.3±2.04, rapeseed oil – 30.0±1.28 and in grapeseed oil – 25.1±1.18 %. From DPPH assay

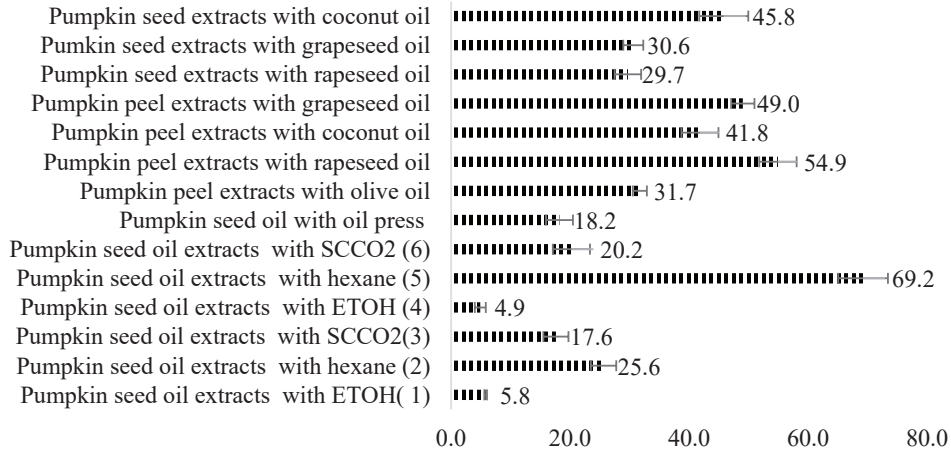

Figure 2. Antiradical scavenging activity (DPPH assay) of extracts from pumpkin by-products
The data reported as average (n=3); Samples: Cv Muscade de Provence (1-3) and Cv Pink Banana Jumbo (4-6).

(Figure 2) it is found that the ability of scavenging free radicals is high in all extracts except those with ethanol extraction. AA has been found in seed extracts with oil press even 69.2%. A very strong correlation of antiradical scavenging activity with the chl a a and chl b content in pumpkin seed extracts with edible oils ($r=0.99$ and $r=0.91$, $p>0.05$) has been found.

Conclusions

High-value bioactive compounds can be extracted with different methods – supercritical CO_2 ($SCCO_2$), Soxhlet extraction with n- hexane, ethanol and vegetable oils. Rapeseed, grapeseed and coconut oils are effective green solvents to be used for carotenoid and chlorophyll extractions from pumpkin by-products – seeds and peel. Vegetable oils with pumpkin seeds and peel gave high content of total carotenes – 47 $\mu g g^{-1}$ in oils from pumpkin seeds with hull, TCC level in vegetable oils received 32 $\mu g\ g^{-1}$ in grapeseed oil and 18.3 $\mu g\ g^{-1}$ in coconut oil with pumpkin by-products. Analyses of chlorophylls a and b profile with different solvents (acetone, hexane, ethanol) showed differences in determination – determination of chlorophyll acetone/ hexane gave higher contents of Chl b, while acetone was better for detection of Chl a in samples. Antiradical scavenging activity of biologically active compounds in extracts from pumpkin by-products with different methods was high in all experimental samples.

Acknowledgment

This work has been supported by the European Regional Development Fund within the Activity 1.1.1.2 'Postdoctoral Research Aid' of the Specific Aid Objective 1.1.1 To increase the research and innovative capacity of scientific institutions of Latvia and the ability to attract external financing, investing in human resources and the infrastructure of the Operational Programme 'Growth and Employment' (No.1.1.1.2/VIAA/4/20/656).

References

Borguini, R.G., Pacheco, S., William, D., Chávez, H., Couto, G.A., & Eduardo, A. (2020). *Carotenoid extraction using edible vegetable oil : an enriched provitamin A product Carotenoid extraction using edible vegetable oil : an enriched provitamin A product*. *August*. DOI: 10.1590/1678-992X-2019-0332.

Braniša, J., Jenisová, Z., Porubská, M., Jomová, K., Valko, M., & Klaudia, R. (2014). Spectrophotometric determination of chlorophylls and carotenoids. An effect of sonication and sample processing*: Journal of Microbiology, Biotechnology and Food Sciences,* 2014. Vol. 3 No. 2 pp. 61–64. ref. 2361–64.

Černiauskiene, J., Kulaitiene, J., Danilčenko, H., Jariene, E., & Juknevičiene, E. (2014). Pumpkin fruit flour as a source for food enrichment in dietary fiber. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *42*(1), 19–23. DOI: 10.15835/nbha4219352.

Delia, B. (2004). *HarvestPlus Handbook for Carotenoid Analysis*, HarvestPlus Tech. Monogr. Ser., 2004, Vol. 2, pp. 63.

Durante, M., Lenucci, M.S., & Mita, G. (2014). *Supercritical Carbon Dioxide Extraction of Carotenoids from Pumpkin (Cucurbita spp .): A Review*. *1*, 6725–6740. DOI: 10.3390/ijms15046725.

Eskicioglu, V., Kamiloglu, S., & Nilufer-Erdil, D. (2015). Antioxidant dietary fibres: Potential functional food ingredients from plant processing by-products. *Czech Journal of Food Sciences*, *33*(6), 487–499. DOI: 10.17221/42/2015-CJFS.

Fikselová, M., Šilhár, S., Mareček, J., & Frančáková, H. (2008). Extraction of carrot (*Daucus carota* L.) carotenes under different conditions, *Czech J. Food Sci*, 26, pp. 268–274. DOI: 10.17221/9/2008-CJFS.

Fruhwirth, G.O., Wenzl, T., El-Toukhy, R., Wagner, F.S., & Hermetter, A. (2003). Fluorescence screening of antioxidant capacity in pumpkin seed oils and other natural oils. *Eur. J. Lipid Sci. Technol.*, *105*(6), 274.

Gebregziabher, B.S., Zhang, S., Qi, J., Azam, M., Ghosh, S., Feng, Y., Huai, Y., Li, J., Li, B., & Sun, J. (2021). *Simultaneous Determination of Carotenoids and Chlorophylls by the HPLC-UV-VIS Method in Soybean Seeds*. 1–15.

Henriques, F., Guiné, R., & Barroca, M.J. (2012). *Chemical Properties of Pumpkin Dried by Different Methods*. *7*, 98–105.

Hsu, C., Chao, P., Hu, S., & Yang, C. (2013). The Antioxidant and Free Radical Scavenging Activities of Chlorophylls and Pheophytins. *Food and Nutrition Sciences*, *4*(August), 1–8. DOI: 10.4236/fns.2013.48A001.

Jain, D., Devi, M., & Thakur, N. (2013). Study on the effect of machine operative parameters on physical characteristics of rice/maize based fruit/vegetable pulp fortified extrudates. *Agricultural Engineering International: CIGR Journal*, *15*(2), 231–242.

Jian, L., Lee, A., Binns, C., & Du, C.-J. (2005). Do dietary lycopene and other carotenoids protect against prostate cancer. *Int. J. Cancer*, *113*(6), 1014.

Juknevi, E., Judita, Č., & Kulaitien, J. (2013). *Oil pumpkins – Important source of antioxidants Oil pumpkins – Important source of antioxidants*. *January*.

Kampuse, S., & Ozola, L. (2015). *Quality parameters of wheat bread enriched with pumpkin*. *XIX*(2), 3–14.

Kļava, D., Kampuse, S., Tomsone, L., Kince, T., & Ozola, L. (2018). Effect of drying technologies on bioactive compounds maintenance in pumpkin by-products. *Agronomy Research*, *16*(4), 1728–1741. DOI: 10.15159/AR.18.156.

Konrade, D., Lidums, I., Klava, D., & Ence, E. (2019). *Investigation of extruded cereals enriched with plant by- products and their use in fermented beverage production*. *17*(X).

Konrade, D., Klava, D., Sabovics, M., Kince, T., & Kruma, Z. (2016). *Plant by – products as source of natural antioxidants for production of crispbreads*. *6*(3), 3001.

Kuncewicz, A. (2008). *Fatty Acid Composition, Tocopherols and Beta-Carotene Content in Polish Commercial Vegetable Oils*. *May 2014*. DOI: 10.3923/pjn.2008.278.282.

Lu, Y., & Yeap Foo, L. (2000). Antioxidant and radical scavenging activities of polyphenols from apple pomace. *Food Chemistry*, *68*(1), 81–85. DOI: 10.1016/S0308-8146(99)00167-3.

Mala, S. (2016). *Nutritional Composition and Antioxidant Activity of Pumpkin Wastes*. *6*(3), 336–344.

Murković, M., Hillebrand, A., Winkler, J., & Pfannhauser, W. (1996). Variability of vitamin E content in pumpkin seeds (*Cucurbita pepo* L.). *Z. Lebensm. Unters. Forsch.*, *202*(4), 278.

Murkovic, M., & Mu, U. (2002). *Carotenoid Content in Different Varieties of Pumpkins*. 633–638. DOI: 10.1006/jfca.2002.1052.

Mustafa, A., Trevino, L.M., & Turner, C. (2012). *Pressurized Hot Ethanol Extraction of Carotenoids from Carrot By-Products*. 1809–1818. DOI: 10.3390/molecules17021809.

Eurostat Database, Statistics. (2021). *FAO Statistical Pocketbook*, Retrieved February 24, 2022, from https://www.eui.eu/research/library/researchguides/economics/statistics/dataportal/edd.

Navale, S.A., Swami, S.B., & Thakor, N.J. (2015). Extrusion Cooking Technology for Foods : A Review. *Journal of Ready To Eat Food*, *2*(3), 66–80.

Niewiadomski, H., Bratkowska, I., & Mossakowska, E. (1965). Content of chlorophylls and carotenes in rapeseed oil. *Journal of the American Oil Chemists' Society*, *42*(8), 731–734. DOI: 10.1007/BF02540050.

Papadaki, S., Kyriakopoulou, K., & Krokida, M. (2017). *Recovery and Encapsualtion of Bioactive Extracts from Haematococcus Pluvialis and Phaedodactylum Tricornutum for food Applications Recovery and Encapsualtion of Bioactive Extracts from Haematococcus Pluvialis and Phaedodactylum Tricornutum for food Applications*. *January*. DOI: 10.9790/2402-1012045358.

Priecina, L., & Karklina, D. (2014). *Natural Antioxidant Changes in Fresh and Dried Spices and Vegetables*. *3001*(5), 492–496.

Rawson, A., Patras, A., Oomah, B.D., Campos-Vega, R., & Hossain, M.B. (2013). Antioxidant Activity of Phytochemicals and Their Method of Analysis. *Advances in Food Science and Nutrition*, 153–256. DOI: 10.1002/9781118865606.ch7.

Redrouthu, R., Sundramurthy, V.P., & Zergu, B. (2020). *Extraction of Essential Oils from Pumpkin Seeds : RSM Based Process Modeling, Optimization and Oil Characterization*. *4*, 1787–1797. DOI: 10.35940/ijeat.D8420.049420.

Saini, R.K., & Keum, Y. (2017). Carotenoid extraction methods : A review of recent developments Carotenoid extraction methods : A review of recent developments. *Food Chemistry*, *240*(September), 90–103. DOI: 10.1016/j.foodchem.2017.07.099.

Salami, A., Asefi, N., & Esmaeilzadeh, R. (2021). Extraction of pumpkin peel extract using supercritical CO 2 and subcritical water technology : Enhancing oxidative stability of canola oil. *Journal of Food Science and Technology*, *58*(3), 1101–1109. DOI: 10.1007/s13197-020-04624-x.

Sciences, F., Republic, S., Modra, B., & Republic, S. (1997). *Extraction of Carrot (Daucus carota L .) Carotenes under Different Conditions*. *26*(4), 268–274.

Secil, T., & Berrin, Ö. (2011). *Pumpkin and Carrot Pomace Powders as a Source of Dietary Fiber and Their Effects on the Mixing Properties of Wheat Flour Dough and Cookie Quality*. *17*(6), 545–553.

Seo, J.S., Burri, B.J., Quan, Z., & Neidlinger, T.R. (2005). Extraction and chromatography of carotenoids from pumpkin. *Journal of Chromatography A*, *1073*(1–2), 371–375. DOI: 10.1016/j.chroma.2004.10.044.

Soengas, P., Sotelo, T., Velasco, P., & Elena, M. (2011). *Antioxidant Properties of Brassica Vegetables*.

Sook, J., Jane, B., Quan, Z., & Neidlinger, T.R. (2005). *Extraction and chromatography of carotenoids from pumpkin*. *1073*, 371–375. DOI: 10.1016/j.chroma.2004.10.044.

Stevenson, D.G., Eller, F.J., Wang, L., Jane, J.-L., Wang, T., & Inglett, G.E. (2007). Oil and Tocopherol Content and Composition of Pumpkin Seed Oil in 12 Cultivars. *Journal of Agricultural and Food Chemistry*, *55*(10), 4005–4013. DOI: 10.1021/jf0706979.

Tirzitis, G., & Bartosz, G. (2010). *Determination of antiradical and antioxidant activity : basic principles and new insights*. *57*(1), 139–142.

Yavuz, M., & Emen, S. (2008). *Antioxidant Activities of Ethanol Extracts of Hypericum triquetrifolium. and Hypericum Antioxidant Activities of Ethanol Extracts of Hypericum triquetrifolium and Hypericum scabroides*. *0209*. DOI: 10.1080/13880200701739363.

 DOI: 10.22616/rrd.28.2022.017

REDUCTION POSSIBILITIES OF GAS EMISSION FROM MEAT PROCESSING COMPANIES: A REVIEW

***Evelina Spaka, Ilze Gramatina, Tatjana Kince**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: evelinka1994@inbox.lv

Abstract
Every year the ecological situation in the world is getting worse. Modern enterprises in their daily activities should provide not only high-quality and safe products, but also strive to improve environmental performance. The meat industry occupies a leading position in terms of the level of environmental pollution in the food industry. The main indicators of the meat chain have an impact on environmental aspects, the production process, the heat treatment of the product has the highest indicators from the slaughter of the animal to the transportation of the finished product. This article looks into possible ways to reduce emission into the atmosphere during the meat processing as smoking and evaluates the effectiveness of possible ways to reduce emission into the atmosphere, highlighting the most effective ways to achieve an environmentally friendly balance. During this research it was revealed that a more optimal and cost-effective method to achieve the desired result is the installation of CAB (Catalytic afterburner).
Key words: environment, ecological aspect, meat industry, impact, environmental situation.

Introduction

The environmental situation in the world is getting worse every year, and it is also gaining momentum in attracting the attention of government agencies and prompting adjustments to tighten tax rates on emission into the atmosphere in order to encourage manufacturers to take measures and introduce practices, as well as to look for methods to reduce emission. This is due to the fact that the ecological situation in the world is deteriorating and growing exponentially every year, which incredibly affects the climate, human health and, in general, the comfortable existence of human civilization (Djekic *et al*., 2016). Modern enterprises in their daily activities should provide not only high-quality and safe products, but also strive to improve environmental performance (Lazarus, McDermid, & Jackuet, 2021). 'Industrial Ecology' is a term whose main goal is to create a balance between enterprises and the environment, that is, to minimize its negative impact (Hyland *et al*., 2017). During the heat treatment processes, carbon dioxide emission is released into the atmosphere, as a result of which the biosphere is damaged and subsequently a greenhouse effect occurs. Such damage provokes global warming of the planet (Kuzlyakina, Yurchak, & Baskhamdgieva, 2019). According to the (FAO, 2019) Food and Agriculture Organization, the meat industry occupies a leading position in terms of environmental pollution in the food industry.

The meat and dairy industry accounts for 14.5% of global greenhouse gases (Gerber *et al*., 2013). This type of production contributes to global warming by generating substances that destroy the ozone layer, and is also distinguished by its high consumption of water and energy, which provokes increased waste and wastewater discharge (Zhernosek & Strukova, 2021).

The production of the meat chain at each stage has an impact on environmental aspects − transport, storage, slaughter, deboning, production and sale. Of all these processes, the most important are the indicators of slaughter and the production process, the heat treatment of the product (Kuzlyakina, Yurchak, & Baskhamdgieva, 2019). During the production of meat products, the frequent technological operation is the smoking process, as a result of which the product acquires a presentable appearance, a specific aroma and antiseptic properties of smoky smoke, which increases the safety of the product during storage (Alimov, Lykasova, & Mizhevikin, 2020). The consumption of smoked meat products is high (Kim *et al*., 2021). Manufacturers are experimenting by trying to give products more and more different and richer flavours using different types of wood and smoking technologies (Nazarov & Majorov, 2020). In the smoke formed during the pyrolysis of wood, more than 200 different groups of chemical compounds were found in the composition, as well as solid, gaseous smoke particles that passing the product chamber through the chimney and enter the atmosphere in such a way that the surrounding environment is cut off (Valdovska, Miculis, & Plotina, 2010). There are a number of methods of air purification from carbon dioxide, the main of which can be divided according to the phase principle into 'gas − solid' and 'gas − liquid' (Bhuyan *et al*., 2018).

The purpose of the present review is to study certain techniques with the ability to simultaneously reduce the impact on the environment into the atmosphere during the heat treatment of meat products during smoking and increase the efficiency of technological and economic processes. Also, its purpose is to determine the most effective method as well as to consider possible ways of smoke filtration during meat smoking in terms of efficiency and economy, in order to determine the most profitable method.

Materials and Methods

The monographic method was used to summarise and analyse the latest information and research articles dedicated to possible emission reduction into the atmosphere during the heat treatment of meat products during smoking. Information published from 2005 till 2022 in total 37 full text research articles, books and databases were analysed and summarised. For statistical analysis FAO databases were used. To select and analyse full text research articles and books Scopus, Web of Science, ScienceDirect and ResearchGate research databases were used. To find relevant information, previously mentioned constituents and processing technologies as keywords in research databases were used.

Results and Discussion

Catalytic afterburner (CAB)

The method of catalysing smoky smoke using a catalyst system (CAB) (Figure 1), which provides the ability to preserve the taste, colour, smell that natural smoke creates for the product while being able to control and minimize emission of harmful substances (Swaney-Stueve *et al*., 2019). The smoke catalysis system combines heat treatment and a catalyst with which it safely removes harmful substances from the smoke (Sullivan, Kafka, & Ferrari, 2012). The operation of the system is based on the afterburning of smoky smoke, when leaving the chamber with a temperature of 500 to 800 °C, then passes through the catalyst, causing a chemical reaction − which eliminates harmful emission leaving water and CO_2 (Emis, 2020a). The system can be installed to any camera, it runs on gas as well as electricity (Hevia, Ordonez, & Diez, 2005).

This system is already used in the world for more complex solutions in such campaigns as the production of synthetic fibres, metallurgy, fuel production, to reduce emission of organic compounds into the atmosphere, allows achieving efficiency results of up to 99% (Dopshak, 2009).

The system has great advantages due to its simple design and low metal consumption, as well as its competitiveness in investment and operating costs.

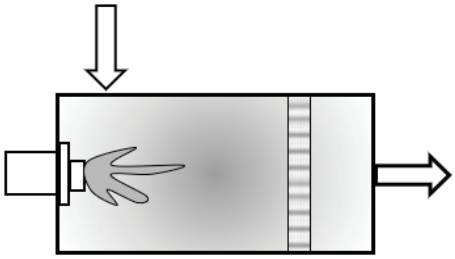

Figure 1. Catalytic afterburner (CAB) (Image created by the author after Emis, 2020a).

Scrubber

Scrubber is industrial equipment that is used to clean emission from dust and gases based on wet filtration. The equipment is a column (Figure 2) in which the main retention or neutralization of impurities is carried out using water or an absorbent. The gas mixture enters the equipment, where it is directed in the right direction with the help of fans, a liquid reagent is supplied from the sprayers installed at the top, thus neutralizing and separating dust and gases. After turbulent mixing, the medium enters the lower part of the scrubber and then into the drain pipe (Pronin *et al*., 2015). The principle of operation of this system is always the same, the gas comes into contact with the medium (water, reagent), which is sent out using nozzles.

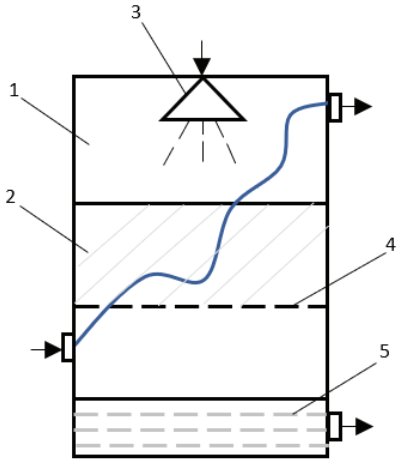

Figure 2. Scrubber scheme (Image created by the author after Pronin *et al*., 2015); 1 – corps; 2 – filling from porous material; 3 – liquid reagent atomizer; 4 – support grid; 5 – collection of liquid reagents.

This equipment has long been known in Europe. The purpose of using this equipment may differ depending on the specifics and specifics of production (Samokhvalov & Zykova, 2019).

Companies that process meat waste into offal use this equipment to reduce volatile organic compounds (VOC) as well as odours, and also use it to reduce solid gas fractions, dust. This system, depending on the composition of the gas, can reduce it to 100%, more complex ones from 20 to 64% (Kastner & Das, 2011). Also, studies from Nordström show that large particles from gas vapor can be separated by 60-70% using a scrubber (Gerber *et al*., 2013). The system is characterized by high mobility of the pile structure, limitations of possible leaks, as well as its unique ability to filter gaseous impurities and mechanical fractions. Among the disadvantages, we can note the high need for a stable installation of electrical energy saving (Wang *et al*., 2020).

Bio bed

The system is based on filtration (Figure 3) of the gas stream using biological purification. The gas stream passes through biological material (peat, trees), which creates a thin water film with microorganisms (Omri *et al*., 2013). Fillers such as wood chips, sawdust, shavings and others are also added to the biofilter to increase porosity (Maia *et al*., 2012). Due to this, substances in the gas stream are absorbed in the filtering material and further decomposed with the help of microorganisms that have settled in the filter material, which also serves as a supplier of essential nutrients for microorganisms (Affek *et al*., 2021). The advantages of decomposition in the filtration process are − sulphates, carbon dioxide and others. The filter material is periodically moistened with the help of air flow treatment, for the functionality and maintenance of the vital activity of microorganisms (Emis, 2020c).

The material contains a sufficient number of different bacteria in order for harmful substances to decompose during filtration, but also in the case of more complex substances, it is possible to add special cultures to the filter, and also to increase the efficiency and speed of the system, it is necessary to nutrients, oxygen level, pH, moisture content of the filter material (Tiwari *et al*., 2019). For the formation and existence of various bacterial cultures, several layers of filter media are usually used, and the second layer serves as an additional barrier for gases with more complex decomposability. The filter material needs to be serviced periodically from 1 to 5 years. The term of the use of the material depends on the composition of the emission as well as the out of the filler itself (Emis, 2020c).

The efficiency of the biofiltration system also depends on the composition of the gas; the purification of impurities varies from 30 to 100% (Melse & Hol, 2017; Tiwari *et al*., 2019). This system is used in the production of gelatine to remove odours with an efficiency of 70-93%, in the processing of chocolate to remove odours with an efficiency of 99%, in the food industry with an efficiency of about 93% (Nesaratnam *et al*., 2014).

The energy consumption of the biofilter itself is small. The energy consumption is determined primarily by the ventilators which compensate for the pressure reduction (Emis, 2020c).

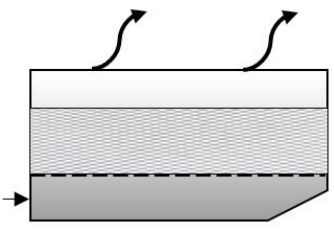

Figure 3. Bio bed filter (Image created by the author after Emis, 2020c).

Thermal afterburner (TAB)

The smoke flow with a certain amount of air is brought to high temperatures of 750 to 1200 °C. Gases are kept at a similar temperature for a long time, as a result of which substances are oxidized with oxygen and destroyed. The chamber is also equipped with automatic removal of combustion ash (Bujak, Sitarz, & Pasela, 2021). The efficiency of this system (Figure 4) depends on the afterburning time, temperature, oxygen and turbulence. For simpler organic compounds, a temperature of 750 to 1000 °C is sufficient, but for toxic compounds affecting the environment, it is necessary to provide a temperature of 1000 to 1200 °C for the destruction of compounds (Brinkmann *et al*., 2016).

With the correct implementation of the system for the specifics of production, setting the time and their circulation, the system can achieve 99% efficiency, depending on the composition of gas mixtures (Bujak, Sitarz, & Pasela, 2021). Such systems (Figure 4) are considered one of the eco-friendly methods of air purification, which provides high rates of various types of pollution of gaseous to solid particles in comparison with scrubbers and biofilters and other systems, but the disadvantage is the high cost of energy spent in maintaining a given temperature with fuel costs (Emis, 2020b).

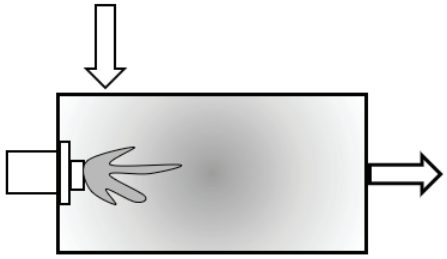

Figure 4. Thermal afterburner diagram (Image created by the author after Emis, 2020b).

Analysing all four types of possible methods and systems (Table 1) to reduce harmful emission into the atmosphere, each identified its advantages and disadvantages. All the described methods relate to difficult solutions to the problem on the part of the resources spent. The systems are not miniature and need installation and further maintenance, they also cannot be treated as budget installations and when choosing a solution to the problem, you need to consider the costs, resources and the result that is needed.

All these methods perform their function to a lesser or greater extent, depending on the composition of gaseous substances.

When choosing a previously studied necessary technique, two things should be considered: the result to be achieved and the economic part.

In this published analysis, four systems were compared from the point of equipment efficiency to parameters which are described below:

TOC – total organic carbon contained in an organic compound, the substance easily settles and accumulates in the soil and further in the water (European environment agency, 2019).

CO – carbon monoxide is a gaseous toxic substance that has no colour taste or smell.

NO – nitric oxide, a poisonous gas that is formed at high temperatures by the combination of nitrogen with oxygen. Dust particles, which are also part of the emission and accumulate in the soil (Nathani *et al*., 2019). Formaldehyde is a colourless gas that is released from wood at high ignition temperatures, which is associated with the thermal decomposition of polysaccharide in wood.

The amount of substance release depends on various factors: wood species, humidity, air temperature and storage time (Salem & Böhm, 2013).

PAH – stands for polycyclic aromatic hydrocarbons whose organic compounds are characterized by the presence of several benzene rings in the structure. The connection is formed in the process of cellulose pyrolysis. In the process of emission, it easily accumulates in the soil and in the plants themselves (Yakovleva, Gabov, & Beznosikov, 2019).

Each of the above parameters in Europe has a set limit in the general administrative regulations of the Federal Law on Emission Control (Air Pollution Control Technical Instructions, 2021).

In the published analysis, the smoking process was carried out with the same parameters and raw wood chips (beech). In the process, the methods are compared with each other and the established limits. The indicators differ in different parameters. The smoke afterburning systems and the thermal catalysing system during the experiment do not exceed any of the established limits on parameters. The scrubber exceeds the limit of carbon monoxide and nitrogen oxide. The biological filter exceeds the limit on three indicators: carbon monoxide, nitrogen oxide and formaldehyde. Organic carbon and dust particles in the smoke were close to the limit, and there was only one indicator in the green zone − polycyclic aromatic hydrocarbon. From the point of view of energy consumption, the largest energy consumption is necessary for the smoke afterburning system (TAB), as well as the biological filtration system (Fesmann, 2020).

The economic part (Table 2) plays an important role in choosing a suitable method of solving the problem of emission. Not only the purchase of this equipment, but also its maintenance, costs, resources and necessary disposal costs must be considered in order to achieve an economic and environmental balance. The most expensive is a scrubber (~150 000-200 000 EUR) and a smoke afterburning system (100 000-150 000 EUR) (Emis, 2020a), but it is also worth considering further investments and maintenance of systems. For example, for a biofilter, there is a need to replace the filter material at a cost (~50 000 EUR /750 m^3) (Emis, 2020c). From the point of view of maintenance, this is needed for all systems practically equally. It is also important to consider the recycling process of biofiltration and scrubber systems that have the requirement to replace and clean up waste. The medium accumulating with the reagent enters the scrubber into the lower part of the system and then into the drain pipe, which periodically requires cleaning.

These substances from the scrubber and the filter material of the biofilter must be sealed by composting or contamination. All these techniques are installed

Table 1

Comparison of emission reduction systems (Table created by the author after Fessmann, 2020)

	Parameters	Thermal afterburner	Cartalytic afterburner	Scrubber	Bio-bed	Limit *
Smocking smoke	Total organic carbon	✚	✚	✚	●	50 mg m^{-2}
	Carbon monoxide	✚	✚	✖	✖	100 mg m^{-3}
	Nitric oxide	✚	✚	✖	✖	100 mg m^{-3}
	Part. matter	✚	✚	✚	●	20 mg m^{-2}
	Formaldehyde	✚	✚	✚	✖	10 mg m^{-2}
	Polycyclic aromatic hydrocarbon	✚	✚	✚	✚	50 mg kg^{-1}

*Air Pollution Control Technical Instructions (2021, August). New edition of the First General Administrative Regulations of the Federal Law on Emissions Control.

✖ Above the set limit; ● the result is equal to the limit; ✚ below the set limit

Table 2

Comparison of emission reduction systems with economic efforts (Table created by the author after Fessmann, 2020)

EUR	Parameters	Thermal afterburner	Catalytic afterburner	Scrubber	Bio-bed
	Investment	●	✚		✚
	Energy	✖	✚	✚	●
	Maintenance	●	●	●	●
	Disposal	✚	✚	●	●

✖ the highest level of costs ● the medium level of costs ✚ the low level of costs

to furnaces, due to which they allow achieving the desired result without affecting the products of their colour, smell or taste of natural smoking (Fessmann, 2020).

Conclusions

Catalysis systems can be attributed to the optimal choice of a system for solving environmental and economic problems. It has shown a good result of effective filtration to reduce emission, and is also optimal in terms of maintenance, costs and dimensions.

Biofiltration has the least result, gas purification is less effective, and there is also a need for constant maintenance. But each system is suitable for certain functions. It is necessary to consider the result to be reached, the type of production, the composition of gas, the dimensions of production, economic opportunities, company policies, location.

References

Affek, K., Tabernacka, A., Załeska-Radziwiłł, M., Doskocz, N., & Muszynski, A. (2021). Bioaerosol Emission from Biofilters: Impact of Bed Material Type and Waste Gas Origin. *Atmosphere*. 18, 2–18. Article No. 1574. DOI: 10.3390/atmos12121574.

Air Pollution Control Technical Instructions (2021, August). New edition of the First General Administrative Regulations of the Federal Law on Emissions Control. Retrieved March 4, 2022, from http://www.verwaltungsvorschriften-im internet.de/bsvwvbund_18082021_IGI25025005.htm.

Alimov, A.V., Lykasova, I.A., & Mizhevikin, I.A. (2020). The influence of the smoking method on the veterinary and sanitary characteristics of a smoked-boiled pork product. *South Ural State Agrarian University*. 4, 2–3. DOI: 637.525[637.5.034]:619:614.31.

Bhuyan, D., Das, A., Laskar, S.K., Bora, D.P., Tamuli, S., & Hazarika, M. (2018). Effect of different smoking methods on the quality of pork sausages. *Veterinary World*. 11(12). Article No. 1712–1719. DOI: 10.14202/vetworld.2018.1712-1719.

Brinkmann, T., Giner Santonja, G., Yükseler, H., Roudier, S., & Delgado Sancho, L. (2016). Best Available Techniques (BAT) Reference Document for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector. *JRC Science for Policy Report*. 110–145. Article No. 1831–9424. DOI: 10.2791/37535.

Bujak, J., Sitarz, P., & Pasela, R. (2021). Possibilities for Reducing CO and TOC Emissions in Thermal Waste Treatment Plants: A Case Study. *Energies*. 10–14. Article No. 2901. DOI: 10.3390/en14102901.

Djekic, I., Blagojevic, B., Antic, D., Cegar, S., Tomasevic, I., & Smigic, N. (2016). Assessment of environmental practices in Serbian meat companies. Cleaner Production. 12(4), 28. DOI: 10.1016/j.jclepro.2015.10.126.

Dopshak, V.N. (2009). Catalytic processes for neutralization gas emissions. *Chemical Technology*. 1–3. Article No. 2451.

Emis (2020a). Catalytic oxidation. Retrieved March 4, 2022, from https://emis.vito.be/nl/node/19482.

Emis (2020b). Thermal afterburning. Retrieved March 5, 2022, from https://emis.vito.be/en/bat/tools-overview/sheets/thermal-afterburning.

Emis (2020c, March). Biofilter. Retrieved February 11, 2022, from https://emis.vito.be/nl/node/19470.

European Environment Agency (2019, February). Total Organic Carbon (TOC). Retrieved March 4, 2022, from https://www.fao.org/3/t0512e/T0512e0d.htm.

Fessman (2022). Climate systems. Retrieved March 4, 2022, from https://www.fessmann.com/en/products/climate-systems/.

Food and Agriculture Organization of the United Nations (2019, February). Gas cleaning and cooling. Retrieved March 6, 2022, from https://www.fao.org/3/t0512e/T0512e0d.htm.

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., & Tempio, G. (2013). *Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities.* Food and Agriculture Organization of the United Nations (FAO), Rome. Retrieved February 01, 2022, from https://www.fao.org/3/i3437e/i3437e.pdf.

Hevia, M.A.G., Ordonez, S., & Dıez, F.V. (2005). Design and Testing of a Control System for Reverse-Flow Catalytic Afterburners. *AIChE Journal*. 15–18. Article No. 10573. DOI: 10.1002/aic.10573.

Hyland, J.J., Henchion, M., McCarthy, M., & McCarthy, S.N. (2017). The role of meat in strategies to achieve a sustainable diet lower in greenhouse gas emissions: A review. *Meat Science*. 24, 3-9. DOI: 10.1016/j.meatsci.2017.04.014.

Kastner, J.R., & Das, K.C. (2011). Wet Scrubber Analysis of Volatile Organic Compound Removal in the Rendering Industry. *Air & Waste Management Association*. 8-11. DOI: 10.1080/10473289.2002.10470800.

Kim, E.N., Glebova, E.V., Timchuk, E.G., Lapteva, E.P., & Zayats, E.A. (2021). Standardization of food smoking production within the framework of environmental engineering. *In IOP Conf. Series: Earth and Environmental Science*. 10, 2–5. DOI: 10.1088/1755-1315/839/4/042070.

Kuzlyakina, Y.A., Yurchak, Z.A., & Baskhamdgieva, B.D. (2019). Analysis of environmental aspects at meat processing plants according to ISO 14001. *Food systems*. 23–28. DOI: 10.21323/2618-9771-2019-2-3-23-28.

Lazarus, O., McDermid, S., & Jacquet, J. (2021). The climate responsibilities of industrial meat and dairy producers. *Climatic Change.* 165, 5–10. DOI: 10.1007/s10584-022-03330-1.

Maia, G.D.N., Sales, G.T., Day, G.B.V., Gates, R.S., & Taraba, J.L. (2012). Characterizing physical properties of gasphase biofilter media. *Transactions of the ASABE*. 3-5. Article No.1939. DOI: 10.13031/2013.42356.

Melse, R.W., & Hol, J.M.G. (2017). 'Biofiltration of Exhaust Air from Animal Houses: Evaluation of Removal Efficiencies and Practical Experiences with Biobeds at Three Field Sites'. *Biosystems Engineering*. 59–69. DOI: 10.1016/j.biosystemseng.2017.04.007.

Nathani, C., Frischknecht, R., Hellmüller, P., Alig, M., Stolz, P., & Tschümperlin, L. (2019, October). *Industry: meat processing.* Federal Office for the Environment FOEN, Retrieved February 02, 2022, from https://treeze.ch/fileadmin/user_upload/downloads/Publications/Case_Studies/Lifestyles/629_UHU_FinalReport_EN_v1.8_FoodTrade.pdf.

Nazarov, V.F., & Mayorov, A.V. (2020). Analysis of the current state and perspective directions of development of smoking technology. *Humanities and Natural Sciences.* 1–4. DOI: 10.24411/2500-1000-2020-10133.

Nesaratnam, S., Nesaratnam, S.T., Taherzadeh, S., & Barratt, R. (2014). Air quality management. *Hoboken: Wiley.* 210–213. DOI: 10.1002/9781118863886.

Omri, I., Aouidi, F., Bouallagui, H., Godon, J.J., & Hamdi, M. (2013). Performance study of biofilter developed to treat H_2S from wastewater odour. *BiolSci*.169–176. DOI: 10.1016/j.sjbs.2013.01.005.

Pronin, V.A., Prilutsky, A.A., Dolgovskaya, O.V., & Podbolotova, T.E. (2015). Study of the effectiveness of the scrubber during absorption carbon dioxide. *Scientific NRU ITMO*. 2–9.

Salem, M.Z.M., & Böhm, M. (2013). Understanding of formaldehyde emissions from solid wood: An overview. *BioRes*. 2–3. Article No. 4775–4790. DOI: 10.15376/biores.8.3.4775-4790.

Samokhvalov, N.M., & Zykova, U.A. (2019). Problems of cleaning gas from industrial dust. *Ecology and science technology*. 106–112. DOI: 10.21285/2227-2925-2019-9-4-759-767.

Sullivan, J.L., Kafka, F.L., & Ferrari, L.M. (2012). An Evaluation of Catalytic and Direct Fired Afterburners for Coffee and Chicory Roasting Odors. *Air Pollution Control Association*. 2–9. Article No. 583–586. DOI: 10.1080/00022470.1965.10468428.

Swaney-Stueve, M., Talavera, M., Jepsen, T., Severns, B., Wise, R., & Deubler, G. (2019). Sensory and consumer evaluation of smoked pulled pork prepared using different smokers and different types of wood. *Food Sci*. 2–9. Article No. 14469. DOI: 10.1111/1750-3841.14469.

Tiwari, A., Alam, T., Kumar, A., & Shukla, A.K. (2019). Control of Odour, Volatile Organic Compounds (VOCs) & Toxic Gases through Biofiltration – An Overview. *Research Gate*. 2–5. DOI: 10.3390/ijerph16173009.

Valdovska, A., Miculis, J., & Plotina, L. (2010). Content of benzo(a)anthracene, benzo(a)pyrene, benzo(b) fluoranthene and chrysenein smoked meat and fish. *Research Institute of Biotechnology and Veterinary Medicine*. 5–7.

Wang, G., Wang, G., Wang, Q., & Yan, Z. (2020). Optimization and control of NOx in coke oven vertical flue under flue gas recirculation. IOP Conference Series. *Materials Science and Engineering*. 110–112. DOI: 10.1088/1757-899X/729/1/012078.

Yakovleva, E., Gabov, D., & Beznosikov, V. (2019). Accumulation of Polycyclic Aromatic Hydrocarbons Betula nana under the Conditions of Technogenesis. *Ecology and Industry of Russia*. 32–37. DOI: 10.1134/S1062359019100340.

Zhernosek, A.V., & Strukova, M.N. (2021). Impact of meat industry enterprises on the environment. *Ural Federal University*. 110–112. DOI: 10.1016/j.profoo.2015.09.025.

 DOI: 10.22616/rrd.28.2022.018

THE AUTHENTICITY OF VEGETABLE OIL USING SMARTPHONE-BASED IMAGE

***Sanita Vucane[1], Ingmars Cinkmanis[1], Lauris Leitans[2], Martins Sabovics[1]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]State Plant Protection Service, Latvia
*Corresponding author's email: sanitavucane@inbox.lv

Abstract
Chlorophylls, tocopherols, and phenolic compounds are fluorescent substances found in vegetable oils. As a result, fluorescence analysis can be used to authenticate vegetable oils in a simple, effective, and non-destructive manner. The goal of the study was to determine the authenticity of vegetable oil using smartphone-based image analysis in fluorescence light. The image was taken with a Huawei P30 Lite and saved as an 8-bit JPG file. Mactronic PHH0062 390 nm-LED flashlight was employed as a light source. Due to the Hue spectral histograms, the image was analyzed in the HSV (Hue, Saturation, Value) color model. Eleven vegetable oils were chosen for testing: sea buckthorn, sunflower, rice, macadamia nut, hemp, corn, grape, linseed, rapeseed, olive, and milk thistle. Because vegetable oils have a diverse Hue spectrum, fluorescence examination can be used to verify their authenticity.
Key words: fluorescence analysis, HSV color, Hue spectral histogram, smartphone, vegetable oil.

Introduction

Vegetable oils are abundant in fatty acids and are one of the nutrients required for normal human function. Carotenoids, chlorophylls, tocopherols, and phenolic compounds are biologically active fluorescent chemicals that play a vital role in human health. Carotenoids are isoprenoids with eight isoprene units that are the primary source of yellow, orange, and red colors in nature. According to the study, carotene is the most studied carotenoids; however, other carotenoids in vegetable oils include lycopene, lutein, and cryptoxanthin. According to scientific literature, carotenoids are not only precursors of vitamin A provitamins and antioxidants, but they also limit the formation of toxic compounds in the cell, use in cancer therapy, and reduce risk of chronic illnesses associated with coronary heart disease (Fakourelis, Lee, & Min, 1987; Anguelova & Warthesen, 2000; Huang *et al*., 2003; Prakash & Gupta, 2014).

Plants and cyanobacteria contain a green pigment – chlorophyll, which consists of a chlorin or porphyrin ring and magnesium ion in the center (Pareek *et al*., 2017). Chlorophyll improves human health by boosting the immune system, purifying the body of toxins, decreasing blood pressure, detoxifying the liver, and defending against skin rashes, sinusitis, fluid buildup, and other ailments (Inanc, 2011). Tocopherols, which have a chromanol ring and a hydrophobic side chain, are fat-soluble antioxidants. They are classified into four congeners (vitamers): α-, β-, γ-, and δ-, which differ in the benzopyran ring methylation pattern (Boschin & Arnoldi, 2011; Schwarz *et al*., 2008). Vitamin E in the form of α-tocopherol is the most active form, and it is thought to reduce risk in the body from degenerative diseases including cancer and cardiovascular disease (Hasani *et al*., 2008; Zingg, 2007). Researchers discovered that γ-tocopherol was superior to α-tocopherol in terms of lowering platelet aggregation, delaying intra-arterial thrombus formation, and slowing low-density lipoprotein (LDL) oxidation (Li *et al*., 1999; Saldeen, Li, & Mehta, 1999). As a result, research into these luminous pigments for human health is crucial. Vegetable oils can be classified using fluorescent pigment molecules.

Traditional for classification and authenticating vegetable oils several analytical techniques, for example, high-performance liquid chromatography (Fasciotti & Pereira Netto, 2010; Lerma-García *et al*., 2007), gas chromatography (Li *et al*., 2016; Troya *et al*., 2015), visible spectrophotometry (Pizarro *et al*., 2013), near and mid-infrared spectroscopy (Sinelli *et al*., 2010), nuclear magnetic resonance spectroscopy (Vlahov, Del Re, & Simone, 2003; Rezzia *et al*., 2005), Fourier transform infrared spectroscopy (Maggio *et al*., 2010; Jiménez-Carvelo *et al*., 2017), ultraviolet photoionization ion mobility spectrometry (Garrido-Delgado, Muñoz-Pérez & Arce, 2018), Raman spectroscopy (Jiménez-Carvelo *et al*., 2017), laser-induced breakdown spectroscopy (Mbesse Kongbonga *et al*., 2014) and microwave reflectometry (Cataldo *et al*., 2012) were used. The majority of these analytical techniques and methodologies necessitate the use of damaging chemicals, highly trained staff, and high operating and maintenance costs. When compared to other techniques, fluorescence spectroscopy for analytical measurements of vegetable oils is simpler and less expensive (Poulli, Mousdis, & Georgiou, 2005; Guimet, Boqué, & Ferré, 2006; da Silva *et al*., 2015). However, there is simpler spectroscopy that is more mobile, has lower operational and maintenance expenses, and requires less sample preparation. Fluorescence spectroscopy can be replaced with smartphone-based image analysis thanks to ultra-high optical and light sensors and high-resolution cameras. The goal of the study was to determine the authenticity of vegetable oil using smartphone-based image analysis in fluorescence light.

Table 1

Vegetable oil sample information

Sample / Type	Brand	Origin	Peroxide value Meq O_2 kg^{-1}
Sea buckthorn/cold pressed	Z/S Extra	Latvia	4.9
Macadamia nut	SIA 'Oil Tree'	Germany	4.2
Hemp/cold pressed	SIA 'Spelta'	Latvia	2.5
Corn seed / extracted	Basso Fedele e figli S.r.l.	Italy	1.2
Grapeseed / extracted	Carapelli	Italy	2.1
Linseed/cold pressed	Ruata F.lli S.p.A	Italy	2.1
Rapeseed/cold pressed	SIA 'Iecavnieks & Co'	Latvia	1.1
Olive / Extra virgin	GOCCIA D'ORO	Italy	2.9
Milk thistle/cold pressed	Z/S Extra	Latvia	3.4
Rice bran oil / extracted	OLITALIA S.r.l.	Italy	1.7
Sunflower/cold pressed	UAB 'FORSAS'	Slovakia	2.0

Materials and Methods

The principle of the classification of vegetable oils by fluorescence analysis of research is a digital imaging of vegetable oils by smartphone in 390 nm LED light spectra.

Samples of research: A total of eleven vegetable oils in their original commercial packaging were purchased in Latvia in 2020 and chosen for analysis: (sea buckthorn, sunflower, rice, macadamia nut, hemp, corn, grape, linseed, rapeseed, olive, and milk thistle) (Table 1).

Equipment for analysis: For digital imaging, the smartphone Huawei P30 Lite (Huawei Technologies Co., Ltd., China) year of issue 2019, April 25, 48-megapixel triple camera, Android 10 – operating system EMUI version 10.0.0, processor Hisilicon Kirin 710, RAM 4.0 GB were used. Light source 390 nm-LED flashlight Mactronic PHH0062 (MACTRONIC Spółka z o.o. Sp.k., Poland) was used.

The system of Image acquisition: The digital image acquisition system is comprised of a black color printed white paper box (C=40%, M=30%, Y=0%) and black color printed white paper (K=100%) (24 x 32 x 38 cm^3). A light-emitting diode (LED) flashlight Mactronic PHH0062 (MACTRONIC Spóka z o.o. Sp.k., Poland) with 390 nm illumination was used. Inside the box, the LED flashlight was situated 21 cm to the front of the oil sample. To take a digital image, a smartphone with a 48-megapixel camera (Huawei P30 Lite) was placed outside in front of the open side of the box, 17 cm away from the PMMA 2.5 mL macro disposable cuvettes (BrandTech Scientific, Inc., US) with vegetable oil. Analyses were carried out in a dark room.

Imaging and image analysis: The image was taken with a smartphone camera and saved in 8-bit JPG format with an average size of 7.0 (8000 x 6000 pixels), ISO auto, f/1.8, 27 mm (wide), 1/2.0″, 0.8 µm, PDAF (Phase Detection Autofocus). The image was analyzed by the open-source software ImageJ. Samples were analyzed in ten repetitions.

Calculation method: For the transformation of the digitally obtained image RGB (Red, Green, and Blue) to HSV (Hue, Saturation, and Value) color the following formula was used, equation 1 (Zhang *et al*., 2016).

$$H = \begin{cases} cos^{-1}\dfrac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}} & if\ (B \le G) \\ 360^0 - cos^{-1}\dfrac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}} & if (B > G) \end{cases} \quad (1)$$

$$S = \frac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)}$$

$$V = \frac{\max(R,G,B)}{255}$$

where: R – red, G – green, B – blue, H – Hue, S – saturation, V – value

Data processing/Statistical analysis

The data of the research was analysed by mathematical and statistical methods (standard deviation, mean, Two-Way ANOVA). For the data analysis the Microsoft Excel software of the version 2019 and ImageJ was used.

Results and Discussion

For obtaining the Hue histograms, the smartphone digital RGB images needed to be converted to Hue images by HSV color space according equation 1. The differences between the RGB and Hue images are illustrated in Figure 1.

Figure 1. Sample RGB and Hue image color difference in vegetable oils.

Despite the fact that the RGB colour model correlates with biochemical processing of human visual system, it does not appear to connect with human color perception. The HSV color model is based on Hue, Saturation and Value characteristics, which corresponds to human color distinction. The separation of achromatic (Value) and chromatic (Hue, Saturation) information is a benefit of this space (Loesdau, Chabrier, & Gabillon, 2014). The obtained Hue color information from RGB image (Figure 1) can be used for generating Hue histograms (Figure 2), which shows fluorescent reflective color characterized by mean, min and max and StdDev of each vegetable oils.

Hue histograms show that large fluorescence differences are found among olive, hemp, macadamia nut oils and most common vegetable oils. Hue histogram includes Hue parameter for quantitative analysis to identify the vegetable oils. Obtained Hue values in Figure 3 show the apparent color similarity of the following samples of vegetable oils: olive-hemp, grape-sunflower, rice-linseed and corn-milk thistler; however, evaluating the calculated t-test and p-values, it can be stated that despite the fact that visually similar colors are visible, the t-test value is well above this limit for all mentioned pairs of vegetable oils. As the t-test value is greater than 5.11 (<0.001), for olive-hemp, grape-sunflower, rice-linseed and corn-milk thistle oils, there is a significant difference between all samples of vegetable oil pairs.

Although there is a significant difference between the pairs of vegetable oils, the studied oils can be divided according to color boundaries, according to Wolfa's scientific data (Woolf *et al*., 2021), images converted to the 8-bit system have a defined Hue color circle that ranges from 0 to 255 px, thus according to this Hue color wheel, vegetable oils can be classified by color based on fluorescent molecules that have been studied in the scientific literature. Cluster analysis (Figure 4) shows and Hue value confirms that Olive and hemp oils are in the red color range 235.0 to 255.0,

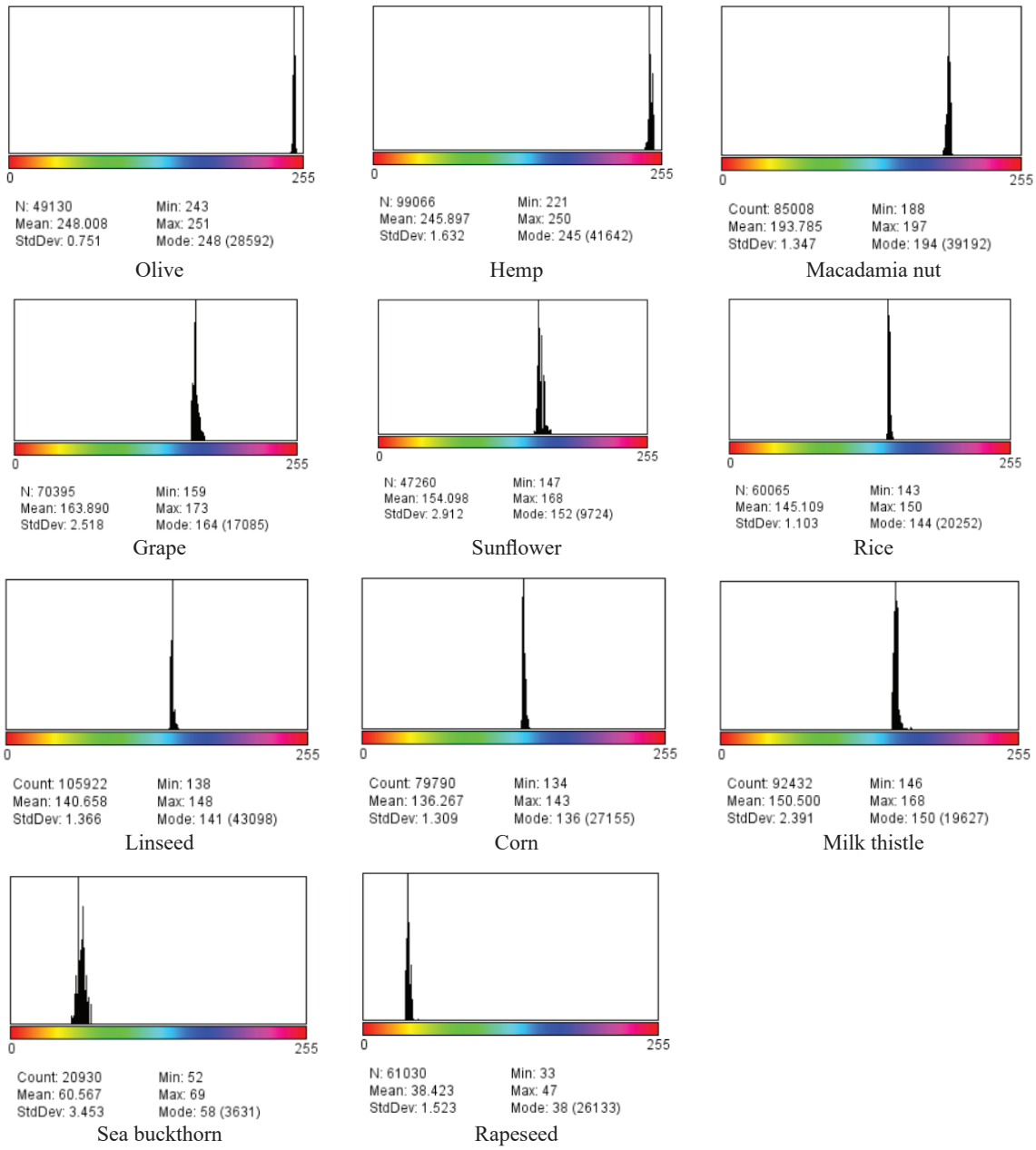

Figure 2. Hue histograms of vegetable oils.

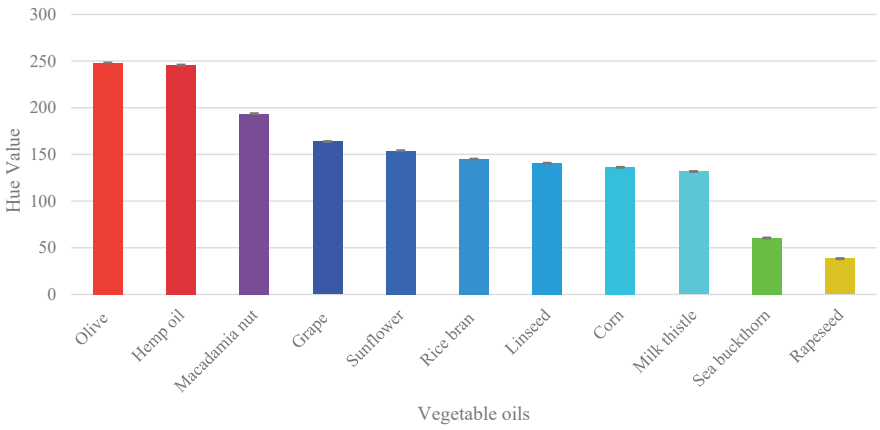

Figure 3. Hue values of vegetable oils.

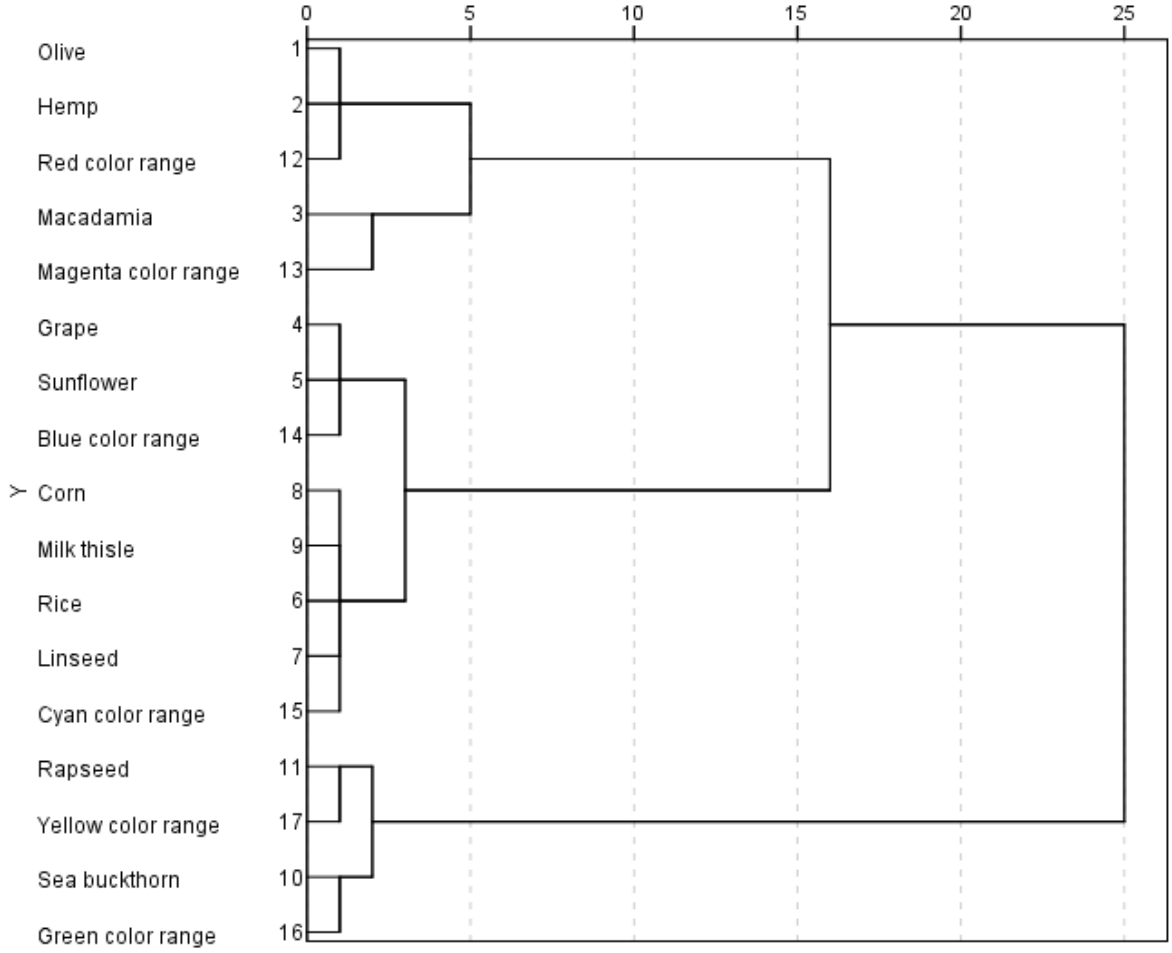

Figure 4. Cluster analysis of color range of vegetable oils by Hue values.

respectively 248.0±0.7 and 245.8±1.6, macadamia nut oil in the magenta color range 175.0 to 231.0, or 193.7±1.3, grape and sunflower oils in the blue color range 150.0 to 175.0, or 163.8±2.5 and 154.0±2.9, rice bran, linseed, corn, and milk thistle oils in the cyan color range 120.0 to 150.0, or 145.1±1.1, 140.6±1.3, 136.2±1.3 and 131.7±2.3, sea buckthorn in the green color range 41.0 to 85.0, or 60.5±3.4 and rapeseed oil in yellow color range, or 38.4±1.5.

Hue values of vegetable oils are in the range from 0 to 255. In order to group vegetable oils according to their Hue values obtained fluorescent colors, hierarchical cluster analysis was used (Figure 4). The first cluster includes olive and hemp oils, which indicate the formation of a similar red color. The second cluster contains only one vegetable oil, macadamia nut because none of the other vegetable oils produced the magenta color tone. The third cluster contains grape and sunflower oils with blue color formation. The fourth cluster includes four vegetable oils – corn, milk thistle, rice bran, and linseed, which by analogy form a cyan color. The fifth and sixth clusters contain one vegetable oil each – rapeseed and sea buckthorn, which form different color tones of yellow and green. Vegetable oils can be classified into 6 hierarchical clusters by the color – red, magenta, blue, cyan, yellow, and green – using fluorescent light and the obtained value of the Hue histograms.

According to scientific articles, it has been discovered that the strong fluorescence of olive oil is due to the natural fluorescent molecules like tocopherols, pheophytins, chlorophylls, chlorophylls, phenolic compounds, and their oxidations products. Fluorescence of phenolic compounds in olive oil was found using excitation with the maximum in the 362-400 nm range (Tena, Garcia-Gonzalez, & Aparicio, 2009). Hemp oil contains phenolic compounds, chlorophylls, carotenoids, and tocopherols which give the same strong red fluorescence as olive oil. The fluorescence of the red color indicates that the olive and hemp oils are high with chlorophyll compounds (Kleinegris *et al*., 2010). Blue to cyano color characterized by a decrease in vitamin E (tocopherol) concentrations in the cyano direction, it means blue is the highest concentration and cyano with lowest concentration of tocopherols. The clear green color in sea buckthorn indicates the presence of a pronounced carotenoid content (Kleinegris *et al*., 2010).

Conclusions

With a simple method using a smartphone digital image and a cheap 390 nm flashlight, vegetable oils can be classified and authenticated by fluorescence converted RGB mode to HSV – Hue histograms. The benefit of such a method is to control fraud of more expensive and valuable oils. The advantage over classical analytical methods is that no chemical solvents, reagents, optical filters, prisms, or grating are used.

Acknowledgments

The research has been carried out under the project 'Capacity Strengthening of Latvia University of Life Sciences and Technologies' project No. 3.2-10 / 126, Z46.

References

Anguelova, T., & Warthesen, J. (2000). Degradation of lycopene, β-carotene, and α-carotene during lipid peroxidation. *Journal of Food Science* 65, 71–75. DOI: 10.1111/j.1365-2621.2000.tb15958.x.

Boschin, G., & Arnoldi, A. (2011). Legumes are valuable sources of tocopherols. *Food Chemistry,* 127:1199–1203. DOI: 10.1016/j.foodchem.2011.01.124.

Cataldo, A., Piuzzi, E., Cannazza, G., De, & Benedetto, E. (2012). Classification and adulteration control of vegetable oils based on microwave reflectometry analysis. *Journal of Food Engineering,* 112:338–345. DOI: 10.1016/j.jfoodeng.2012.04.012.

da Silva, C.E.T., Filardi, V.L., Pepe, I.M., Chaves, M.A., & Santos, C.M.S. (2015). Classification of food vegetable oils by fluorimetry and artificial neural networks. *Food Control,* 47:86–91. DOI: 10.1016/j.foodcont.2014.06.030.

Fakourelis, N., Lee, E.C., & Min, D.B. (1987). Effects of chlorophyll and β-carotene on the oxidation stability of olive oil. *Journal of Food Science,* 52, 234–236. DOI: 10.1111/j.1365-2621.1987.tb14018.x.

Fasciotti, M., & Pereira Netto, A.D. (2010). Optimization and application of methods of triacylglycerol evaluation for characterization of olive oil adulteration by soybean oil with HPLC–APCI–MS–MS. *Alanta,* 81, 1116–1125. DOI: 10.1016/j.talanta.2010.02.006.

Garrido-Delgado, R., Muñoz-Pérez, M.E., & Arce, L. (2018). Detection of adulteration in extra virgin olive oils by using UV-IMS and chemometric analysis. *Food Control,* 85, 292–299. DOI: 10.1016/j.foodcont.2017.10.012.

Guimet, F., Boqué, R., & Ferré, J. (2006). Application of nonnegative matrix factorization combined with Fisher's linear discriminant analysis for classification of olive oil excitation–emission fluorescence spectra. *Chemometrics and Intelligent Laboratory Systems*, 81, 94–106. DOI: 10.1016/j.chemolab.2005.10.003.

Hasani, N.A., Yussof, P.A., Khalid, B.A.K., Ghapor, M.T.A., & Ngah, W.Z.W. (2008). The possible mechanism of action of palm oil gamma-tocotrienol and alpha-tocopherol on the cervical carcinoma caski cell apoptosis. *Biomedical Research – India*, 19, 194–200.

Huang, H.Y., Alberg, A.J., Norkus, E.P., Hoffman, S.C., Comstock, G.W., & Helzlsouer, K.J. (2003). Prospective study of antioxidant micronutrients in the blood and the risk of developing prostate cancer. *American Journal of Epidemiology*, 157, 35–344.

Inanc, A.L. (2011). Chlorophyll: Structural Properties, Health Benefits and Its Occurrence in Virgin Olive Oils. *Akademik Gida*, 9, 26–32.

Jiménez-Carvelo, A.M., Osorio, M.T., Koidis, A., González-Casado, A., & Cuadros-Rodríguez, L. (2017). Chemometric classification and quantification of olive oil in blends with any edible vegetable oils using FTIR-ATR and Raman spectroscopy. *LWT Food Science and Technology,* 86, 174–184. DOI: 10.1016/j.lwt.2017.07.050.

Kleinegris, D.M.M., van Es, M.A., Janssen, M., Brandenburg, W.A., & Wijffels, R.H. (2010). Carotenoid fluorescence in Dunaliella salina. *Journal of Applied Phycology*, 22(5), 645–649. DOI: 10.1007/s10811-010-9505-y.

Li, X., Kong, W, Shi, W., & Shen, Q. (2016). A combination of chemometrics methods and GC–MS for the classification of edible vegetable oils. *Chemometrics and Intelligent Laboratory,* 155, 145–150. DOI: 10.1016/j.chemolab.2016.03.028.

Li, D., Saldeen, T., Romeo, F., & Mehta, J.L. (1999). Relative effects of alpha- and gamma-tocopherol on low-density lipoprotein oxidation and superoxide dismutase and nitric oxide synthase activity and protein expression in rats. *Journal of Cardiovascular Pharmacology and Therapeutics*, 4, 219–226. DOI: 10.1177/107424849900400403.

Loesdau, M., Chabrier, S., & Gabillon, A. (2014). Hue and Saturation in the RGB Color Space. Lecture Notes in Computer Science. *6th International Conference, ICISP 2014. Lecture Notes in Computer Science. At: Cherbourg, FranceVolume,* 8509, 203–212. DOI: 10.1007/978-3-319-07998-1_23.

Lerma-García, M.J., Ramis-Ramos, G., Herrero-Martínez, J.M., & Simó-Alfonso, E.F. (2007). Classification of vegetable oils according to their botanical origin using amino acid profiles established by High Performance Liquid Chromatography with UV–vis detection. *Rapid Communications in Mass Spectrometry*, 2007; 21(22):3751–5. DOI: 10.1002/rcm.3272.

Maggio, R.M., Cerretani, L., Chiavaro, E., Kaufman, T.S., & Bendin, A. (2010). A novel chemometric strategy for the estimation of extra virgin olive oil adulteration with edible oils. *Food Control,* 21, 890–895. DOI: 10.1016/j.foodcont.2009.12.006.

Mbesse Kongbonga, Y.G., Ghalila, H., Boyomo Onana, M, Majdi, Y., Ben Lakhdar, Z., Mezlini, H., & Sevestre-Ghalila, S. (2011). Characterization of Vegetable Oils by Fluorescence Spectroscopy. *Food and Nutrition Sciences*, 2, 692–699. DOI: 10.4236/fns.2011.27095.

Pareek, S., Sagar, S.P., Sharma, S.,Kumar, V., Agarwal, T., González-Aguilar, G.A., & Yahia, E.M. (2017). Chlorophylls: Chemistry and Biological Functions. In: *Fruit and Vegetable Phytochemicals: Chemistry and Human Health.* Edition: Second, Wiley-Blackwell, John Wiley & Sons Ltd., 269–284.

Pizarro, C., Rodríguez-Tecedor, S., Pérez-del-Notario, N., Esteban-Díez, I., & González-Sáiz, J.M. (2013). Classification of Spanish extra virgin olive oils by data fusion of visible spectroscopic fingerprints and chemical descriptors. *Food Chemistry,* 138, 915–922. DOI: 10.1016/j.foodchem.2012.11.087.

Poulli, K.I., Mousdis, G.A., & Georgiou, C.A. (2005). Classification of edible and lampante virgin olive oil based on synchronous fluorescence and total luminescence spectroscopy. *Analytica Chimica Acta*, 542, 151–156. DOI: 10.1016/j.aca.2005.03.061.

Prakash, D., & Gupta, C. (2014). Carotenoids: Chemistry and health benefits. Phytochemicals of Nutraceutical Importance.*CAB International.* 181–195. DOI: 10.1079/9781780643632.0181.

Rezzia, S., Axelsonb, D.E., Hébergera, K., Renieroa, F., Marianid, C., & Guilloua, C. (2005). Classification of olive oils using high throughput flow 1H NMR fingerprinting with principal component analysis, linear discriminant analysis and probabilistic neural networks. *Analytica Chimica Acta*, 552, 13–24. DOI: 10.1016/j.aca.2005.07.057.

Saldeen, T., Li, D., & Mehta, J.L. (1999). Differential effects of alpha-and gamma - tocopherol on low-density lipoprotein oxidation, superoxide activity, platelet aggregation and arterial thrombogenesis. *Journal of the American College of Cardiology ,* 34, 1208–1215. DOI: 10.1016/s0735-1097(99)00333-2.

Schwarz, H., Ollilainen, V., Piironen, V., & Lampi, A-M. (2008). Tocopherol, tocotrienol and plant sterol contents of vegetable oils and industrial fats. *Journal of Food Composition and Analysis*, 152–161. DOI: 10.1016/J.JFCA.2007.07.012.

Sinelli, N., Cerretani, L., di Egidio, V., Bendini, A., & Casiraghi, E. (2010). Application of near (NIR) infrared and mid (MIR) infrared spectroscopy as a rapid tool to classify extra virgin olive oil on the basis of fruity attribute intensity. *Food Research International*, 43, 369–375. DOI: 10.1016/j.foodres.2009.10.008.

Tena, N., Garcia-Gonzalez, D.L., & Aparicio, R. (2009). Evaluation of Virgin Olive Oil Thermal Deterioration by Fluorescence Spectroscopy. *Journal of Agricultural and Food Chemistry*, 57(22), 10505–10511, ISSN 1520-51. DOI: 10.1021/jf902009b.

Troya, F., Lerma-García, M.J., Herrero-Martínez, J.M., & Simó-Alfonso, E.F. (2015). Classification of vegetable oils according to their botanical origin using n-alkane profiles established by GC–MS. *Food Chemistry*, 167, 36–39. DOI: 10.1016/j.foodchem.2014.06.116.

Vlahov, G., Del Re, P., & Simone, N. (2003). Determination of geographical origin of olive oils using 13C nuclear magnetic resonance spectroscopy. I–Classification of olive oils of the puglia region with denomination protected origin. *Journal of Agricultural and Food Chemistry*, 51:5612–5615. DOI: 10.1021/jf0207124.

Woolf, M.S., Dignan, L.M., Anchi, T.S., & Landers, J.P. (2021). Landers Digital postprocessing and image segmentation for objective analysis of colorimetric reactions. *Nature Protocols,* Volume 16, pages 218–238.32.

Zhang, H., Lin, H., Zhang, Y., & Weng, Q. (2016). Remote Sensing of Impervious Surfaces in Tropical and Subtropical Areas. ISBN 9780367870621 Published December 12, 2019 by CRC Press 200 Pages. 48.

Zingg, J.M. (2007). Modulation of signal transduction by vitamin E. *Molecular Aspects of Medicine*, 28 (5-6), 481–506. DOI: 10.1016/j.mam.2006.12.009.

 DOI: 10.22616/rrd.28.2022.019

THE PROBIOTIC MIXTURE X FEEDING EFFECT ON THE GROWTH AND DEVELOPMENT OF BROILER CHICKEN DIGESTIVE TRACT

***Sabine Eglite[1], Aija Ilgaza[1], Maksims Zolovs[2,3]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]Daugavpils University, Latvia
[3]Riga Stradiņš University, Latvia
*Corresponding author's e-mail: sabiine.eglite@gmail.com

Abstract
The issue of antibiotic resistance has become more pressing in the last decades. Therefore, substitutes for antibiotics are being sought. The aim of our study was to evaluate the effect of the mixture x of lactic acid bacteria on development of the broiler chicken digestive tract and the growth. The study was organised in three trials. In each trial, 260 one day old Ross 308 broiler chicks (males and females) were obtained from a commercial hatchery. They were randomly divided in two groups – the control group and the probiotic group. The dietary treatment was basal diet for the control group and basal diet + the mixture X of lactic acid bacteria 4 g 10 kg^{-1} for the probiotic group. Broilers were raised till day 35. All broilers were weighted on the day 1, 7, 14, 21, 28, 35 and 10 birds per treatment were randomly selected and killed by cervical dislocation. The gastrointestinal tract was excised (proventriculus, gizzard, intestines) and weighed with content. Overall, this study achieved significant results of the body weight results in the probiotic and the control groups, 2,835.7g ±161.74 and 2,828.02±115.64, respectively. The body weight of chickens and their gastrointestinal tract parts (proventriculus, gizzard, intestines) did not differ between the probiotic and control groups ($p > 0.05$).
Key words: body weight, *Lactobacillus farciminis*, *Lactobacillus rhamnosus,* poultry, Ross 308.

Introduction

The use of antibiotics in poultry, as in other agricultural sectors, has been very widespread since the discovery of antibiotics. The main uses of antibiotics in poultry are the treatment and prevention of diseases, as well as growth promoters (Abudabos, Al-Batshan, & Murshed, 2015; Al-Khalaifa *et al.*, 2019; Reuben *et al*., 2021; Wang *et al*., 2016).

The issue of antibiotic resistance has become more pressing in the last decades. There are studies linking the emergence of antibiotic resistance to the use of antibiotics as growth promoters in the poultry industry (Cosby *et al*., 2015).

The European Union has banned the use of human antibiotics in animals as growth promoters since 2006 (Djuric, 2005). Since that ban, producers in the European Union have been facing various problems, such as reduced growth rates, dysbacteriosis and enteritis caused by various pathogens (Palamidi, 2016; Reuben, 2021). Therefore, substitutes for antibiotics are being sought. The beneficial effects of probiotics, prebiotics, acidifiers and phytogenic substances etc. on birds have been studied very actively (Abudabos, Al-Batshan, & Murshed, 2015).

Probiotics have been shown to inhibit the development and growth of pathogens and to improve the intestinal microflora. Colonization of the intestinal tract by beneficial bacteria, such as *Lactobacillus spp.*, *Bifidobacterium spp.* etc., reduces attachment sites and nutrients to the pathogenic microflora. Probiotics promote the development and growth of intestinal beneficial bacteria in the intestinal tract, thus improving the functioning of the intestinal barrier (Adhikari & Kim, 2017; Jha, 2020; Reuben *et al*., 2021) and improving feed digestibility. Due to the ability of probiotics to suppress the pathogenic microflora, it is possible to prevent the development of various diseases, such as salmonellosis, campylobacteriosis and coccidiosis (Markowiak & Slizewska, 2018). Probiotic bacteria have been shown to stimulate and enhance the immune system (Adhikari & Kim, 2017; Ajuwon, 2016; Ebeid, Al-Homidan, & Fathi, 2021). Studies have been reported that the use of probiotics improves the histo-morphology of the intestinal tract, especially crypt depth and villus height, thus increasing the nutrient absorption surface. It significantly improves the percentage of moisture, protein and ash in the meat (Ebeid, Al-Homidan, & Fathi, 2021). Probiotics have been shown to improve blood biochemistry, such as lowering cholesterol (Jha, 2020; Reuben *et al*., 2021).

All these good properties of probiotics described above contribute to the improvement of growth rates - weight gain, feed conversion, etc. Shah *et al*. (2020) has shown that feeding probiotics has improved live weight gain at all stages of the bird's development. Positive results have been obtained Chen *et al.* (2018) and Wang *et al.* (2016), as well as Awad *et al*. (2009), who added *Lactobacillus sp.* product to the diet, achieved a higher live weight and live weight gain of broilers on the last day of the study compared to the control group. The absolute and relative weight of the proventriculus and the relative weight of the gizzard did not differ significantly between the groups. The effectiveness of probiotics, which also contain *Lactobacillus spp.* bacteria, has

been described, where weight gain is observed in the final growth phase (Palamidi, 2016). Positive results in weight gain were also shown in male strain ISA brown, to which *Lactobacillus acidophilus*, *Lactobacillus plantarum* and *Bifidobacterium spp*. in the feed were added (Agustono *et al*., 2022). In contrast, the results of the study, such as the addition of a mixture of *Bacillus spp.* to the diet, did not affect the live weight and feed conversion of broilers at the end of the study (Sugiharto *et al*., 2018). The study that used *Lactobacillus* strains also did not show a positive effect on live body wight and feed conversion (Olnood *et al*., 2015). It is explained that the effects of beneficial bacteria may depend on the age, sex of the animal, as well as microclimatic conditions, feed composition, etc. Under favorable conditions, where the animal is not exposed to the risk of disease, stress, the addition of probiotics to the feed may not give the expected results (Baurhoo, Phillip, & Ruiz-Feria, 2007; Ebeid, Al-Homidan, & Fathi, 2021).

Therefore, the aim of our study was to evaluate the effect of the mixture x of lactic acid bacteria on development of the broiler chicken digestive tract and the body weight.

Materials and Methods

Experimental design and management of broiler chickens

The study was conducted from April to December, 2021. The study was organised in three trials. The first trial was from April 21 to May 26. The second trial was from June 22 to July 27. The third trial was from November 10 to December 14. The study was performed at the Faculty of Veterinary Medicine, Latvia University of Life Sciences and Technologies, Jelgava, Latvia.

In each trial, 260 one day old Ross 308 broiler chicks (males and females) were obtained from a commercial hatchery. They were weighted and randomly divided in two groups – the control group and the probiotic group. The birds were placed in closed and ventilated similar pens, on a deep litter system of wood shavings. The lighting program was 23h light and 1h dark at the first day. Afterwards, the dark hours were slowly extended to 18h light and 6h dark from day 7 till the day 26. Afterwards, dark hours were slowly reduced to 20h light and 4h dark till the end of the study. The temperature of the first week of life was 33-34 ℃, and it was slowly decreased to 22 ℃ until the end of experiment. Fresh drinking water was provided *ad libitum*. The dietary treatments was basal diet for the control group and basal diet + the mixture X of lactic acid bacteria 4 g 10 kg^{-1} for the probiotic group. The mixture X is a bio active substances complex based on probiotic strains of heat-inactivated lactic acid bacteria – *Lactobacillus farciminis* CNCM-I-3699 – 2.10^{10} CFU/g and *Lactobacillus rhamnosus* CNCM-I-3698 – 2.10^{10} CFU/g, which is activated upon entering the digestive tract. Also in other authors' works, these lactic acid bacteria strains are mentioned as probiotics used in animal feed as an additive (Tareb, Bernardeau & Vernoux, 2015; Tareb *et al.*, 2015). The mixture is in a powder form, stable at room temperature.

The broilers were fed with Starter diet from day 0 to day 10, Grower diet from day 11 to day 24 and Finisher diet from day 25 till the end of the study. The main sources of the protein in the basal diet are wheat grain, soyabean and rape. The analytical composition of the feed is summarized in Table 1.

oilers were raised till day 35. All broilers were weighted in day of the placing and afterwards on the day 7, 14, 21, 28, 35 all birds of both groups with, used calibrated scales 'Soehnl' (±1g), average body weight was calculated for each group. At the day 1, 7, 14, 21, 28, 35 of age 15 birds per treatment were randomly selected and killed by cervical dislocation. The gastrointestinal tract was excised (proventriculus,

Table 1

Analytical composition of basal diet

Components	Starter diet, %	Grower diet, %	Finisher diet, %
Crude protein	22.50	21.50	19.50
Crude fiber	2.40	2.86	2.83
Crude fat	4.24	5.20	7.22
Crude ash	4.32	4.73	3.68
Lysine	1.36	1.20	1.14
Methionine	0.84	0.60	0.85
Calcium (Ca)	0.96	1.00	0.78
Sodium (Na)	0.35	0.16	0.19
Phosphorus (P)	0.50	0.50	0.50

gizzard, intestines) and weighed with content, used calibrated scales 'Kern EW 420-3NM' (±0.01g), average organ relative weight (percentage of each bird's live weight) was calculated for each group.

Statistical data analysis

The assumption of normal data distribution was assessed using the Shapiro–Wilk test and visual inspection of their histograms and normal Q–Q plots. The assumption of homogeneity of variances was tested using the Levene test. To determine whether there were statistically significant differences between three independent groups, we used the Kruskal–Wallis H test with pairwise comparisons using Dunn's procedure with Bonferroni adjustment. To determine whether there were statistically significant differences between two independent groups, we used the independent samples T test or Mann-Whitney U test.

Results and Discussion

Comparative analysis of the trials showed that the data come from one population ($p > 0.05$). Therefore, to increase the power of analysis and the precision of the results obtained, we combined data from three trials.

The results about the average body weight are summarized in Table 2. The initial body weight for the probiotic and the control groups is considered to be bred appropriately and did not differ between the probiotic and the control groups ($p > 0.05$), meaning the output data will not affect further results. The initial body weight is very important factor in broiler production. Mendes et al. (2011) have studied that birds with an initial weight of 39.29-41.30g at 42 days of age weigh 1.98% more than birds with an initial weight of 39.9-41.3g. However, Patbandha *et al*. (2017) have studied that chickens with high initial body weight (47.76g ±0.37) gained significantly more weight (19.65g, $P \leq 0.05$) than those with low initial weight (41.24g ±0.23) up to day 15, but body weight did not differ on later age among the groups.

We see a tendency for the probiotic group to gain weight slightly faster than the control group, but basically body weight did not differ between probiotic and control groups on all weighting days ($p > 0.05$). Similar results were obtained by Olnood et al. (2015), when the mixture of *Lactobacillus* strains on a basal diet did not increase live weight and feed conversion at the end of the study.

The results about the relative weight of gastrointestinal tract parts are summarized in Table 3. There are various trends. The relative weight of the proventriculus is slightly higher in the probiotic group than in the control group up to day 14, but later in the age the weight is equalized between groups and in the control group it is slightly milder than in the probiotic group at the end of the study. The relative weight of the gizzard on day 21 is slightly higher in the probiotic group than in the control group, but does not differ on other weighing days. Intestinal relative weight increases to day 7 in both groups and then gradually decreases until the end of the study. The relative weight of the gastrointestinal tract remains relatively high until day 7 of age in the probiotic group and the control group, 16.61g ±1.74 and 16.76g ±2.12, respectively, it decreases with increasing body weight.

In general, the weight of relative gastrointestinal tract parts did not differ between the probiotic and control groups ($p > 0.05$). Overall, this study achieved very good results in both groups. This could be explained by the fact that in favourable conditions, where the bird is not exposed to the risk of disease, stress, as in the case of our study, the addition of probiotics to the feed may not give the expected results. Various factors that could affect the results have been described in the literature, such as the age, sex of the bird, as well as microclimatic conditions, feed composition, etc. (Baurhoo, Phillip, & Ruiz-Feria, 2007).

We compared these results with Awad *et al*. (2009) study (Awad study). Used the same broiler cross in both studies – Ross 308. Housing conditions were similar, like bedding were wood shawings, broilers were raised till day 35. The *Lactobacillus*

Table 2

Body weight

Trial day	Probiotic group		Control group		p
	mean value, g	SD	mean value, g	SD	
Initial weight (n=130)	45.40	2.03	44.64	1.92	0.331
Day 7 (n=115)	209.89	14.30	211.32	18.55	0.460
Day 14 (n=100)	588.86	49.50	582.43	43.46	0.437
Day 21 (n=85)	1,184.88	114.55	1,168.62	91.11	0.428
Day 28 (n=70)	1,962.612	100.52	1,957.71	101.94	0.480
Day 35 (n=55)	2,835.7	161.74	2,828.02	115.64	0.475

Table 3

Organ relative weight

Trial day	Parameter	Probiotic group (n=15)		Control group (n=15)		p
		Mean value, %	SD	Mean value, %	SD	
Day 1	Gastrointestinal tract	16.9	1.91	16.77	1.18	0.742
	Proventriculus	1.02	0.09	1.04	0.07	0.4
	Gizzard	7.48	0.79	7.62	0.57	0.442
	Intestines	8.41	1.34	8.11	0.94	0.332
Day 7	Gastrointestinal tract	16.61	1.74	16.76	2.12	0.763
	Proventriculus	0.96	0.18	0.92	0.13	0.377
	Gizzard	4.74	0.68	4.77	0.78	0.852
	Intestines	10.92	1.3	11.07	1.69	0.696
Day 14	Gastrointestinal tract	13.34	1.02	13.45	1.2	0.693
	Proventriculus	0.71	0.15	0.64	0.09	0.058
	Gizzard	3.77	0.34	3.67	0.4	0.317
	Intestines	8.85	0.83	9.14	1.06	0.246
Day 21	Gastrointestinal tract	11.08	1.5	10.8	1.19	0.423
	Proventriculus	0.5	0.08	0.52	0.08	0.49
	Gizzard	2.94	0.45	2.05	1.11	0.051
	Intestines	7.64	1.19	8.11	1.91	0.254
Day 28	Gastrointestinal tract	9.04	0.58	9.04	0.76	0.986
	Proventriculus	0.41	0.06	0.43	0.1	0.274
	Gizzard	2.36	0.38	2.36	0.39	0.941
	Intestines	6.28	0.6	6.25	0.72	0.87
Day 35	Gastrointestinal tract	7.94	1.22	7.81	1.45	0.707
	Proventriculus	0.36	0.05	0.4	0.11	0.099
	Gizzard	1.81	0.51	1.85	0.51	0.777
	Intestines	5.77	1.19	5.56	1.32	0.532

spp. products for probiotic groups are used in both studies.

Comparing initial body weight of chicken from the probiotic group significantly differs between this study (mean = 45.39 SD = 1.90) and mean value (mean = 40.85) of Awad study, a significant difference is 4.54, 95% CI [3.92 – 5.16], t = 14.92, df = 38, p< 0.001, d = 2.39. The same is with chicken from the control group on the 1st (0) day of experiment significantly differs between this study (mean = 44.81 SD = 2.08) and mean value (mean = 40.32) of Awad study, a significant difference is 4.49, 95% CI [3.82 – 5.17], t = 13.47, df = 38, p< 0.001, d = 2.16.

On the one hand, based on the available literature, it can be stated that the initial body weight is very important for the chicken to achieve a good increase in live weight during its lifetime. As it has been shown in Mendes et al. (2011) study, where birds with an initial weight of 39.29-41.30g at 42 days of age weigh 1.98% more than birds with an initial weight of 39.9-41.3g. On the other hand, Patbandha *et al.* (2017) have studied that chickens with high initial body weight gained significantly more weight (19.65g, p≤0.05) than those with low initial weight up to day 15, but body weight did not differ on later age among the groups.

At the end of the study, body weight of chicken from the probiotic group at day 35 of experiment significantly differs between this study (mean = 2,771.80, SD = 271.92) and mean value (mean = 1,765.51) of Awad study, a significant difference is 1,006.29, 95% CI [904.75-1,107.83], t = 20.27, df = 29, p< 0.001, d = 3.70, also the same with body weight of chicken from the control group at day 35 of experiment that significantly differs between this study (mean = 2,816.0, SD = 252.39) and mean value (mean = 1,753.64) of Awad study, a significant difference is 1,062.32, 95% CI [968.12-1,156.60], t = 23.05, df = 29, p< 0.001, d = 4.21. Other studies are available that have achieved a better body weight

than study Awad. Shah *et al.* (2021) have described that body weight of the control group (CTL), probiotic group (CP) supplemented with commercial product that also contained lactic acid bacteria and probiotic group (SP) supplemented with *Enterococcus spp.* and *Pediococcus spp.* gained 2,293.75g 2,533.75g un 2,503.00g, respectively ($p<0.05$). Comparing the results of this study with the results of Shah *et al*. (2021) study, we still have gained better body weight on day 35.

There is no difference of chicken's proventriculus relative weight in the probiotic group at day 35 of the experiment between this study and Awad study, $p = 0.310$, as well as no difference in the control group, $p = 0.703$.

The relative weight of chicken's gizzard from the control group on day 35 of experiment significantly differs between this study (mean =1.85, SD = 0.51) and mean value (mean = 2.30) of Awad study, a significant difference is 0.45, 95% CI [0.26-0.65], $t = - 4.825$, $df = 29$, $p< 0.001$, $d = 0.88$. The relative weight of chicken's gizzard from the probiotic group on day 35 of experiment that significantly differs between this study (mean =1.81, SD = 0.46) and mean value (mean = 2.28) of Awad study, a significant difference is 0.47, 95% CI [0.30-0.64], $t = - 5.563$, $df = 29$, $p< 0.001$, $d = 0.92$. This could be explained by the fact that, as the bird grows and the muscle mass increases, the relative weight of the gizzard decreases in proportion. A large increase in live weight was achieved in this study, resulting in a lower relative weight of gizzard than in the Awad study, where such a high body weight was not achieved.

Conclusions

Exploring other studies, we can conclude that this study achieved very good body weight results in both groups, which could be explained by the favourable housing conditions (no risk of diseases, stress), the daily regime and initial body weight which contributed to this significant weight gain. Comparing with similar studies with *Lactobacillus spp.* products at the end of the study body weight of chicken from the probiotic group on day 35 of experiment significantly differ between this study and mean value of Awad study, also the same with body weight of chicken from the control group.

Various trends were observed in the study, but overall the weight of chickens and the relative weight of gastrointestinal tract parts did not differ between the experimental and control groups ($p > 0.05$). In order to evaluate the effect of mixture of lactobacilli x on the development of the digestive tract of broiler chickens, the study with histological samples should be continued.

Acknowledgements

This study was funded by the ESF project 'Transition to the new doctoral funding model at the Latvia University of Life Sciences and Technologies' (No. 8.2.2.0/20/I/001), Latvia University of Life Sciences and Technologies program 'Realisation of Fundamental research at LLU' project G7 'Changes in postnatal ontogenesis, health status and greenhouse gas emissions of broiler chickens after addition of a new composition of probiotic mixture to bedding and feed' (No. 3.2.-10/273) and AS 'Putnu fabrika Ķekava'.

References

Abudabos, A.M., Al-Batshan, H.A., & Murshed, M.A. (2015). Effects of prebiotics and probiotics on the performance and bacterial colonization of broiler chickens. *South African Journal of Animal Science.* 45(4), 419–428. DOI: 10.4314/sajas.v45i4.8.

Adhikari, A., & Kim, W.K. (2016). Overview of prebiotics and probiotics: focus on performance, gut health and immunity – a review. *Annals of Animal Science.* 14(4), 949–966. DOI: 10.1515/aoas-2016-0092.

Ajuwon, K.M. (2015). Toward a better understanding of mechanisms of probiotics and prebiotics action in poultry species. *The Journal of Applied Poultry Research*. 25(2), 277–283. DOI: 10.3382/japr/pfv074.

Al-Khalaifa, H., Al-Nasser, A., Al-Surayee, T., Al-Kandari, S., Al-Enzi, N., Al-Sharrah, T., Ragheb, G., Al-Qalaf, S., & Mohammed, A. (2019). Effect of dietary probiotics and prebiotics on the performance of broiler chickens. *Poultry Science.* 98(10), 4465–4479. DOI: 10.3382/ps/pez282.

Augustono, B., Lokapirnasari, W.P., Yunita, M.N., Kinanti, R.N., Cesa, A.E., & Windria, S. (2022). Efficacy of dietary supplementary probiotics as substitutes for antibiotic growth promoters during the starter period on growth performances, carcass traits, and immune organs of male layer chicken. *Veterinary World.* 15(2), 324–330. DOI: 10.14202/vetworld.2022.324-330.

Awad, W.A., Ghareeb, K., Abdel-Raheem, S., & Böhm, J. (2009). Effects of dietary inclusion of probiotic and synbiotic on growth performance, organ weights, and intestinal histomorphology of broiler chickens. *Poultry Science.* 88(1), 49–56. DOI: 10.3382/ps.2008-00244.

Baurhoo, B., Phillip, L., & Ruiz-Feria, C.A. (2007). Effects of purified lignin and mannan oligosaccharides on intestinal integrity and microbial populations in the ceca and litter of broiler chickens. *Poultry Science*. 86(6), 1070–1078. DOI: 10.1093/ps/86.6.1070.

Chen, F., Gao, S.S., Zhu, L.Q., Qin, S.Y., & Qiu, H.L. (2018). Effects of dietary Lactobacillus rhamnosus CF supplementation on growth, meat quality, and microenvironment in specific pathogen-free chickens. *Poultry Science.* 97, 118–123. DOI: 10.3382/ps/pex261.

Cosby, D.E., Cox, N.A., Harrison, M.A., Wilson, J.L., Buhr, R.J., & Fedorka-Cray, P.J. (2015). Salmonella and antimicrobial resistance in broilers: a review. *Journal of Applied Poultry Research.* 24(3), 408–426. DOI: 10.3382/japr/pfv038.

Djuric, M. (2005, December). European union prohibits the use of antibiotics as growth promoters. Retrieved March 2, 2022, from https://www.cabi.org/animalscience/news/15063.

Ebeid, T.A., Al-Homidan, I.H., & Fathi, M.M. (2021). Physiological and immunological benefits of probiotics and their impacts in poultry productivity. *World's Poultry Science Journal.* 77(4), 883–899. DOI: 10.1080/00439339.2021.1960239.

Jha, R., Das, R., Oak, S., & Mishra, P. (2020). Probiotics (direct-fed microbials) in poultry nutrition and their effects on nutrient utilization, growth and laying performance, and gut health: a systematic review. *Animals.* 10(10), 1863. DOI: 10.3390/ani10101863.

Markowiak, P., & Slizewska, K. (2018). The role of probiotics, prebiotics and synbiotics in animal nutrition. *Gut pathogens.* 10(21). DOI: 10.1186/s13099-018-0250-0.

Mendes, A.S., Paixão, S.J., Restelatto, R., Reffatti, R., Possenti, J.C., de Moura, D.J., Morello, G.M.Z., & de Carvalho, T.M.R. (2011). Effects of initial body weight and litter material on broiler production. *Brazilian Journal of Poultry Science.* 13(3), 165–170. DOI: 10.1590/S1516-635X2011000300001.

Olnood, C.G., Beski, S.S., Choct, M., & Iji, P.A. (2015). Novel probiotics: their effects on growth performance, gut development, microbial community and activity of broiler chickens. *Animal Nutrition.* 1(3), 184–191. DOI: 10.1016/j.aninu.2015.07.003.

Palamidi, I., Fegeros, K., Mohnl, M., Abdelrahman, W.H.A., Schatzmayr, G., Theodoropoulos, G., & Mountzouris, K.C. (2016). Probiotic form effects on growth performance, digestive function, and immune related biomarkers in broilers. *Poultry Science.* 95(7), 1598-1608. DOI: 10.3382/ps/pew052.

Patbandha, T.K., Garg, D.D., Marandi, S., Vaghamashi, D.G., Patil, S.S., & Savsani, H.H. (2017). Effect of chick weight and morphometric traits on growth performance of coloured broiler chicken. *Journal of Entomology and Zoology Studies.* 5(6), 1278–1281.

Reuben, R.C., Sarkar, S.L., Roy, P.C., Anwar, A., Hossain, M.A., & Jahid, I.K. (2021). Prebiotics, probiotics and postbiotics for sustainable poultry production. *World's Poultry Science Journal.* 77(4), 825–882. DOI: 10.1080/00439339.2021.1960234.

Shah, S.M.T., Islam, M.T., Zabin, R., Roy, P.C., Meghla, N.S., & Jahid, I.K. (2021). Assessment of novel probiotic strains on growth, hematobiochemical parameters, and production costs of commercial broilers in Bangladesh. *Veterinary World.* 14(1), 97–103. DOI: 10.14202/vetworld.2021.97-103.

Sugiharto, S., Isroli, I., Yudiarti, T., & Widiastuti, E. (2018). The effect of supplementation of multistrain probiotic preparation in combination with vitamins and minerals to the basal diet on the growth performance, carcass traits, and physiological response of broilers. *Veterinary World*. 11(2), 240–247. DOI: 10.14202/vetword.2018.240-247.

Tareb, R., Bernardeau, M., Vernoux, J.P. (2015). Genome sequence of *Lactobacillus rhamnosus* strain CNCM I-3698. *Genome Announc.* 3(3), e00582-15. DOI: 10.1128/genomeA.00582-15.

Tareb, R., Bernardeau, M., Horvath, P., Vernoux, J.P. (2015). Rough and smooth morphotypes isolated from *Lactobacillus farciminis* CNCM I-3699 are two closely-related variants. *International Journal of Food Microbiology.* 193, 82–90. DOI: 10.1016/j.ijfoodmicro.2014.08.036.

Wang, X., Farnell, Y.Z., Peebles, E.D., Kiess, A.S., Wamsley, K.G.S., & Zhai, W. (2016). Effects of prebiotics, probiotics, and their combination on growth performance, small intestine morphology, and resident Lactobacillus of male broilers. *Poultry Science.* 95(6), 1332–1340. DOI: 10.3382/ps/pew030.

 DOI: 10.22616/rrd.28.2022.020

DECENTRALIZATION AND RURAL DEVELOPMENT: CASE STUDY OF UKRAINE

***Maksym Bezpartochnyi[1], Igor Britchenko[2]**
[1]National Aerospace University 'Kharkiv Aviation Institute', Ukraine
[2]Higher Institute of Insurance and Finance, Bulgaria
*Corresponding author's email: m.bezpartochnyi@khai.edu

Abstract
The formation of state-building processes requires the development of various sectors of the economy, and agriculture is no exception. In Ukraine, administrative-territorial reform was carried out, which led to the formation of administrative-territorial regulations (decentralization) – the creation of amalgamated territorial communities. Such formations are concentrated in cities, urban-type settlements and rural areas. The decentralization process has actively influenced the rural development in Ukraine. The aim of the study is to determine the directions of rural development in the decentralization process in Ukraine. It is based on the analysis of the current regulatory framework of Ukraine and the results of monitoring the decentralization process, as well as the assessment of the spheres of rural development in Ukraine (economic, social, environmental). The number of amalgamated territorial communities and residents, including ones in rural areas of Ukraine was analyzed. An assessment of the dynamics main indicators of agricultural activity in Ukraine was carried out, positive and negative trends were identified. A comparative analysis was conducted of the existing concept of rural development, based on state subsidies and the new one – through active investment in agriculture, development of promising activities in rural areas, attracting more actors and their collaboration. The results of study are the justification of current paradigm of rural development in Ukraine and the formation of appropriate concept. Prospects for rural development in decentralization are the introduction of entrepreneurship, diversification of agricultural production, investment in agriculture, increasing the economic entities in rural areas, increasing of employees and wages, introduction of organic agricultural production.
Key words: rural areas, development, decentralization, agriculture, amalgamated territorial community.

Introduction

The need to optimize the activities of administrative-territorial entities in Ukraine at all levels requires a fuller disclosure of socio-ecological, sectoral-technological and territorial-economic features of their development. The dynamic nature of the formation of public sector relations in the context of decentralization arose the need to determine fundamentally new approaches to administration. Specific conditions of the natural and social environment of rural areas in Ukraine, the formation of which is accompanied by ideological, political, social and economic factors and macro- and micro-levels, is characterized by instability, increasing asymmetries and imbalances, which requires certain socio-economic and administrative-informational influences to maintain the viability and management of the developing population. Strengthening integration processes in the world economic and political space determines the vector of national economic development, and a balanced domestic and foreign policy in the socio-economic sphere contributes to the realization of domestic potential, building sustainable strengths, including within local economies – rural areas.

Features and nature of changes in the current challenges in rural areas in Ukraine are the result of a significant number of subjective and objective aspects. Rural development is accompanied by a number of negative trends that indicate gaps in economic policy. This forces to intensify activities in the direction of decentralization of power and implementation of modern principles of economic reform of rural areas, because today a significant transformational aspect that determines the direction of socio-economic development of rural areas is the decentralization of governance.

The role of decentralization of management in the processes of socio-economic development of rural areas in Ukraine is crucial. The most important tasks of decentralization are to overcome economic disunity, deintegration processes, asymmetries and imbalances in rural development, which have affected a significant part of them, and that the relationship between public authorities and rural communities remains unbalanced and unsettled. As a result, most community initiatives to improve the efficiency of rural management have faced serious challenges. In this aspect, it is important to study the role of decentralization of management in the processes of socio-economic rural development.

The strengthening of this problem characterizes the process of Ukraine's integration into the European Union and requires a systematic solution to the problems of rural development. After all, the current state of the socio-economic situation of agriculture in Ukraine is characterized by declining living standards of the rural population, its partial degradation and impoverishment, low profitability of agricultural producers, reduced rural infrastructure, lack of financial support for small farms, ect.

Therefore, in modern conditions there is a need to develop conceptual provisions for rural development in Ukraine based on decentralization, search and attraction of financial resources necessary for continuous reproduction of the production process

and comprehensive rural development, which should be addressed through government, economic entities and directly rural residents. For the practical implementation of this task, an important and relevant issue is the coverage of theoretical and practical aspects of ensuring rural development in the context of decentralization in Ukraine.

Materials and Methods

The research methodology is based on the assessment of statistical data of the State Statistics Service of Ukraine (2017-2021) on the state of rural development in Ukraine and the Ministry of Community and Territorial Development of Ukraine on the implementation of decentralization and monitoring the results of local government reform. The study of the dynamics of territorial reform and the formation of amalgamated territorial community (ATC) was carried out using the methods of statistics, analysis and synthesis based on the principle of determinism. Comparative and structural research methods were used in the process of scientific research of rural development in Ukraine.

Defining the problem of research and ways to solve it is based on a comprehensive approach to the elaboration of scientific achievements of scientists, historical experience of rural development, regulations and author's developments. So, Parker considers the problems of reducing poverty in rural areas through decentralization and rural development programs. In the paper, Parker analyzes the level implementation of rural development programs and points to the need to assess their components of decentralization. The author proposes conceptual model that combines elements of political, fiscal and institutional decentralization and indicates that it will promote rural development (Parker, 1995). In research, the literature on decentralization and rural development is analyzed the concept proposed and methods of decentralization identified; participants in the process and types of participation in rural areas indicate obstacles to participation in decentralization processes in rural areas. (Shakil & Noraini, 2011). Craig explores the problem of implementing decentralization for the development of poor rural areas. The author notes that the bureaucratic system of hierarchy hinders the introduction of decentralization in poor rural areas, points to limited access to information for rural residents, states that there are problems with control over the implementation of decentralization processes; democratic institutions and political activities need to be improved (Craig, 2001).

Results and Discussion

Ukraine has always had significant potential in agriculture. Rural areas in Ukraine provide raw materials and agricultural products for the city. Employment in agriculture has always been high, the process of urbanization has shown a high rate, but since the early 90's of the twentieth century, it has virtually stopped. Ukraine is experiencing a protracted economic crisis, accompanied by declining activity, deteriorating socio-economic indicators, cities are losing part of their traditional economy, which is replaced by imports of goods and services, reducing the need for new labor due to lower living standards and migration. The deterioration of the crisis in Ukraine's economy has also affected rural areas. The collapse of collective farms with their inefficient, labor-intensive production has led to sharp decline in employment among the rural population, degradation of the social sphere of the village, sharp decline in population, especially in remote and small villages.

In this situation, many attempts have been made at the state level to support the village, starting with the very old, still essentially Soviet Law of Ukraine 'On State Support to Agriculture of Ukraine', but no positive changes have taken place (June 24, 2004). The reasons were different, the main role being played by the ratio of prices for industrial and agricultural products, as well as weak state financial support for producers of agricultural products. Examples of the significant level of state subsidies for agriculture in EU countries have always been cited as explanations for this. This is partly true, but rather large subsidies to agriculture in the EU have not led to stable development of rural areas, stopping their depopulation. The results of research by leading European researchers and the focus of EU governments on solving problems of development of their territories through the creation of smart city concepts, have led to transformation of approaches to rural development.

Rural development in Ukraine focuses on three components of rural life: economic, social and environmental (Figure 1).

In order to ensure the effective development of territories and improve local self-government, maintain decent standard of living, organize and provide quality public services, harmonize the interests of local communities and the state, decentralization reform was introduced in Ukraine.

In Ukraine, decentralization reform was launched in 2014 through the adoption of the Concept of Local Self-Governance and Territorial Power Reforming in Ukraine (April 1, 2014), Laws of Ukraine 'On Cooperation of Territorial Communities' (June 17, 2014), 'On Voluntary Amalgamation of Territorial Communities' (February 5, 2015), amendments to the Budget and Tax Codes on financial decentralization.

This process in accordance with the provisions of the European Charter of Local Self-Government (European Charter, 1985) allowed to form an effective

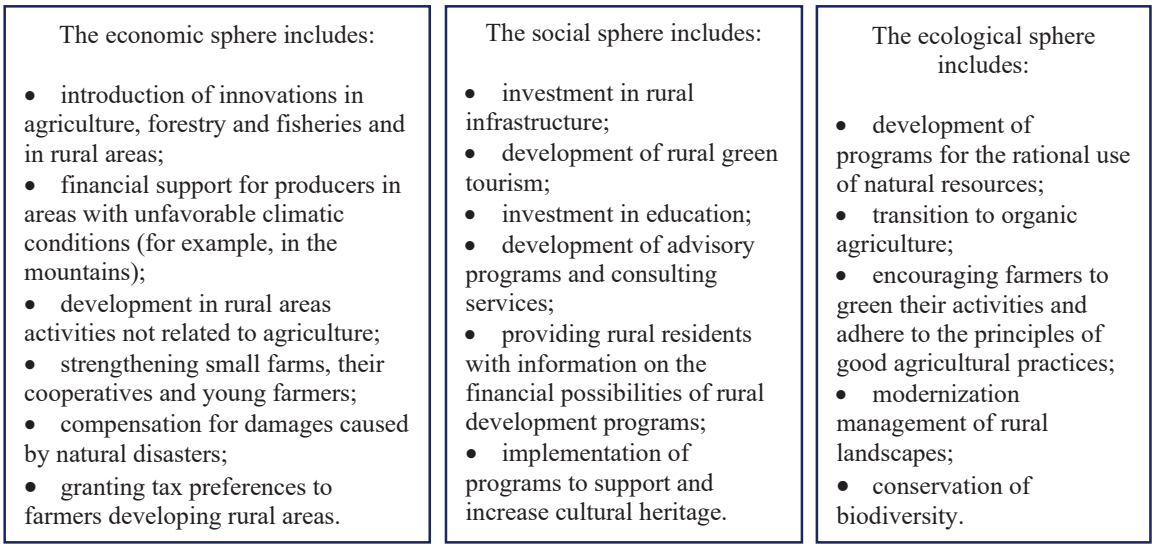

Figure 1. Spheres of rural development in Ukraine (authors' vision).

and capable institution of local self-government – amalgamated territorial community (ATC).

The importance of decentralization process in Ukraine is that the formation of ATC primarily concerns rural and urban cities of district importance of communities. As a result of the formation of ATC, rural areas now have the opportunity to merge with urban areas, as communities will be formed in Ukraine where there are rural and urban settlements, and where cities will have a direct impact on rural areas. Even purely rural ATCs formed around villages are empowered to make decisions that were previously uncharacteristic of village councils, as well as finances that will be directed to their own needs and ensure their growth.

In accordance with Law of Ukraine 'On Amendments to Certain Laws of Ukraine Concerning the Definition of Territories and Administrative Centers of Territorial Communities' (April 16, 2020), the Cabinet of Ministers of Ukraine in 2021 identified administrative-territorial centers and approved the territories of 1469 capable ATCs. Of these, 882 urban-type settlements and 28,372 rural settlements were formed (Table 1). The number of territorial communities in Ukraine has increased 6.8 times in 5 years. Due to the consolidation of settlements in cities and districts of the country, the number of urban-type settlements and rural settlements decreased by 3 and 5 units, respectively. Dnipropetrovsk, Zhytomyr, Cherkasy, Zaporizhia and Volyn showed the best results in the overall ranking of Ukrainian regions in terms of ATC formation, while Kharkiv, Donetsk and Zakarpattia regions showed the lowest results.

The reform of decentralization has created driving force for the formation of a viable and closest to the citizens institution of power – local self-government. Voluntary association of territorial communities allowed the newly formed local governments to obtain the appropriate powers and resources that previously had cities of regional importance. The interests of citizens living in the united community are now represented by the elected chairman, deputies and executive bodies of the community council, which ensure the exercise of statutory powers in the interests

Table 1

Administrative-territorial structure of basic level (communities) in Ukraine, 2017-2021

Years	Territorial communities	Cities	Areas in cities	Urban-type settlements	Rural settlements
2017	216	460	111	885	28377
2018	458	461	108	883	28378
2019	686	461	108	883	28376
2020	841	461	108	882	28376
2021	1469	461	108	882	28372

Source: created by authors based on Monitoring of local government reform and territorial organization of government for 2021.

Table 2

Resident population of ATCs in Ukraine, 2017-2021

Years	Population – total, persons			Share of population, %		
	Urban and rural areas	Urban area	Rural area	Urban and rural areas	Urban area	Rural area
2017	42584542	29482313	13102229	100,00	69,23	30,77
2018	42386403	29370995	13015408	100,00	69,29	30,71
2019	42153201	29256696	12896505	100,00	69,41	30,59
2020	41902416	29139346	12763070	100,00	69,54	30,46
2021	41588354	28959536	12628818	100,00	69,63	30,37

Source: created by authors based on Monitoring of local government reform and territorial organization of government for 2021.

of the community. In the settlements that are part of the united community, the right of residents to local self-government and the provision of services to citizens is guaranteed by their elected elders. According to the Law of Ukraine 'On Voluntary Amalgamation of Territorial Communities', the increase and unification of communities was carried out through voluntary unification, taking into account the opinion of citizens. When planning for the creation of communities, it is mandatory to identify the potential resource opportunities of the community for economic and social development and the ability to provide quality services to the population.

The population of ATCs in Ukraine, including rural areas and its share is presented in Table 2. Over the past five years, the population of Ukraine has decreased by 996,2 thsnd. persons or 2.34%. The population of rural areas for the corresponding period decreased by 473,4 thsnd. persons or 3.61%. During the period under study, there was a decrease in the share of rural population, in 2021 its share was 30.37%.

The key indicators of agriculture in Ukraine are presented in Table 3. During the study period, the number of enterprises engaged in agricultural activity in Ukraine decreased by 3,225 units or 4.21%. There is negative dynamics of decreasing the number of enterprises engaged in agricultural activity in Ukraine every year. Agricultural lands have similar dynamics, which in 4 years decreased by 906 thsnd. ha (2.18%). The number of people employed in agriculture in Ukraine decreased by 139,5 thsnd. persons. In 2020, the share of those employed in agriculture was 17.19% of the total number of people employed in the country's economy. A positive trend in agriculture of Ukraine is an increase of average monthly nominal weight – it increased by 61.09%.

The volume of activity in agriculture depends on sown areas, crop yields, production technologies, natural and climatic conditions, the cost of material resources, ect. Output in agriculture in Ukraine increased by 26.15% for four years. The increasing of gross value added in Ukraine is due to higher selling

Table 3

Key indicators of agriculture in Ukraine, 2017-2020

Indicators	2017	2018	2019	2020
Number of enterprises engaged in agricultural activity, units	76593	76328	75450	73368
Agricultural land, thsnd. ha	41489,3	41329,0	41310,9	40583,3
Employment, thsnd. persons	2860,7	2937,6	3010,4	2721,2
percentage to total	17,73	18,12	18,25	17,19
Average monthly nominal wage, UAH	6057	7557	8856	9757
Output in agriculture, fact prices; mln. UAH	707792	847587	842767	892852
Gross value added, fact prices; mln. UAH	303419	360998	356563	388428
percentage to total	12,15	12,08	10,41	10,85
Financial results before taxation, mln. UAH	68606,5	70770 ,2	93553,6	81596,7
Net profit, mln. UAH	68276,8	70461,8	92892,9	81032,6
Profitability level of all types of activity, percentage	16,52	14,24	16,68	13,93
Profitability level of operating activities, percentage	23,23	18,94	19,82	19,06

Source: created by authors based on Agriculture of Ukraine for 2020.

Table 4

Current and past paradigm of rural development in Ukraine

	Past paradigm	Current paradigm
Objects	Equalization, income and competitiveness of farms	Improving the efficiency use of rural areas and unused resources, development of local initiatives
Sphere of activity	Production of agricultural products	Various industries, including entrepreneurship, crafts, information technology, rural tourism
Support tools	State financial support	Financial instruments and investments
Key actors	National government	Public authorities at all levels, local authorities, private business, NGOs, R&D personnel

Source: authors' generalization.

prices for agricultural products. In 2020, gross value added increased by 28.02% compared to 2017. In 2020, gross value added amounted to 10.85% of total in the country's economy. Financial results before taxation in 2020 decreased by 18.93% compared to 2017. In 2019, we note the maximum value of this indicator, which is associated with rising prices for agricultural products. Taking into account production costs and other operating costs, we get positive result in agriculture for the study period; net profit increased by 18.68%. In 2020, the profitability level of all types of activity and operating activities is 13.93% and 19.06%, respectively. During the study period, negative trend is the decrease in profitability. Changes in key indicators in agriculture of Ukraine in 2019-2020 are due to fluctuations in agricultural markets, changes in supply and demand for agricultural products, the price situation in connection with the COVID-19 pandemic.

Decentralization in Ukraine has formed the current paradigm of rural development, which has diametrically opposed characteristics to the past paradigm (Table 4).

In terms of development opportunities, rural areas in Ukraine differ from urban areas in the following ways: low population density; small number of enterprises and entrepreneurs; focus of people on employment in agricultural production; insufficient mobility of rural residents; low level of the implementation of innovation and scientific research; less accessible public services and services needed by people at the place of residence.

These differences are extremely important for deciding to start business, because in market environment, it is important for businesses to make the most profit. In rural areas with the above characteristics, businesses that require a large number of employees or are focused on local markets, work is not as comfortable and profitable as in large cities or urban areas with high population density. Therefore, traditional approaches to rural development policy have been reduced (and still used) to essentially subsidize agricultural production in order to raise farmers' incomes not through market instruments but through the state aid.

Often such subsidy was calculated per hectare of land / arable land for the farmer. Over the years, subsidies per hectare of arable land have given rise to the experience of misusing such subsidies. So the farmer who has in addition to a small farm, 20-50 hectares of arable land, some other service station, sawmill or hotel, the surcharge from the state per hectare of land was very satisfying and he often just stopped cultivating land, and spent the money on other activities that are unrelated to agriculture. Such cases became not uncommon and only confirmed the ineffectiveness of subsidies per hectare of arable land for rural development.

The artificial increase in farmers' incomes through subsidies did not stop the depopulation of rural areas, as technology increasingly penetrated agricultural production and led to natural reduction in the number of people employed in such production, it also did not improve the social situation in such areas. The formal increase in farmers' incomes through subsidies did not deter people in rural areas, as the level of services and social security in these areas remained lower than that received by urban residents. In order to improve public services to rural residents, local authorities used equalization tools in addition to subsidizing farmers.

However, the rapid development of technologies, which on the one hand reduces the need for people for certain types of production, on the other hand, these technologies allow people to find themselves in other areas of activity that were previously closed to them. The latest technologies, design and technological solutions that have emerged in recent years, both in agriculture and in other sectors of the economy allow to do business in areas with lower population density.

The latest communication technologies, biotechnologies, new energy, creative and cultural economy, segmental tourism have become new areas of human activity in rural areas. New technologies

in agricultural production allow to raise labor productivity here and achieve greater competitiveness of the agricultural sector in open global markets. In the conditions of the new paradigm caused by decentralization, the agricultural sector needs fewer subsidies, which is positive for the budget, but the highly productive agricultural sector will also need fewer employees, which is negative for rural areas. That is why the policy of support is changing: from targeting support through subsidies to the agricultural sector to supporting integrated rural development. Thus, subsidies per unit of arable land are replaced by investment in specific projects; the priority of increasing farm incomes through subsidies is replaced by the priority of strengthening the competitiveness of territories, and the focus on the agricultural sector in rural areas is inferior to the formation or development of multisectors that exist in rural areas.

Another key difference between the past and the current paradigm of rural development is the change of the main actor in politics. If in the past paradigm it is the national government, in the current paradigm it is public authorities at all levels, and the role of local authorities will now be constantly growing. Partnerships between the government (local authorities, rural communities, local activists), business and academia are now involved in shaping and implementing rural development policies in the new paradigm.

The quality of rural development in Ukraine in the conditions of decentralization significantly depends on local government structures. Therefore, cooperation with the EU within the framework of the Association Agreement is designed to introduce best practices of local self-government for the development of local initiatives (Association agreement between…, 2014).

It will also facilitate the decentralization process of decision-making taking into account the needs of rural development in Ukraine.

As a result of the implementation of On Approval of the Concept of Rural Development, the following goals are achieved:

1) an increase in the number of rural population and reduction of the mortality rate of rural population to the corresponding indicator in cities;

2) an increase in the level of wages in agriculture; over the last 4 years, the average wage in agriculture increased from 6,057 UAH in 2017 to 9,757 UAH in 2020 (Table 3);

3) an increase in the number of jobs in rural areas to 1 million persons. In February 2020, the Government of Ukraine announced plans to create 200,000 new jobs in rural areas over the next 5 years and equalize the level of wages in rural areas at the national average from 85% to 100% (Programme of Activity …, 2019);

4) an increase in the number of employed rural population by 1.5 times (Programme of Activity …, 2019). According to the State Statistics Service of Ukraine and the Pension Fund of Ukraine, the number of employed people aged 15-70 in rural areas during the last 4 years fluctuates within 53.61% (Agriculture of Ukraine…, 2021);

5) an increase in the share of income in rural households from entrepreneurship and self-employment to 15%. By 2024, more development opportunities are planned for rural residents through attracting direct investment in agriculture; increase the list of state support programs; creation of special fund; business incubators for 5,000 participants who are ready to create small and medium enterprises; new mechanisms for cooperation; support for organic producers; ATC measures to increase the comfort of residents (Programme of Activity …, 2019);

6) an increase in the share of organic certified agricultural land to 7%, of which arable land – up to 5%. By 2024, the number of state support programs should increase and the support of organic producers should improve (Programme of Activity …, 2019).

Conclusions

1. Based on historical research, the factors that inhibited the rural development in Ukraine have been identified. The characteristic of economic, social and ecological spheres of rural development in Ukraine is defined and given.
2. Based on the analysis of current regulatory framework of Ukraine, the decentralization process and its impact on rural development were studied. Using the statistical information of monitoring the decentralization process in Ukraine, the administrative-territorial structure of the basic level was determined. An assessment of dynamics of the number of ATCs and the number of urban-type and rural settlements was carried out. The number of residents in rural areas is analyzed and the dynamics of their reduction and the share is determined.
3. An assessment of the key indicators of agriculture in Ukraine for 4 years is made. Positive and negative tendencies are revealed in indicators: the number of enterprises engaged in agricultural activity, agricultural land, employment, average monthly nominal wage, output in agriculture, gross value added, financial results before taxation, net profit, profitability. The main changes relate to the volume of agricultural production, production costs and pricing system, market conditions of agricultural products and more.
4. It is established that positive direction of decentralization in Ukraine to form the current

paradigm of rural development, which involves ensuring the competitiveness of rural areas through more efficient use of agricultural resources, diversification of rural activities and active entrepreneurship, investment, attracting more actors – public authorities, private business, NGOs and scientists. On this basis, the effective direction is collaboration between different actors (including public-private partnerships) for fuller use of resource potential, development and implementation of socio-economic projects and strategies, involvement of rural residents and rural development.

5. A comparative analysis of the rural support system was conducted according to the old paradigm, which provides subsidies for agriculture in rural areas and the new paradigm through the active introduction of investments and modern technologies for managing production processes. In the future, given the available resource potential in agriculture and favorable opportunities for agriculture, the implementation of the concept of rural development and further decentralization in Ukraine will provide investment from domestic and foreign investors in the latest communication technologies, biotechnology, new energy, which will provide gradual development of rural areas. Active involvement of large agricultural holdings in the process of rural development will have a synergistic effect.
6. Prospects for rural development in Ukraine can also be achieved by organizing production in rural areas according to European principles of farming (family type with a small number on private property), promoting agricultural cooperation by establishing production and service cooperatives, implementing support programs for local agricultural producers, ensuring competitiveness and improving the quality of agricultural products and raw materials, expanding the product range, introducing new types of services provided by financial-credit institutions and local governments.

References

Council of Europe. (1985). *European Charter of Local Self-Government*. Strasbourg. Retrieved February 11, 2022, from https://rm.coe.int/168007a088.

Craig, J. (2001). *Local Democracy, Democratic Decentralisation and Rural Development: Theories, Challenges and Options for Policy*. Retrieved February 11, 2022, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.467.3242&rep=rep1&type=pdf.

EU. (2014). *Association agreement between the European Union and its Member States, of the one part, and Ukraine*, of the other part March 21, 2014. Brussels. Retrieved February 11, 2022, from https://trade.ec.europa.eu/doclib/docs/2016/november/tradoc_155103.pdf.

Koncepciya reformuvannya miscevogo samovryaduvannya ta terytorialnoyi organizaciyi vlady. Rozporyadzhennya vid 01.04.2014 r. No. 333-p (*Concept of Local Self-Governance and Territorial Power Reforming*). Prescription of 01.04.2014 No. 333-p. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/333-2014-%D1%80#Text. (in Ukrainian).

Ministry for Communities and Territories Development of Ukraine. (2022). Monitorynh reformy mistsevoho samovriaduvannia ta terytorialnoi orhanizatsii vlady v 2021. (*Monitoring of local government reform and territorial organization of government for 2021)*. Kyiv. Retrieved February 11, 2022, from https://decentralization.gov.ua/uploads/library/file/800/10.01.2022.pdf. (in Ukrainian).

Parker, A. (1995). *Decentralization: the way forward for rural development?* Washington, DC: World Bank, Agriculture and Natural Resources Dep., Sector Policy and Water Div. DOI: 10.1596/1813-9450-1475.

Pro derzhavnu pidtrymku silskogo gospodarstva Ukrayiny. Zakon Ukrainy vid 24.06.2004 r. No. 1877-IV (*On State Support to Agriculture of Ukraine*). Law of Ukraine of 24.06.2004 No. 1877-IV. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/1877-15#Text. (in Ukrainian).

Pro dobrovilne obyednannya terytorialnyh gromad. Zakon Ukrainy vid 05.02.2015 r. No. 157-VIII (*On Voluntary Amalgamation of Territorial Communities*). Law of Ukraine of 05.02.2015 No. 157-VIII. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/157-19#Text. (in Ukrainian).

Pro Programu diyalnosti Kabinetu Ministriv Ukrayiny. Postanova Verhovnoyi Rady Ukrayiny vid 04.10.2019 r. No. 188-IX (*Programme of Activity of the Cabinet of Ministers of Ukraine*). Resolution of the Verkhovna Rada of Ukraine of 04.10.2019 No. 188-IX. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/file/text/75/f488621n7.docx. (in Ukrainian).

Pro shvalennya Koncepciyi rozvytku silskyh terytorij. Rozporyadzhennya vid 23.09.2015 r. No. 995-p (*On Approval of the Concept of Rural Development*). Prescription of 23.09.2015 No. 995-p. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/995-2015-%D1%80#Text. (in Ukrainian).

Pro spivrobitnycztvo terytorialnyh gromad. Zakon Ukrainy vid 17.06.2014 r. No. 1508-VII (*On Cooperation of Territorial Communities*). Law of Ukraine of 17.06.2014 No. 1508-VII. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/1508-18#Text. (in Ukrainian).

Pro vnesennya zmin do deyakyh zakoniv Ukrayiny shhodo vyznachennya terytorij ta administratyvnyh centriv terytorialnyh gromad. Zakon Ukrainy vid 16.04.2020 r. No. 562-IX (*On Amendments to Certain Laws of Ukraine Concerning the Definition of Territories and Administrative Centers of Territorial Communities*). Law of Ukraine of 16.04.2020 No. 562-IX. Retrieved February 11, 2022, from https://zakon.rada.gov.ua/laws/show/562-20#Text. (in Ukrainian).

Shakil, A., & Noraini, T. (2011). Decentralization and participatory rural development: A literature review. *Contemporary Economics,* 5:4, 58–67.

State Statistics Service of Ukraine. (2021). *Agriculture of Ukraine for 2020*. Kyiv. Retrieved February 11, 2022, from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2021/zb/09/zb_sg_20.pdf.

 DOI: 10.22616/rrd.28.2022.021

SELECTION OF COMPANIES FOR STUDENT INVOLVEMENT IN WORK-BASED LEARNING

Ilze Brante[1,2], *Biruta Sloka[2]
[1]Ogres Tehnikums, Latvia
[2]University of Latvia, Latvia
*Corresponding author's email: Biruta.Sloka@lu.lv

Abstract
Work-based learning takes place in education of competitive employees with required professional qualifications, skills, competence in Latvia. Researchers in many countries in different parts of the globe in their academic research are investigating factors influencing work-based learning. In successful work-based learning all involved stakeholders are important and influential: vocational education institution and its teaching staff and management of this vocation education institution, company where students spend part of their education and skills development process. There are several important aspects recognised as very significant and valuable for consideration in involvement of students in work-based learning analysed in scientific research and reflected in respective scientific internationally peer-reviewed publications as well as taken into account in creation of legislative frame for work-based learning and practical implementation of work-based learning with optimal solutions in many countries on the globe and also in the Republic of Latvia. The aim of the research is to analyse aspects of student involvement in work-based learning process. Research methods applied: analysis of scientific peer-reviewed publications, analysis of statistical data related to analysis of tendency of number of vocational education establishments with trend analysis and case studies on work-based learning. Results indicate that there are many requirements for companies to involve students in work-based learning.
Key words: work-based learning, company, vocational education.

Introduction

Work-based learning takes place in education of competitive employees in Latvia which has been realised already for several years and respective legislative regulations are prepared and implemented. There are several important aspects for involvement of students in work-based learning analysed in scientific research as well as taken into account in creation of legislative frame and practical implementation of work-based learning. Work-based learning takes place in education of competitive employees with required professional qualifications, skills, competence in Latvia. Researchers in many countries in different parts of the globe in their academic research are investigating factors influencing work-based learning. In successful work-based learning all involved stakeholders are important and influential: vocational education institution and its teaching staff and management of this vocation education institution, company where students spend part of their education and skills development process. There are several important aspects recognised as very significant and valuable for consideration in involvement of students in work-based learning analysed in scientific research and reflected in respective scientific internationally peer-reviewed publications as well as taken into account in creation of legislative frame for work-based learning and practical implementation of work-based learning with optimal solutions in many countries on the globe and also in the Republic of Latvia. The aim of the research is to analyse aspects of student involvement in work-based learning process. Research methods: investigation of scientific peer-reviewed publications, analysis of statistical data related to vocational education establishment number analysis with trend analysis and case studies on work-based learning.

Materials and Methods

Materials and empirical research methods used: analysis based on results reflected in scientific peer-reviewed publications, analysis of tendency of number of vocational education establishment analysis with trend analysis and case studies on work-based learning. For statistical data on analysis on tendency, the following is used: the total number of vocational schools (programmes of vocational education and professional secondary education can be acquired) in the Republic of Latvia. From the CSB report 'Vocational Education Institution' data are obtained on the activities of vocational education institution (foreign language acquisition by students, foreign teachers and funding of a vocational education institution). Data collection on vocational schools in Latvia - data on the operation of a vocational education institution (number of enrollments by educational programs and school years, numbers and shares of enrolled students by age and by sex, number of teachers) are obtained from State Education Information System of the Ministry of Education and Science of Republic of Latvia. Information on vocational school entrants and graduates of the vocational education is collected annually from October 1 till September 30 as on October 1 all agreements for involvement in vocational education have to be signed by vocational education institution

and by the student at respective vocational education institution (Official Statistics portal, 2022). For time series of vocational education establishment empirical data is applied to the trend analysis of statistical data and case studies of vocational education organisation, and practical realisation on work-based learning involving all stakeholders (vocational education teaching staff, employers and entrepreneurs, public administration representatives and vocational education students) in the organisation and realisation of work-based learning.

Theoretical Findings

Researchers in many countries on several aspects of work-based learning in academic research are analysed from different angles with many important findings for possible practical use – like application and practical exploration of domains and elements of integrated training competency model through work-based learning (Ciptono *et al*., 2021) including important part of pedagogical aspects of inter-professional workplace learning with analysis (Baerheim & Raaheim, 2020; Smith, 2010; Sergejeva & Aboltins, 2020; Romanova *et al*., 2018) of different case studies indicating importance of student views, organisation of vocational education and vocational education school management attitude. Work-based learning has been chosen by many researchers as the field of deeper study (Gibbs, 2011; Salisbury & Jephcote, 2010) and has been covered by many researchers world-wide. The contribution of professional education to entrepreneurship innovation and competitiveness (Brante & Sloka, 2021a) is analysed on importance of aspects influencing entrepreneurship of work-based learning (Brante & Sloka, 2021b) and several aspects for realisation of competitive vocational education experience of Latvia already taking place for several years. Researchers (Cangialosi, Odoardi, & Battistelli, 2020) have investigated the three-way interaction model of innovative behaviour useful for organisation of vocational education, task-related learning, and job characteristics as they are recognised as an important part of work-based learning for several firm size and differences of work-based learning processes realisation in different sectors (Bishop, 2020; Sergejeva, Aboltins, & Atslega, 2021) stressing that different sector needs and specifics are important for respective sector and have to be considered also for vocational education organisation and realisation. Researchers (Sauli, Wenger, & Berger, 2021) recognise the aspects on supporting apprentices integration of vocational school and work-based learning in different countries with remarkable results in Swiss initial vocational education and training which could be studied and considered also in other countries. Requirements for discipliniarity and work (Fergusson & van der Laan, 2021) which are very important for work-based learning realised as an emergeng transdisciplinary mode of study and getting increasing importance for sustaining work-based learning (Namjoshi *et al*., 2021) what has been confirmed also during the special requirements for work-based learning in Covid-19 pandemic conditions. Program coherence and integration of vocational education school and work-based learning in different countries with special attention to the Icelandic dual vocational education and training (VET) system (Namjoshi *et al*., 2021) analysis by researchers also on pedagogical aspects (Burke *et al*., 2009) and practical experience and recommendations could be useful for other countries. Self-design project based learning as part of work-based learning and alternative learning model for vocational education (Hamdani & Suherman, 2021) has been recognised for consideration. Different countries have different experience. First successful realisation of work-based learning was conducted in the Netherlands where a very deep analysis of work-based learning in Dutch vocational education experience by their considerable experience in connecting learning places, learning content and learning processes (Onstenk, 2017; Onstenk & Blokhuis, 2007) has indicated important aspects in organisation of work-based learning especially by connecting school with companies and application of gained knowledge, skills and competence in the best possible way. Also, researchers have investigated experience of work-based learning in Spain (López Fogués, 2017) and in Germany analysing the areas of learning and several aspects of the shift towards work and competence orientation within the school-based vocational education has already been well-known for a long time as well as analysed German dual apprenticeship system (Gessler, 2017; Gessler & Howe, 2015) in detail, and made comparisons of practical findings in different countries (Pilz, 2007) with practical findings useful also for other countries. Sweden vocational education has also valuable experience discussed in academic research (Fjellström & Kristmansson, 2016) whose findings are practically usable for policy development. Employability aspects of graduates from vocational education schools (Mishra, Alseddiqi, & Pislaru, 2009) are on researchers agenda. Efficiency of realisation of college and career readiness program (Detgen *et al*., 2021) in work-based learning has been recognised as valuable bridge to employment and competitiveness in labour market and scaling of competitive workforce development by using MOOCs to reduce several costs by different stakeholders and narrow the skills gap required by entrepreneurs (Rosendale & Wilkie, 2021; Seimuskane, Vilka, & Brekis, 2017) as an important part of vocational education organisation and realisation in compliance

of labour market needs. Researchers in investigation of mediating effects of school engagement between high school on-time completion which sometimes is a problem, career development and technical education realisation (Xing & Gordon, 2021; Batraga *et al*., 2019; Esmond & Atkins, 2020) stressing the importance of work-based learning where public administration attitude is important (Savrina & Seimuskane, 2018), on analysis of matching vocational training and labour market demands with investigation of the opinion of public administrations on different levels – state and municipality (Buligina & Sloka, 2013), importance of marketing tools (Salkovska *et al*., 2020; Kalkis, Graveris, & Roja, 2021) and ergonomic aspects (Kalkis, Andza, & Roja, 2021) and perceptions and practical realisation on the role of practical and simulated learning in promoting successful entrepreneurship start and realisation (Lose, 2021) having importance also in work-based learning.

Results and Discussion

The number of vocational schools in Latvia is reducing almost every year in recent decades – see data in Figure 1.

Data indicate that the number of vocation schools in Latvia reduced on average by 4.4 schools annually, it indicates that vocational education is becoming more concentrated in best vocational education establishments transferred in well-equipped education centers where work-based learning is organised with significant involvement of entrepreneurs in education process.

More and more attention is paid in vocational education schools to work-based learning with good results in realisation of this education.

Involvement of students in WBL, company selection takes place:

1. Based on the company's request. A company representative conducts a job interview. During the interview, the student justifies his / her choice to study in the chosen profession, his / her current experience related to the chosen profession.

2. A vocational education institution offers a student a WBL internship place from its database, taking into account the company's compliance with WBL implementation.

3. The student chooses the place of WBL practice, taking into account the company's compliance with WBL implementation.

It should be noted that students differ in their character traits, interest in learning a profession, work ability, attitudes towards studies and work. All companies want to involve very good students into practice, not so much in terms of their level of knowledge, but in terms of their attitude towards work and their responsibilities, integrity, dedication and punctuality.

Companies in the realisation of work-based learning are involved on a voluntary basis. In order to involve a company in the successful implementation of work-based learning, it is necessary to carry out:

1. great explanatory work, which takes place both individually and in cooperation with professional organizations and local governments in the field:

1.1. business seminars organized by the local government;

1.2. seminars organized by sectoral professional organizations;

1.3. events organized in vocational education institutions, meeting with entrepreneurs in the sector;

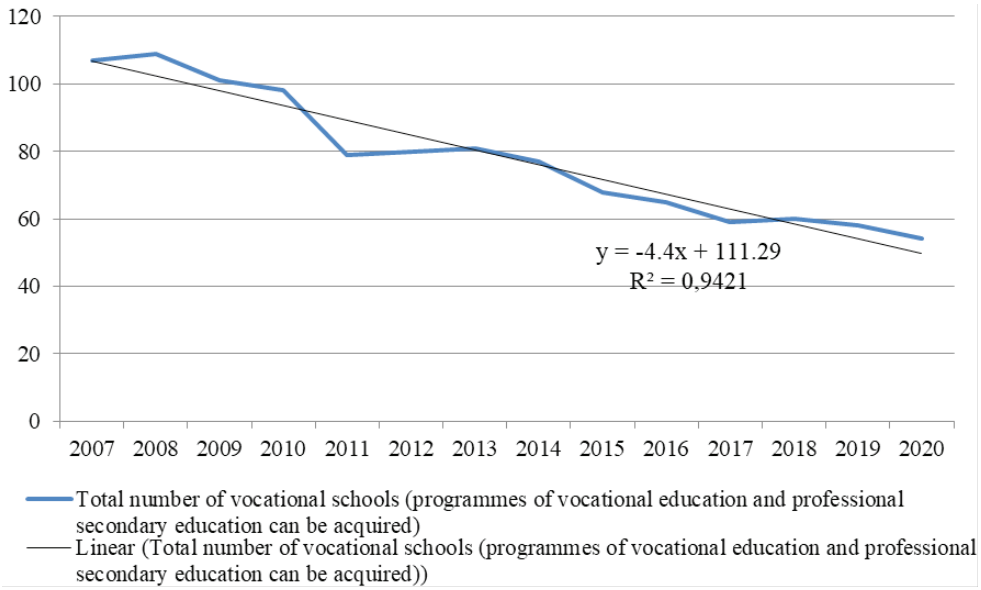

Figure 1. Number of vocational schools in Latvia in 2007-2020.

Source: Author's construction and calculation based on Official Statistics database IPP010.

1.4. events organized in companies, student study tours in companies;

1.5. the vocational education institution meets individually with entrepreneurs.

2. preparation of informative material, presentation on the benefits of the company in implementing WBL;

3. Establishment of a database of companies that meet the requirements for WBL provision.

Requirements for each WBL participant are now set at a national level.

When concluding a cooperation agreement with a company on the implementation of WBL, a vocational education institution fulfills several conditions:

1) In close and well-designed co-operation with the enterprise, develops and approves an individual plan for the implementation of WBL for each student, determining the accepted before proportion of the theory and practice of the professional content needed for the respective specialisation of the educational program in the respective vocational education institution and respective enterprise;

2) Provide or approve a company selected by the student for the implementation of the individual plan for each student;

3) Evaluates and makes a decision on the company's compliance with the implementation of the individual studies and training plan;

4) Ensures the conclusion of a training contract of each student after the approval of the individual plan of studies and work;

5) Introduces each student to:

5.a) The objectives, tasks as well as content of the individual plan for each student;

5.b) The basic principles of the implementation of the content of the individual plan for studies/work and the assessment on regular basis of the student's learning and work achievements;

5.c) Indicates each student rights as well as obligations during the implementation of the individual plan of each student;

6) If necessary, provides the student with support for transport and service hotels during the implementation of the individual plan for each student and could cover the related transportation and accommodation expenses;

7) Determines the responsible coordinating person for work-based learning implementation in the vocational education institution and the selected and accepted enterprise;

8) Provides necessary methodological support to realisation of the work-based learning manager in the respective company who supervises and manages the implementation of the vocational education student's accepted individual plan;

9) Ensures that the lesson record is completed on the basis of the accepted content of the student's individual plan and assessment on regular basis of the student's knowledge, professional skills and competences agreed with the selected company during the implementation of the student's individual plan;

10) Performs the evaluation of the student's knowledge, student's level of professional skills and professional abilities, observing the accepted main principles and realisation procedures for the evaluation of vocational secondary education with work-based learning and competitive vocational education taking into account the accepted regulatory framework regarding the state vocational secondary education standard;

11) Ensures the insurance of the student's possible accidents during the implementation of the accepted student's individual plan, determining in the insurance student's life, student's health and student's physical condition of the student as the object of respective insurance;

12) Implements co-operation on regular basis with the sectoral expert councils involving employers regarding the promotion of the vocational education quality, efficiency of vocational education and compliance of the implementation of vocational education in the relevant sector with the respective requirements of the labor market in realisation of work-based learning.

The vocational education institution is among the most important stakeholder in realisation of a system for work-based learning management and establishes:

1. Structure of work-based learning participants involving

1.1) Deputy Director of vocational education institution for Education and Practical Training responsible for work-based learning training in general;

1.2) Head of the study department of the vocational education institution who is responsible for the realisation of the study schedule in the vocational education institution and respective company involved in work-based learning;

1.3) Head of the Department of Educational Programs who is responsible for the development and practical implementation of the content of the internship program for successful vocational education and implementation of the student's individual plan;

1.4) Supervisor from the vocational education institution responsible for practical placement or practice in close co-operation with the practice supervisor from the company on the work-based learning process in accordance with the accepted student's individual plan.

2. Prepared and accepted document by vocation education institution - order on the responsibilities of each participant involved in work-based learning.

The company involved in realisation of work-based learning fulfills several conditions in the preparation

of the agreement with the respective vocational education institution on the implementation of work-based learning:

1) Ensures that a WBL practice manager is assigned to the company;

2) At the beginning of WBL, provides instruction to the student on labor protection issues and introduces the company's rules of procedure;

3) Ensures the implementation of WBL for each student in accordance with the accepted individual plan of each student respecting the respective company's internal regulations, labor protection aspects, required fire safety and electrical safety realisation as well as respecting sanitary and hygienic norms of each company;

4) Provides with individual labor protection means for each student during the realisation of the individual plan in accordance with the regulations in the company related to labor protection requirements, using personal protective equipment;

5) Supervises the student in the company during the realisation of the accepted individual plan;

6) Determines the number of students accepted to one work-based learning supervisor in the company;

7) Submits to the educational institution the evaluation of the student's knowledge, student's professional skills and student's abilities regarding the realisation of the accepted student's individual plan;

8) Enters into the employment contract of the student or his or her legal representative aspects related to legal relations of employment or an agreement regarding the award of a work-based scholarship (as there could be several possibilities);

9) Implements co-operation with the respective sectoral expert councils on the promotion of the quality of respective vocational education program, efficiency of the respective program and compliance of the implementation of vocational education in the relevant sector corresponding with the requirements of the labor market needs in the situation of realisation of work-based learning;

10) Ensures the student's civil liability insurance during the realisation of the accepted student's individual plan in accordance with the accepted student's study contract.

In order to ensure the quality of WBL implementation, several requirements are set for the WBL practice manager in the company:

1. The WBL practice manager must have pedagogical competence in the company. The WBL practice manager in the company has several opportunities to prove his / her pedagogical competence:

1.a) The head of the WBL practice has the professional qualification as the involved teacher;

1.b) The head of WBL practice needs to have pedagogical knowledge and competence which are requested in the program for the improvement of teachers' professional competence improvement qualification courses in the amount of at least 72 academic hours;

1.c) The head or so called supervisor of WBL practice has pedagogical knowledge and skills obtained by acquiring the educational program for WBL managers in the amount of not less than 32 academic hours.

2. The WBL practice manager in the company must have the following professional knowledge:

2.a) The head of WBL practice in the company has the qualification of recognised experienced and certified craftsman recognised by the Latvian Chamber of Crafts and with an official certificate on relevant master practice;

2.b) The WBL internship manager in the company has officially recognised professional education in the respective industry;

2.c) The WBL internship manager has at least three years of professional work experience in the respective industry.

3. WBL practice manager in the company is able to ensure and guarantee the realisation of the accepted student's individual plan in the respective company and prepare the student's assessment realisation and preparation of relevant documentation;

4. The head of WBL practice in the company complies or corresponds with the agreed requirements specified in Section number 72 of the Law on the Protection of the Rights of the Child (if the student has reached certain age when he/she is an adult and can make his/her decisions).

Conclusions

1. Number of vocational education establishments is reducing during the last decade and the vocational education is concentrated in best equipped vocational education schools and many of them are involved in work-based learning.
2. Work-based learning is important in educating professionals for competitive labour market and includes finding of common language and co-operation with employers, with public administrations and education institution management to organise part of education at work place.
3. Big challenges for optimal organisation of work-based learning is to educate practice managers at work-place to comply with requirements for pedagogical skills and ability to teach students as most of them are excellent professionals and not so skilled in teaching.
4. Management of municipalities have different attitude for involvement in work-based learning with excellent results when all stakeholders are interested in co-operation.

5. Research results indicate that there are many requirements for companies to involve students in work-based learning.

Acknowledgements

The research is supported by National Research Program 'INTERFRAME-LV', No. VPP-IZM-2018/1-0005.

References

Baerheim, A., & Raaheim, A. (2020). Pedagogical aspects of interprofessional workplace learning: a case study. *Journal of Interprofessional Care*, 34(1), 59–65. DOI: 10.1080/13561820.2019.1621805.

Batraga, A., Salkovska, J., Braslina, L., Legzdina, A., & Kalkis, H. (2019). New innovation identification approach development matrix**.** *Advances in Intelligent Systems and Computing*, 783, 261–273. DOI: 10.1007/978-3-319-94709-9_26.

Bishop, D. (2020). Firm size and workplace learning processes: a study of the restaurant sector. *European Journal of Training and Development*, 44(2-3), 305–320. DOI: 10.1108/EJTD-08-2019-0139.

Brante, I., & Sloka, B. (2021a). The Contribution of Professional Education to Entrepreneurship Innovation and Competitiveness. *Regional Formation and Development Studies*, 2(34), 18–25. DOI: 10.15181/rfds.v34i2.2241.

Brante, I., & Sloka, B. (2021b). Work-based Learning – Challenge for Competitive Vocational Education Experience of Latvia. *Journal of Service, Innovation and Sustainable Development*, 2(1), 62–71. DOI: 10.33168/SISD.2021.0105.

Buligina, I., & Sloka, B. (2013). Matching vocational training and labour market demands – The opinion of public administrations. *Economic Research*, 26, 299–310. DOI: 10.1080/1331677X.2013.11517653.

Burke, L., Marks-Maran, D.J., Ooms, A., Webb, M., & Cooper, D. (2009). Towards a pedagogy of work-based learning: Perceptions of work-based learning in foundation degrees. *Journal of Vocational Education and Training*, 61(1), 15–33. DOI: 10.1080/13636820902819917.

Cangialosi, N., Odoardi, C., & Battistelli, A. (2020). Three-way Interaction Model of Innovative Behavior, Task-Related Learning, and Job Characteristics. *Performance Improvement Quarterly*, 33(2), 153–172. DOI: 10.1002/piq.21322.

Ciptono, A., Abd Samad, N., Hassan, R., Muslim, S., & Ismail, A. (2021). Exploration of domains and elements of integrated training competency model through work-based learning (Wbl). *Journal of Technical Education and Training,* 13(3), 201–212. DOI: 10.30880/jtet.2021.13.03.020.

Detgen, A., Fernandez, F., McMahon, A., Johnson, L., & Dailey, C.R. (2021). Efficacy of a College and Career Readiness Program: Bridge to Employment. *Career Development Quarterly*, 69(3), 231–247. DOI: 10.1002/cdq.12270.

Eiríksdóttir, E. (2020). Program coherence and integration of school-and work-based learning in the Icelandic dual vocational education and training (Vet) system. *Education Sciences*, 10(11), 1–17. DOI: 10.3390/educsci10110314.

Esmond, B., & Atkins, L. (2020). VET Realignment and the Development of Technical Elites: Learning at Work in England. *International Journal for Research in Vocational Education and Training*, 7(2), 193–213. DOI: 10.13152/IJRVET.7.2.4.

Fergusson, L., & van der Laan, L. (2021). Disciplinarity and Work: Work-Based Learning as an Emergent Transdisciplinary Mode of Study. *World Futures*, 77(7), 508–531. DOI: 10.1080/02604027.2021.1984158.

Fjellström, M., & Kristmansson, P. (2016). Learning as an apprentice in Sweden: A comparative study on affordances for vocational learning in school and work life apprentice education. Education and Training, 58(6), 629–642. DOI: 10.1108/ET-12-2015-0113.

Gessler, M. (2017). Areas of learning: The shift towards work and competence orientation within the school-based vocational education in the German dual apprenticeship system. *Technical and Vocational Education and Training*, 23, 695–717. DOI: 10.1007/978-3-319-41713-4_32.

Gessler, M., & Howe, F. (2015). From the reality of work to grounded work-based learning in German vocational education and training: Background, concept and tools. *International Journal for Research in Vocational Education and Training*, 2(3), 214–238.

Gibbs, P. (2011). Work-based learning as a field of study. *Professional and Practice-based Learning*, 4, 11–22. DOI: 10.1007/978-90-481-3933-0_2.

Hamdani, A., & Suherman, A. (2021). Self-design project based learning: An alternative learning model for vocational education. *Journal of Technical Education and Training*, 13(3), 67–78. DOI: 10.30880/jtet.2021.13.03.007.

Kalkis, H., Andza, K., & Roja, Z. (2020). Physical Load and Preventive Measures in Metal Manufacturing Industry. *Advances in Intelligent Systems and Computing*, 1215, 48–55. DOI: 10.1007/978-3-030-51549-2_7.

Kalkis, H., Graveris, I., & Roja, Z. (2021). Ergonomic Indicators and Physical Workload Risks in Food Production and Possibilities for Risk Prevention. *Lecture Notes in Networks and Systems*, 273, 47–53. DOI: 10.1007/978-3-030-80713-9_7.

López Fogués, A. (2017). Addressing mismatch in Spain: A concern and proposal beyond the economic sphere. Technical and Vocational Education and Training, 24, 355–368. DOI: 10.1007/978-3-319-47856-2_19.

Lose, T. (2021). Perceptions on the role of practical and simulated learning in promoting successful entrepreneurship. *Knowledge and Performance Management*, 5(1), 29–37. DOI: 10.21511/kpm.05(1).2021.03.

Mishra, R., Alseddiqi, M., & Pislaru, C. (2009). An improved employability skills model and its compliance through vocational educational system in Bahrain. *International Journal of Learning,* 16(9), 699–718. DOI: 10.18848/1447-9494/cgp/v16i09/46581.

Namjoshi, R., Pani, S., Despande, U., & Ranade, A. (2021). Sustaining work-based learning during the covid-19 pandemic. *Journal of Learning for Development*, 8(2), 412–430.

Official Statistics portal (2022). Official Statistics of Latvia, Responsible agency – Central Statistical Bureau of Latvia – database, IPP010.

Onstenk, J. (2017). Work-Based Learning (WBL) in Dutch Vocational Education: Connecting Learning Places, Learning Content and Learning Processes. *Professional and Practice-based Learning*, 18, 219–243. DOI: 10.1007/978-3-319-50734-7_11.

Onstenk, J., & Blokhuis, F. (2007). Apprenticeship in the Netherlands: Connecting school-and work-based learning. *Education and Training*, 49(6), 489–499. DOI: 10.1108/00400910710819136.

Pilz, M. (2007). Two countries - One system of vocational education? A comparison of the apprenticeship reform in the commercial sector in Switzerland and Germany. *Compare*, 37(1), 69–87. DOI: 10.1080/03057920601061802.

Romanova, I., Grima, S., Spiteri, J., & Kudinska, M. (2018). The payment services Directive II and competitiveness: The perspective of European fintech companies. *European Research Studies Journal*, 21(2), 3–22.

Rosendale, J., & Wilkie, L. (2021). Scaling workforce development: using MOOCs to reduce costs and narrow the skills gap. *Development and Learning in Organizations*, 35(2), 18–21. DOI: 10.1108/DLO-11-2019-0258.

Salisbury, J., & Jephcote, M. (2010). Mucking in and mucking out: Vocational learning in Animal Care. Teaching and Teacher Education, 26(1), 71–81. DOI: 10.1016/j.tate.2009.09.018.

Salkovska, J., Batraga, A., Braslina, L., Kalkis, H., & Legzdina, A. (2020). Four Conceptual Perspectives of Innovation Components, *Advances in Intelligent Systems and Computing*, 783, 72–82. DOI: 10.1007/978-3-030-20154-8_7.

Sauli, F., Wenger, M., & Berger, J.-L. (2021). Supporting Apprentices' Integration of School and Workplace-Based Learning in Swiss Initial Vocational Education and Training. *Research in Post-Compulsory Education*, 26(4), 387–409. DOI: 10.1080/13596748.2021.1980660.

Savrina, B., & Seimuskane, L. (2018). Income and Quality of Life Influence on Citizens' Participations in Activities of Local Governments in Latvia. CBU International Conference Proceedings 2018: Innovations in Science and Education, 6, 424–432. DOI: 10.12955/cbup.v6.1193.

Sergejeva, N., & Aboltins, A. (2020). Knowledge of mathematics and physics as basis for studies in engineering sciences. *Engineering for Rural Development*, 19, 1302–1307. DOI:10.22616/ERDev.2020.19.TF325.

Sergejeva, N., Aboltins, A., & Atslega, S. (2021). Problems and solutions of acquiring mathematical knowledge at university during COVID-19 crisis. *Engineering for Rural Development*, 20, 1266–1271. DOI: 10.22616/ERDev.2021.20.TF276.

Seimuskane, L, Vilka, I., & Brekis, E. (2017). Assessment of Socio-Economic Status Relevance for Latvian Electoral Participation, LOCAL GOVERNMENT AND URBAN GOVERNANCE IN EUROPE, 209–232.

Smith, P.H. (2010). Teaching assistant apprentices? English TAs' perspectives on apprenticeships in schools. *Journal of Vocational Education and Training*, 62(3), 367–380. DOI: 10.1080/13636820.2010.510250.

Xing, X., & Gordon, H.R.D. (2021). Mediating Effects of School Engagement between High School on-Time Completion and Career and Technical Education. *Vocations and Learning*, 14(1), 1–21. DOI: 10.1007/s12186-020-09252-2.

 DOI: 10.22616/rrd.28.2022.022

ANALYSIS OF FACTORS AFFECTING ZERO-WASTE FOOD CONSUMPTION IN SCHOOLS

***Juta Deksne**, **Lienite Litavniece**, **Anda Zvaigzne**, **Jelena Lonska**, **Sergejs Kodors**
Rezekne Academy of Technologies, Latvia
*Corresponding author's email: Juta.Deksne@inbox.lv

Abstract
The research aims to identify the factors affecting food waste and waste generation in schools and, consequently, barriers to zero-waste food consumption based on a systematic review of literature for the period 2015-2022. The research employed qualitative methods: systematic literature review, analysis and synthesis, as well as the monographic method. The literature review examined 1702 research papers and the abstracts. Using a PRISMA 2020 flow diagram, 54 papers were selected from the ScienceDirect, Scopus and Google Scholar databases for an in-depth analysis. Based on the literature review, 8 groups of factors that affected the generation of food waste in schools in the consumption process were identified: demographical, political, school food policy, environmental, socio-economic, personal/human, physical/human and geographical. The factors identified and aggregated might provide a basis for further discussions on zero-waste food consumption and food waste reduction in schools, as well as specific actions to optimize school food consumption and promote effective food and food waste management.
Key words: zero-waste, food consumption, factors, food waste.

Introduction

Every year, one third of the food produced for human consumption worldwide is lost or wasted at some stage in the food supply chain, totalling approximately 1.3 billion tonnes of food, which causes significant economic, social and environmental damage (Massari *et al*., 2021). To protect the planet and contribute to prosperity, in 2015 the UN developed the Sustainable Development Goals for 2030. Goal 12 involves ensuring responsible consumption and production patterns – it is necessary to halve global food waste per capita at the level of retailers and consumers, as well as reduce food losses in production and supply chains, which could help to ensure food security and shift to a more resource-efficient economy (UNDP, 2022).

In developed countries, raising awareness of food waste and loss is particularly important at the stage of consumption, which is the main source of food waste. In this respect, public school canteens create a unique environment that shows eating habits and the way the available resources are managed (García-Herrero *et al*., 2019). School canteens, where sustainable food consumption habits need to be passed on to future generations, produce a lot of food waste. There is a need to find a solution to the conflict between education on best practices and schoolchildren behaviour through incorporating school catering into a sustainability strategy (García-Herrero *et al*., 2021).

To date, the factors affecting food waste in schools in the consumption process have not been extensively researched in Latvia; therefore, the research aims to identify the factors affecting food waste and waste generation in schools and, consequently, barriers to zero-waste food consumption based on a systematic review of literature for the period 2015-2022. To achieve the aim, the following specific research tasks were set: to make a systematic literature review to identify the factors that hinder zero-waste food consumption in schools; to summarize the results and draw conclusions.

The zero-waste approach has been introduced not only in several industries of the economy but also in educational institutions (Munguía *et al*., 2018). Food consumption and food waste reduction is a social responsibility of every educational institution; therefore, food waste management requires a holistic approach to sustainable resource use and waste management (Hamid *et al*., 2020). Food waste relates to the final consumption stage and is a consequence of consumer behaviour (Principato *et al*., 2018); therefore, it is important to identify the factors that affect food waste and food waste generation in schools in order to optimize food consumption and promote effective food and food waste management.

Materials and Methods

The research employed qualitative methods: systematic literature review, analysis and synthesis, as well as the monographic method. The literature review examined 1702 research papers and the abstracts. Using a PRISMA 2020 flow diagram, 54 papers were selected from the ScienceDirect, Scopus and Google Scholar databases for an in-depth analysis.

Results and Discussion

Systematic literature reviews could be defined as a kind of research synthesis that is conducted to identify and obtain international evidence or practices and answer a specific question (Munn *et al*., 2018).

The research question is as follows: what factors affect food waste and food waste generation in schools and are therefore a barrier to zero-waste food consumption?

The process of selecting and synthesising the relevant literature is shown in Figure 1, i.e. a PRISMA

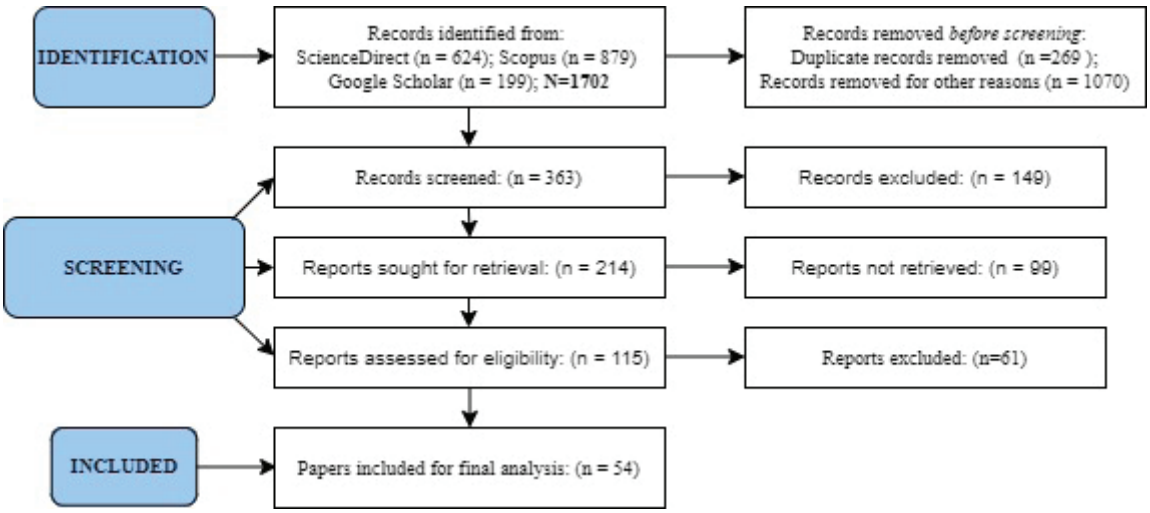

Figure 1. PRISMA 2020 flow diagram for new systematic literature reviews.
Source: authors' construction based on (Page *et al*., 2021).

2020 flow diagram, which was developed to help the researchers to clearly represent the process of literature selection (Page *et al*., 2021).

To select the most relevant literature, it is important to choose the right keywords (Linnenluecke, Marrone, & Singh, 2020; Tseng *et al*., 2019). Since food consumption closely relates to food waste, the authors chose the keywords 'food consumption in schools', 'food waste in schools', 'plate waste in schools' for the selection of research papers. Using the keywords and selecting the period of 2015 to 2022, several thousand papers were initially found, of which 1702 were selected using the advanced search technique (ScienceDirect – 624, Scopus – 879, Google Scholar – 199). Of the total, 269 overlapped and 1070 were excluded because of their titles. At the next step, 363 papers were left for screening, which were evaluated by the abstract, and 214 were left for reading. After analysing the papers, another 99 papers were excluded because they did not answer the research question. Finally, 54 out of the 115 most relevant papers were selected for further analysis.

Based on the literature review, 8 groups of factors that affected food waste in schools in the consumption process were identified.

Demographical factors. The amount of food waste in schools is significantly affected by the age of schoolchildren (Derqui & Fernandez, 2017; Park, Choi, & Kim, 2015). However, no unambiguous conclusions could be drawn based on the available research studies due to conflicting research findings that younger schoolchildren waste more than older ones (Niaki *et al*., 2017) and that the amount of food waste in educational institutions increases with age (Steen *et al*., 2018), and adolescents have a negative attitude towards school food (Tuorila *et al*., 2015). Based on the findings, children at the age of 6-7 years begin to form their food waste behaviour; therefore, environmentally friendly interventions aimed at reducing food waste should begin at this age (Sorokowska *et al*., 2020). Food consumption is also affected by gender (Park, Choi, & Kim, 2015; Qian *et al*., 2022a). It has been observed that boys tend to eat more food and are even willing to eat someone else's uneaten portion, thus producing less food waste than girls do (Moreno-Black & Stockard, 2018; Painter, Thondhlana, & Kua, 2016), whereas girls prefer fruits and vegetables, thus wasting less food of this category (Cerrah & Yigitoglu, 2022; Moreno-Black & Stockard, 2018). It is emphasized that the level of education also shapes food consumption behaviour (Chen & Chen, 2018; Qian *et al*., 2021; Qian *et al*., 2022a), i.e. the lower the level of education, the more food is wasted (Wu *et al*., 2019).

Political factors. School catering is governed by laws, regulations and policies at several levels, which must comply with a number of standards: hygiene, health, etc., as well as international standards and various regulations regarding procurement, waste management, etc. (Derqui, Fernandez, & Fayos, 2018; Priefer, Jörissen, & Bräutigam, 2016), not focusing on nutrition or taste issues (Göbel *et al*., 2015). In addition, the rigidity and inflexibility of procurement specifications in adjusting various foods (Falasconi *et al*., 2015) and issues related to catering policies and school catering management plays some role (Boschini *et al*., 2020). It has been found that changing school dietary guidelines reduced the amount of food waste of plant origin by up to 28%, and it is suggested that a healthy diet could be part of strategies to reduce food waste (Reynolds *et al.*, 2019). Schoolchildren comments and feedback from

the school kitchen are equally important, which helps to develop appropriate food waste reduction measures (Malefors, Eriksson, & Osowski, 2017). Often the main barrier to reducing food waste is inappropriate and unsupportive school policies, e.g. food is not allowed to be shared or taken away (Panizza *et al*., 2017; Zhao *et al*., 2019), which could relate to the old and common but ineffective habits (Persson Osowski *et al*., 2022). Schoolchildren's eating habits vary from school to school, yet the habits are strongly linked to school management priorities and positions regarding waste management and nutrition education for schoolchildren (Derqui & Fernandez, 2017; Torres-Pereda *et al*., 2020). Education, training, additional activities and awareness about nutrition, as well as the negative impacts of wasteful behaviour and food waste have been identified as key success factors in reducing food waste in schools (Chen & Chen, 2018; Schanes, Dobernig, & Gözet, 2018).

School food policy. Catering providers could have different strategies for planning and managing the catering process (Boschini *et al*., 2020; Pirani & Arafat, 2016). A lot of food waste is generated after cooking or serving the food, as well as because the food is not consumed before the expiry date (Ishangulyyev, Kim, & Lee, 2019). Canteen employee professional skills (Heikkilä *et al*., 2016) to cook well or reuse leftovers are also important (Pires *et al*., 2022). The menu and designing it are also considered to be important factors, as the reduction of food waste requires a change in practices, in particular improved planning and management based on past experience (Silvennoinen, Nisonen, & Pietiläinen, 2019), as the cause of additional food waste from school meals is associated with the composition of the menu, e.g. non-standard food (Prescott *et al*., 2019), the presence of alternative foods (Falasconi *et al*., 2015) or special diets in schools (Eriksson *et al*., 2017). Food leftovers could be reduced by providing enough time to eat (Kodors *et al*., 2022; Painter, Thondhlana, & Kua, 2016), as the amount of food waste is affected by the duration of lunch, a sense of urgency and a lack of time to eat (Burton *et al*., 2022; Painter, Thondhlana, & Kua, 2016; Qian *et al*., 2021; Silvennoinen, Nisonen, & Pietiläinen, 2019). Several research studies emphasized the role of a lunch supervisor as crucial, as a lack of control over food leftovers made by schoolchildren is a major source of food waste (Derqui & Fernandez, 2017; Martins *et al*., 2020). Teachers should be encouraged to have lunch with their schoolchildren, as they play an important role in shaping long-term eating habits (Martins *et al*., 2016). The different and unequal availability of resources in schools, e.g. kitchen facilities and human resources, can affect the amount of food waste generated (Derqui & Fernandez, 2017; Derqui, Fernandez, & Fayos, 2018). Too large portions are also one of the most important factors in food waste (Betz *et al*., 2015; Boschini *et al*., 2020; Pires *et al*., 2022; Shanks, Banna, & Serrano, 2017; Steen *et al*., 2018; Talwar *et al*., 2021), and reducing food waste could be achieved by simply reducing portions (Visschers, Gundlach, & Beretta, 2020) or by offering portions of different sizes (Vizzoto, Testa, & Iraldo, 2021). The size and shape of the plate also significantly affects the food waste generated (Betz *et al*., 2015; Priefer, Jörissen, & Bräutigam, 2016; Richardson, Prescott, & Ellison, 2021), with larger plate sizes generating more food waste per schoolchildren per meal (Qian *et al*., 2022a), which could be prevented by introducing smaller oval plates in catering establishments (Gwozdz *et al*., 2020), or by changing the size of the plates from large to small (Ravandi & Jovanovic, 2019). The design of food (Falasconi *et al*., 2015; Gwozdz *et al*., 2020) and the serving dishes are not less important (Talwar *et al*., 2021).

Environmental factors. There are many reasons for consuming and wasting food, including the environment in which schoolchildren eat (Shanks, Banna, & Serrano, 2017). The amount of food waste increases with the capacity of the dining hall, which is associated with increased levels of stress and noise (Steen *et al*., 2018). The availability of food at the school snack bar also increases food waste, which encourages schoolchildren to eat more than they can (Priefer, Jörissen, & Bräutigam, 2016). Schoolchildren waste less food if there is a positive atmosphere in the dining hall (Elnakib *et al*., 2021).

Socio-economic factors. Several researchers have pointed out that food waste is affected by the family's socio-economic status and income level (Park, Choi, & Kim, 2015; Qian *et al*., 2021; Qian *et al*., 2022a; Wu *et al*., 2019). The family's socio-economic status also affects schoolchildren's attitude to food, as it has been found that primary school children from families with lower socio-economic status associate healthy food with something tasty rather than tasteless, thus wasting less healthy food (van der Heijden *et al*., 2020).

Personal/human factors. The amount of food waste generated by school canteens is also affected by schoolchildren's eating habits (Shanks, Banna, & Serrano, 2017) and dietary choices (Moreno-Black & Stockard, 2018; Wu *et al*., 2019). It has been observed that food brought from home and breakfasts in the classroom generate less food waste in the school canteen (Farris *et al*., 2019); however, the schoolchildren who ate snacks high in saturated fat or calories in the morning, which cause loss of appetite at noon, were more likely to waste lunch food (Falasconi *et al*., 2015; Martins *et al*., 2020). School lunch food is adequate for schoolchildren's daily diet and is generally more nutritious than other foods, including those taken from home (Pagliarino, Santanera, &

Falavigna, 2021). Schoolchildren eating habits are extremely different, as it could be associated with the regularity of meals, the kind of breakfast, even the age at which schoolchildren start smoking (Park, Choi, & Kim, 2015), as well as their appetite (Martins *et al*., 2016; Wu *et al*., 2019), as food is wasted more when the schoolchildren are not hungry (Betz *et al*., 2015) or are not satisfied with the taste of the food served (Qian *et al*., 2021; Talwar *et al*., 2021) or other sensory properties of the food (Tuorila *et al*., 2015; Martins *et al*., 2020). It has been found that most of the schoolchildren discarded uneaten food from school lunch (60%), and much fewer did that at a restaurant (8%) (Mitchell & Prescott, 2020), which indicates that it is acceptable to discard unwanted food, but it is not acceptable to discard wanted food (Zhao *et al*., 2019). In addition, stress (Philippe *et al*., 2021), peers, pressure from others and the presence of other people during lunch (Qian *et al*., 2021; Qian *et al*., 2022a) can increase food waste. The behaviours of teachers and schoolchildren also affect food consumption (Blondin *et al*., 2018). In China, it is believed that the only child in the family is more likely to waste food than someone who has siblings (Qian *et al*., 2022a). People often blame other individuals for food waste and waste generation or mention other conditions that they cannot influence or control; therefore, knowledge and an in-depth understanding of food waste and personal attitudes could reduce the effects but not completely eliminate them (Malefors *et al*., 2022; Qian *et al*., 2021; Visschers, Gundlach, & Beretta, 2020).

Physical human factors. Food consumption is affected by body weight (Park, Choi, & Kim, 2015), metabolism (Shanks, Banna, & Serrano, 2017), as well as the body mass index (BMI); it was found that the lower the BMI, the higher the probability of food waste, and various tests showed that the slimmest participants tended to waste more food (Qian *et al*., 2022b).

Geographical factors. Attitudes to food waste vary from culture to culture (Qian *et al*., 2022a). The development of a menu and the wishes of schoolchildren are also associated with the region where the school is located; therefore, food waste differs for each kind of menu (Bustamente, Afonso, & De los Ríos, 2018).

The results show that a very wide range of factors affect food waste in schools in the consumption process, what should be taken into account developing effective strategies to reduce food waste in schools.

Conclusions

Comprehensive research studies on the problem of food consumption and waste in schools is available in the scientific literature. Using a PRISMA 2020 flow diagram and applying the systematic literature review method, 54 most relevant research papers were selected to answer the research question. Based on the literature review, 8 groups of factors were identified: demographical, political, school food policy, environmental, socio-economic, personal/human, physical/human and geographical, which affected food waste and food waste generation in schools and were therefore a barrier to zero-waste food consumption. The factors identified and aggregated might provide a basis for further discussions on zero-waste food consumption and food waste reduction in schools, as well as specific actions to optimize school food consumption and promote effective food and food waste management.

Acknowledgments

This research is funded by the Latvian Council of Science project ‘E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions’, project No. lzp-2020/2-0115.

References

Betz, A., Buchli, J., Göbel, C., & Müller, C. (2015). Food waste in the Swiss food service industry–Magnitude and potential for reduction. *Waste management*, *35*, 218–226. DOI: 10.1016/j.wasman.2014.09.015.

Blondin, S.A., Goldberg, J.P., Cash, S.B., Griffin, T.S., & Economos, C.D. (2018). Factors influencing fluid milk waste in a Breakfast in the Classroom School Breakfast Program. *Journal of nutrition education and behavior*, *50*(4), 349–356. DOI: 10.1016/j.jneb.2017.12.006.

Boschini, M., Falasconi, L., Cicatiello, C., & Franco, S. (2020). Why the waste? A large-scale study on the causes of food waste at school canteens. *Journal of Cleaner Production*, *246*, 118994. DOI: 10.1016/j.jclepro.2019.118994.

Burton, M., Wood, J.M., Booth, A.O., Worsley, A., Larsson, C., & Margerison, C. (2022). Enough time for lunch? The duration and governance of lunch eating times in Australian primary schools: A mixed-methods study. *Appetite*, *169*, 105817. DOI: 10.1016/j.appet.2021.105817.

Bustamente, M., Afonso, A., & De los Ríos, I. (2018). Exploratory analysis of food waste at plate in school canteens in Spain. *LA GRANJA. Revista de Ciencias de la Vida*, *28*(2), 20–42. DOI: 10.17163/lgr.n28.2018.02.

Cerrah, S., & Yigitoglu, V. (2022). Determining the effective factors on restaurant customers’ plate waste. *International Journal of Gastronomy and Food Science*, 100469. DOI: 10.1016/j.ijgfs.2022.100469.

Chen, C.R., & Chen, R.J. (2018). Using two government food waste recognition programs to understand current reducing food loss and waste activities in the US. *Sustainability*, *10*(8), 2760. DOI: 10.3390/su10082760.

Derqui, B., & Fernandez, V. (2017). The opportunity of tracking food waste in school canteens: Guidelines for self-assessment. *Waste management*, *69*, 431–444. DOI: 10.1016/j.wasman.2017.07.030.

Derqui, B., Fernandez, V., & Fayos, T. (2018). Towards more sustainable food systems. Addressing food waste at school canteens. *Appetite*, *129*, 1–11. DOI: 10.1016/j.appet.2018.06.022.

Elnakib, S.A., Quick, V., Mendez, M., Downs, S., Wackowski, O.A., & Robson, M.G. (2021). Food Waste in Schools: A Pre-/Post-Test Study Design Examining the Impact of a Food Service Training Intervention to Reduce Food Waste. *International journal of environmental research and public health*, *18*(12), 6389. DOI: 10.3390/ijerph18126389.

Eriksson, M., Osowski, C.P., Malefors, C., Björkman, J., & Eriksson, E. (2017). Quantification of food waste in public catering services–A case study from a Swedish municipality. *Waste Management*, *61*, 415–422. DOI: 10.1016/j.wasman.2017.01.035.

Falasconi, L., Vittuari, M., Politano, A., & Segrè, A. (2015). Food waste in school catering: An Italian case study. *Sustainability*, *7*(11), 14745–14760. DOI: 10.3390/su71114745.

Farris, A.R., Roy, M., Serrano, E.L., & Misyak, S. (2019). Impact of breakfast in the classroom on participation and food waste. *Journal of nutrition education and behavior*, *51*(7), 893–898. DOI: 10.1016/j.jneb.2019.04.015.

García-Herrero, L., De Menna, F., & Vittuari, M. (2019). Food waste at school. The environmental and cost impact of a canteen meal. *Waste Management*, *100*, 249–258. DOI: 10.1016/j.wasman.2019.09.027.

García-Herrero, L., Costello, C., De Menna, F., Schreiber, L., & Vittuari, M. (2021). Eating away at sustainability. Food consumption and waste patterns in a US school canteen. *Journal of Cleaner Production*, *279*, 123571. DOI: 10.1016/j.jclepro.2020.123571.

Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P., & Ritter, G. (2015). Cutting food waste through cooperation along the food supply chain. *Sustainability*, *7*(2), 1429–1445. DOI: 10.3390/su7021429.

Gwozdz, W., Reisch, L., Eiben, G., Hunsberger, M., Konstabel, K., Kovács, E., Luszczki, E., Mazur, A., Mendl, E., Saamel, M., & Wolters, M. (2020). The effect of smileys as motivational incentives on children's fruit and vegetable choice, consumption and waste: A field experiment in schools in five European countries. *Food Policy*, *96*, 101852. DOI: 10.1016/j.foodpol.2020.101852.

Hamid, S., Skinder, B.M., & Bhat, M.A. (2020). Zero waste: A sustainable approach for waste management. In *Innovative Waste Management Technologies for Sustainable Development* (pp. 134–155). IGI Global. DOI: 10.4018/978-1-7998-0031-6.ch008.

Heikkilä, L., Reinikainen, A., Katajajuuri, J.M., Silvennoinen, K., & Hartikainen, H. (2016). Elements affecting food waste in the food service sector. *Waste Management*, *56*, 446–453. DOI: 10.1016/j.wasman.2016.06.019.

Ishangulyyev, R., Kim, S., & Lee, S.H. (2019). Understanding food loss and waste–why are we losing and wasting food? *Foods*, *8*(8), 297. DOI: 10.3390/foods8080297.

Kodors, S., Zvaigzne, A., Litavniece, L., Lonska, J., Silicka, I., Kotane, I., & Deksne, J. (2022). Plate Waste Forecasting Using the Monte Carlo Method for Effective Decision Making in Latvian Schools. *Nutrients*, *14*(3), 587. DOI: 10.3390/nu14030587.

Linnenluecke, M.K., Marrone, M., & Singh, A.K. (2020). Conducting systematic literature reviews and bibliometric analyses. *Australian Journal of Management*, *45*(2), 175–194. DOI: 10.1177/0312896219877678.

Malefors, C., Eriksson, M., & Osowski, C.P. (2017). From quantification to reduction-identification of food waste reduction strategies in public food services. In *Conference: 16th Waste management and landfill symposium At: Caligari*. Retrieved April 14, 2022, from http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-e-4436.

Malefors, C., Sundin, N., Tromp, M., & Eriksson, M. (2022). Testing interventions to reduce food waste in school catering. *Resources, Conservation and Recycling*, *177*, 105997. DOI: 10.1016/j.resconrec.2021.105997.

Martins, M.L., Rodrigues, S.S., Cunha, L.M., & Rocha, A. (2016). Strategies to reduce plate waste in primary schools–experimental evaluation. *Public health nutrition*, *19*(8), 1517–1525. DOI: 10.1017/S1368980015002797.

Martins, M.L., Rodrigues, S.S., Cunha, L.M., & Rocha, A. (2020). Factors influencing food waste during lunch of fourth-grade school children. *Waste Management*, *113*, 439–446. DOI: 10.1016/j.wasman.2020.06.023.

Massari, S., Antonelli, M., Principato, L., & Pratesi, C.A. (2021). Design Thinking to engage consumers in achieving zero waste food experiences: The CEASE framework. *Design Thinking for Food Well-Being*, 247–260. DOI: 10.1007/978-3-030-54296-2_15.

Mitchell, A., & Prescott, M.P. (2020). O9 Food Systems, Climate Change, and Food Waste: Knowledge, Attitudes, and Beliefs Among Middle School Students. *Journal of Nutrition Education and Behavior*, *52*(7), S4–S5. DOI: 10.1016/j.jneb.2020.04.021.

Moreno-Black, G., & Stockard, J. (2018). Salad bar selection patterns of elementary school children. *Appetite*, *120*, 136–144. DOI: 10.1016/j.appet.2017.08.034.

Munguía, N.E., Díaz, Á.M., Velazquez, L.E., Perez, R., Esquer, J., & Zepeda, D.S. (2018). Valorization of solid waste recovery in an institution of higher education. *Green and Sustainable Chemistry*, *8*(02), 180. DOI: 10.4236/gsc.2018.82013.

Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol, 18*(1), 143. DOI: 10.1186/s12874-018-0611-x.

Niaki, S.F., Moore, C.E., Chen, T.A., & Cullen, K.W. (2017). Younger elementary school students waste more school lunch foods than older elementary school students. *Journal of the Academy of Nutrition and Dietetics*, *117*(1), 95–101. DOI: 10.1016/j.jand.2016.08.005.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *International Journal of Surgery, 88*, 105906. DOI: 10.1136/bmj.n71.

Pagliarino, E., Santanera, E., & Falavigna, G. (2021). Opportunities for and limits to cooperation between school and families in sustainable public food procurement. *Sustainability*, *13*(16), 8808. DOI: 10.3390/su13168808.

Painter, K., Thondhlana, G., & Kua, H.W. (2016). Food waste generation and potential interventions at Rhodes University, South Africa. *Waste Management, 56*, 491–497. DOI: 10.1016/j.wasman.2016.07.013.

Panizza, C., Fox, K., Boushey, C., Shanks, C., Serrano, E., Zee, J., Fialkowski, M., & Banna, J. (2017). Barriers, Motivators and Perspectives on Minimizing Lunchtime Food Waste of Early Adolescents in the National School Lunch Program. *The FASEB Journal*, *31*, 302–1. DOI: 10.1096/fasebj.31.1_supplement.302.1.

Park, S.Y., Choi, Y.J., & Kim, S.H. (2015). Factors related to school food waste in high school students in Gyeongnam. *Journal of the East Asian Society of Dietary Life, 25*(4), 710–719. DOI: 10.17495/easdl.2015.8.25.4.710.

Persson Osowski, C., Osowski, D., Johansson, K., Sundin, N., Malefors, C., & Eriksson, M. (2022). From Old Habits to New Routines—A Case Study of Food Waste Generation and Reduction in Four Swedish Schools. *Resources*, *11*(1), 5. DOI: 10.3390/resources11010005.

Philippe, K., Chabanet, C., Issanchou, S., & Monnery-Patris, S. (2021). Child eating behaviors, parental feeding practices and food shopping motivations during the COVID-19 lockdown in France: (How) did they change? *Appetite, 161*, 105132. DOI: 10.1016/j.appet.2021.105132.

Pirani, S.I., & Arafat, H.A. (2016). Reduction of food waste generation in the hospitality industry. *Journal of cleaner production, 132*, 129–145. DOI: 10.1016/j.jclepro.2015.07.146.

Pires, I., Machado, J., Rocha, A., & Liz Martins, M. (2022). Food Waste Perception of Workplace Canteen Users—A Case Study. *Sustainability*, *14*(3), 1324. DOI: 10.3390/su14031324.

Prescott, M.P., Herritt, C., Bunning, M., & Cunningham-Sabo, L. (2019). Resources, barriers, and tradeoffs: a mixed methods analysis of school pre-consumer food waste. *Journal of the Academy of Nutrition and Dietetics, 119*(8), 1270–1283. DOI: 10.1016/j.jand.2019.03.008.

Priefer, C., Jörissen, J., & Bräutigam, K.R. (2016). Food waste prevention in Europe–A cause-driven approach to identify the most relevant leverage points for action. *Resources, Conservation and Recycling, 109*, 155–165. DOI: 10.1016/j.resconrec.2016.03.004.

Principato, L., Pratesi, C.A., & Secondi, L. (2018). Towards zero waste: An exploratory study on restaurant managers. *International Journal of Hospitality Management*, *74*, 130–137. DOI: 10.1016/j.ijhm.2018.02.022.

Qian, L., Li, F., Cao, B., Wang, L., & Jin, S. (2021). Determinants of food waste generation in Chinese university canteens: Evidence from 9192 university students. *Resources, Conservation and Recycling, 167*, 105410. DOI: 10.1016/j.resconrec.2021.105410.

Qian, L., Li, F., Liu, H., Wang, L., McCarthy, B., & Jin, S. (2022a). Rice vs. Wheat: Does staple food consumption pattern affect food waste in Chinese university canteens? *Resources, Conservation and Recycling, 176*, 105902. DOI: 10.1016/j.resconrec.2021.105902.

Qian, L., Li, F., Liu, H., & Wang, L. (2022b). Are the Slimmer More Wasteful? The Correlation between Body Mass Index and Food Wastage among Chinese Youth. *Sustainability*, *14*(3), 1411. DOI: 10.3390/su14031411.

Ravandi, B., & Jovanovic, N. (2019). Impact of plate size on food waste: Agent-based simulation of food consumption. *Resources, Conservation and Recycling, 149*, 550–565. DOI: 10.1016/j.resconrec.2019.05.033.

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V.K., Evans, D., Koh, L., Carlsson Kanyama, A., Katzeff, C., Svenfeltf, A., & Jackson, P. (2019). Consumption-stage food waste reduction interventions–What works and how to design better interventions. *Food policy*, *83*, 7–27. DOI: 10.1016/j.foodpol.2019.01.009.

Richardson, R., Prescott, M.P., & Ellison, B. (2021). Impact of plate shape and size on individual food waste in a university dining hall. *Resources, Conservation and Recycling*, *168*, 105293. DOI: 10.1016/j.resconrec.2020.105293.

Schanes, K., Dobernig, K., & Gözet, B. (2018). Food waste matters-A systematic review of household food waste practices and their policy implications. *Journal of cleaner production*, *182*, 978–991. DOI: 10.1016/j.jclepro.2018.02.030.

Shanks, C.B., Banna, J., & Serrano, E.L. (2017). Food waste in the National School Lunch Program 1978-2015: A systematic review. *Journal of the Academy of Nutrition and Dietetics*, *117*(11), 1792–1807. DOI: 10.1016/j.jand.2017.06.008.

Silvennoinen, K., Nisonen, S., & Pietiläinen, O. (2019). Food waste case study and monitoring developing in Finnish food services. *Waste Management, 97*, 97–104. DOI: 10.1016/j.wasman.2019.07.028.

Sorokowska, A., Marczak, M., Misiak, M., Stefańczyk, M.M., & Sorokowski, P. (2020). Children older than five years do not approve of wasting food: An experimental study on attitudes towards food wasting behavior in children and adults. *Journal of Environmental Psychology, 71*, 101467. DOI: 10.1016/j.jenvp.2020.101467.

Steen, H., Malefors, C., Röös, E., & Eriksson, M. (2018). Identification and modelling of risk factors for food waste generation in school and pre-school catering units. *Waste management, 77*, 172–184. DOI: 10.1016/j.wasman.2018.05.024.

Talwar, S., Kaur, P., Yadav, R., Sharma, R., & Dhir, A. (2021). Food waste and out-of-home-dining: antecedents and consequents of the decision to take away leftovers after dining at restaurants. *Journal of Sustainable Tourism*, 1–26. DOI: 10.1080/09669582.2021.1953512.

Torres-Pereda, P., Parra-Tapia, E., Rodríguez, M.A., Félix-Arellano, E., & Riojas-Rodríguez, H. (2020). Impact of an intervention for reducing waste through educational strategy: A Mexican case study, what works, and why? *Waste management, 114*, 183–195. DOI: 10.1016/j.wasman.2020.06.027.

Tseng, M.L., Islam, M.S., Karia, N., Fauzi, F.A., & Afrin, S. (2019). A literature review on green supply chain management: Trends and future challenges. *Resources, Conservation and Recycling*, *141*, 145–162. DOI: 10.1016/j.resconrec.2018.10.009.

Tuorila, H., Palmujoki, I., Kytö, E., Törnwall, O., & Vehkalahti, K. (2015). School meal acceptance depends on the dish, student, and context. *Food Quality and Preference, 46*, 126–136. DOI: 10.1016/j.foodqual.2015.07.013.

UNDP (2022). *What are the Sustainable Development Goals?* Retrieved April 14, 2022, from https://www.undp.org/sustainable-development-goals?utm_source=EN&utm_medium=GSR&utm_content=US_UNDP_PaidSearch_Brand_English&utm_campaign=CENTRAL&c_src=CENTRAL&c_src2=GSR&gclid=Cj0KCQiAgP6PBhDmARIsAPWMq6mgQ0av5U-ggVVOjS4brE8q7TCmFTsEwEo2KKabg-GDCgbJJJhN5kIaAi8AEALw_wcB.

Van der Heijden, A., te Molder, H., de Graaf, C., & Jager, G. (2020). Healthy is (not) tasty? Implicit and explicit associations between food healthiness and tastiness in primary school-aged children and parents with a lower socioeconomic position. *Food Quality and Preference, 84*, 103939. DOI: 10.1016/j.foodqual.2020.103939.

Visschers, V.H.M., Gundlach, D., & Beretta, C. (2020). Smaller servings vs. information provision: Results of two interventions to reduce plate waste in two university canteens. *Waste Management, 103*, 323–333. DOI: 10.1016/j.wasman.2019.12.046.

Vizzoto, F., Testa, F., & Iraldo, F. (2021). Strategies to reduce food waste in the foodservices sector: A systematic review. *International Journal of Hospitality Management*, *95*, 102933. DOI: 10.1016/j.ijhm.2021.102933.

Wetherill, M.S., Williams, M.B., Reese, J., Taniguchi, T., Sisson, S.B., Malek-Lasater, A.D., Love, C.V., & Jernigan, V.B.B. (2022). Methods for Assessing Willingness to Try and Vegetable Consumption among Children in Indigenous Early Childcare Settings: The FRESH Study. Nutrients, 14(1), 58. DOI: 10.3390/nu14010058.

Wu, Y., Tian, X., Li, X., Yuan, H., & Liu, G. (2019). Characteristics, influencing factors, and environmental effects of plate waste at university canteens in Beijing, China. *Resources, Conservation and Recycling, 149*, 151–159. DOI: 10.1016/j.resconrec.2019.05.022.

Zhao, C., Panizza, C., Fox, K., Boushey, C.J., Shanks, C.B., Ahmed, S., Chen, S., Serrano, E.L., Zee, J., Fialkowski, M.K., & Banna, J. (2019). Plate waste in school lunch: barriers, motivators, and perspectives of SNAP-eligible early adolescents in the US. *Journal of nutrition education and behavior*, *51*(8), 967–975. DOI: 10.1016/j.jneb.2019.05.590.

 DOI: 10.22616/rrd.28.2022.023

FACTORS AFFECTING THE DEVELOPMENT OF URBAN AGRICULTURE IN LATVIA

***Madara Dobele**, **Andra Zvirbule**, **Aina Dobele**, **Aina Muska**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: Madara.Dobele@llu.lv

Abstract
Urban agriculture is not only a practice of providing food, but also a social lifestyle trend. Different approaches to practice provide the opportunity of different forms and functions, from growing products for household self-consumption to setting up community gardens and commercial practices. Despite the international experience and the potential of urban agriculture in the sustainable development, in Latvia the practice is mostly implemented through individual or community initiatives. The development of urban agriculture in Latvia is influenced by several factors; therefore, the aim of the scientific article is to identify, classify and characterize factors affecting urban agriculture in Latvia. To achieve the aim, tasks are set: 1) to identify factors influencing urban agriculture, 2) to classify factors and characterize the impact. Several methods have been used in the study to fulfil tasks: systematic theoretical review for factor selection, coverage and characterization, methods of analysis, synthesis and deduction for identification and classification of factors, mathematical statistics correlation method for data correlation, force field analysis for the visualization of the factors impact.
Results show that urban agriculture in Latvia has several obstacles – unclear status in legislation, the high cost of needed resources compared to rural areas, the increasing level of the household income. However, there are also factors that contribute to the development, such as criteria for urban greening and sustainability in the development strategies, the concentration of food-demand-driven businesses in cities, food-growing habits and positive attitudes among urban dwellers, and the potential of urban agriculture to promote environmental sustainability.
Key words: urban agriculture, factors, development, Latvia.

Introduction

Since the second half of the 20th century urban agriculture is experiencing a new stage of the development, characterized by its integration into sustainable development processes and goals, rapidly growing research activity, technological development that allows greater adaptation of territory to practice, and changing social values, emphasizing minimalism, zero waste, nature-linked and other aspects of lifestyle (Dobele & Zvirbule, 2020). However, despite the functionality of urban agriculture and the diversity of its adaptation and practices, the development varies in different regions and countries. It is influenced by both general factors similar to all regions and aspects specific to national situations.

Cities are seen as a key factor in prosperity and development, but they are also very resource-intensive, responsible for most of the pollution, unsustainable growth and social inequalities. Europe is the third most urbanized region in the world, with 74% of its population living in cities (World urbanization prospects.., n.d.). Urbanization is a trend that characterizes the development of society, which is largely influenced by the imbalance in the ability to raise individual living standards with the burden of total resources and the environment, which increases significantly as the proportion of people living in cities is growing. Several aspects characterizing the urbanization are the direct influencing factors in the development of urban agriculture – the availability of land resources for agricultural practices, social stratification, the increasing topicality of the environmental diversification. However, in general, as urbanization increases, so does the role of urban agriculture as a factor in ensuring a healthy, fresh, local food supply, thus reducing the pressure of urbanization on the ecosystem and reducing the risk of creating so-called food desserts (Boneta *et al*., 2019).

In Latvia, urban agriculture is still practiced mainly for self-consumption and in the form of micro-agriculture. Historically, agriculture has been a traditional occupation of the Latvian population, but the improvement of living standards reduces the amount of individual practice. However, the opposite trend is also taking place: people in different regions are increasingly looking for the linkage with nature and traditional activities, including agriculture. Thus, urban agriculture in Latvia is affected by various factors, often in opposite directions. Analysing the role and development of urban agriculture, it is necessary to identify the influencing factors and determine the direction of their impact. Therefore, the aim of the research is to identify, classify and characterize the main factors influencing urban agriculture in Latvia.

Materials and Methods

In order to identify influencing factors, two approaches have been used in the research: 1) compiling a sample of factors from the results of research in other countries published in scientific articles (publications in the databases Scopus and Web of Science, published in the period from 2015

to 2021); 2) supplementing and adjusting the list of factors by analysing tendencies of urbanization in Latvia. In the analysis of factors, 12 the most important are identified and selected, which were classified in 4 groups.

From the beginning of 2011 until July 1, 2021, there were stated 9 cities of national importance in Latvia. From July 1, 2021, as a result of the administrative reform, the country's largest cities have been defined as the capital and 9 state-cities. As in the research, data from the period 2016-2021 are used in order to evaluate the practice of urban agriculture in Latvia, cities of the former status of the national importance were analysed.

Methods of monographic, descriptive, analysis, deduction and mathematical statistics (correlation analysis) were used to characterize the influence of factors. For the correlation analysis, statistical data were obtained from the database of the Central Statistical Bureau of Latvia.

Aspects of the habits of the population were identified and analysed using results of the survey of the population of Latvia conducted in 2021 (753 respondents), the aim of which was to identify the tendencies, motivation and attitude of the population towards urban food in Latvia. Aspects of motivation and opinions were evaluated using the calculation of the significance coefficient in the range from 0-1, where 0 – insignificant factor, 1 – significant factor.

To visualize results of the factor impact assessment, the method of the force field analysis was used.

Results and Discussion

The long historical development of urban agriculture practices has led to its multifunctional role in the urban environment (Dobele & Zvirbule, 2020). Different approaches and realizations on a global scale have demonstrated the functionality of urban agriculture in terms of food security, generating additional household income, realizing short food chains and thus reducing the environmental impact of the food logistics, promoting social cohesion in public gardens, diversification and greening of urban environment, improving air quality, promoting and diversifying the physical activities of the population, promoting a healthier, fresher diet, improving mental health and recreation (Dobele, Zvirbule, & Dobele, 2021). However, its development varies, depending on specific situations and factors in different regions and countries.

In this research, factors influencing the development of urban agriculture in Latvia are classified into four groups: ***political, economic, social and environmental factors***.

The most important **political factors** that affect the development of urban agriculture in Latvia are:

- principles of the urban sustainability (P1);
- the sustainability of food systems and the inclusion of short food chains in development plans and strategies (P2);
- lack of concept and status of urban agriculture in laws and regulations (P3).

The rapidly growing world population, rising demand for consumer goods, increasing life expectancy, urbanization and other factors determine that further development is only possible through the principles of sustainability. Sustainable development is a major challenge for cities. ***Urban sustainability*** is one of UN's goals for sustainable development, which includes several areas of action: balancing resources consumed by cities, improving the quality of the environment, promoting climate neutrality, greening public areas, etc. (United Nations, n.d.). Urban agriculture, as one of urban landscaping forms and thus of processes that shape environmental diversity and quality, is also in line with the Food and Agriculture Organization's guidelines for the future, green cities, by maintaining the urban biodiversity, improving the emotional and physical health of the population, promoting healthy lifestyle and decreasing temperature and pollution (Rethinking the future…, 2018). One of the priorities of Latvia's sustainable development strategy is a high-quality living environment and territorial development, which envisages the development of a biologically diverse and healthy environment and the growth of green areas in cities (Latvija2030, 2010). Thus, principles of urban sustainability strategies are related to the implementation of urban agriculture practices and are important contributing factors.

The growth of the population and its demands have determined challenges to ***food security and sustainability***. Urban agriculture is able to ensure at least partial self-sufficiency of food resources, as it implements the principle of short food chains and the idea of a 21st century's foodshed (WinklerPrins, 2017). The EU's strategy 'The Farm to Fork' also focuses on the sustainability of food systems and the promotion of short food chains with a neutral impact on the environment (European Commission, 2020). Although food transportation in Latvia has a smaller impact on the environment than in larger countries, the reorientation of development strategies towards short food chains and flexible local food supply is a factor that promotes urban agriculture.

The most important political factor hindering the development of urban agriculture in Latvia is the ***lack of concept and status*** in legislation documents. Agricultural trends and support systems in Latvia are subordinated to the EU's Green deal and the Common agricultural policy, incorporating the basic principles into the law On Agriculture and Rural Development.

Table 1

The base of cadastral values for land types in state-cities and counties in Latvia, in the period of 2016-2022, euro m^{-2}

Territory	I*	II*	III*, average value	IV*
Riga	1.00	8.54	72.49	1.00
Daugavpils	0.28	7.40	2.78	0.28
Jelgava	0.43	7.40	4.06	0.43
Jekabpils	0.14	4.27	1.92	0.14
Jurmala	0.71	7.83	30.99	0.71
Liepaja	0.43	7.40	8.43	0.43
Rezekne	0.14	4.98	2.14	0.14
Valmiera	0.14	6.83	3.95	0.14
Ventspils	0.28	7.40	5.06	0.28
State-cities, average	**0.39**	**6.89**	**42.03**	**0.43**
Counties, average	**0.09**	**2.73**	**1.00**	**0.09**

* I – agriculture is the main economic activity, II – agricultural warehouses and processing buildings, III – undeveloped land for construction of individual residential buildings, IV – natural bases, parks, green areas, etc. objects of recreational significance

Source: authors'compilation on the basis of data from Kadastrālo vērtību bāze, 2020.

The law does not define urban agriculture and although it does not restrict agricultural practices to rural areas, support mechanisms and requirements are largely enforceable only for agriculture in rural areas with appropriate processing approaches and production volumes (On Agriculture and.., 2004). Other laws of the Republic of Latvia and regulations of the Cabinet of Ministers, including plans for receiving various types of support and their criteria, also do not specify urban agriculture. Without defining and including a specific status and functions in the development, the impact of legislation documents regulating agriculture in Latvia is negative.

The impact of **economic factors** on urban agriculture is ambiguous. Previous research looks at a wide range of aspects, which include the development trends of the national economics, such as inflation, employment, wage levels, etc. factors, as well as productivity, consumption and demand for resources, including food and energy (Foodmetres..., 2015; Glavan *et al*., 2016).

For the analysis of the development of urban agriculture in Latvia, the main economic factors have been identified:

- the value of land resources (E1);
- entrepreneurship trends (E2);
- number of households and average income (E3);
- changes in the consumption of different groups of food (E4).

Land resource value and prices are one of factors with the greatest negative impact on urban agriculture. According to the data of the State Land Service's base of cadastral values (Kadastrālo vērtību bāze, 2020), the highest value of the land where the main economic activity is agriculture, is in Riga (1euro m^{-2}), relatively lower in other cities, but in counties the average value is 0.09 euro m^{-2}, with a moda of 0.07 euros m^{-2}.

Other values of agricultural land are also significantly higher in state-cities. The average value of land as a type of agricultural warehouses and processing buildings is 6.89 euros m^{-2} in state-cities and 2.73 euros m^{-2} in counties. Comparing costs of land resources, they are significantly higher in cities, which hinders the development of agricultural practices. The negative impact of the land value factor is further exacerbated by the comparison of land types in the real estate group – for example, the average value of undeveloped land for construction of individual residential buildings is 42.03 euros m^{-2} in state-cities and 1.00 euro m^{-2} in counties, with a moda of 0.14 euros m^{-2}. The base value of commercial and public construction land is also higher in cities: for the type of recreational areas it is an average 0.43 euros m^{-2} in state-cities and 0.09 euros m^{-2} in counties. The value of land resources in cities is much higher, due to which the possibility to purchase additional land resources to increase the volume of agricultural production is relatively low. In addition, land values in the urban environment are much higher for commercial and industrial activities (Kadastrālo vērtību bāze, 2020), which makes the type of agricultural land in cities economically unprofitable.

No less important factor in the development of urban agriculture is ***entrepreneurship trends***.

According to the data of the Central Statistical Bureau of Latvia (Tirgus sektora ekonomiski.., n.d.), in 2020, which is the latest data collected on March 1, 2022, only 2.15% of all agricultural enterprises in the country (3.10% of the agrarian sector) are registered in the state-cities, which shows a lack of interest in commercial practices in urban agriculture. Although this aspect reduces the intensity of competition for existing and potential entrepreneurs in the urban environment, the proximity of rural areas and, consequently, rural enterprises significantly reduces the competitiveness of urban agriculture enterprises, primarily in terms of land availability and price. However, aspects of entrepreneurship trends such as the number of companies involved in food processing and food use and market participants in cities that are direct demanders of urban agricultural products have a positive impact on the development of urban agriculture. 11.52% of all participants in food production are registered in state-cities (another 23.67% in close regions), 14.71% in accommodation (+ 23.26% in close regions) and 17.92% (+ 52.24% in close regions) catering companies, 20.21% (+ 47.16% in close regions) participants in educational institutions, 13.79% (+ 44.83% in close regions) in social care with accommodation and 20.96% (+ 40.40% in close regions) in health care sector. The concentration of market participants in these sectors in and around state-cities indicates the territorial accessibility of consumers of urban agricultural products. In addition, the number of market participants in all sectors has a strongly positive correlation with the number of the population (the correlation coefficient in the analysed groups varies from +0.95 to +0.99). With the exception of the number of market participants in the agricultural sector, a positive correlation is also with the base of the cadastral values of land in other categories (the correlation coefficient ranges from +0.76 to +0.82).

From the point of view of entrepreneurship tendencies, not only the concentration of entrepreneurs in state-cities, but also the ***unemployment rate*** is important. The registered unemployment rate in Latvia in 2020 was on average 6.0% and the data show a very different situation in cities and counties. However, the difference between the average unemployment rate in state-cities (6.3%) and the rest of Latvia (6.7%) are insignificant (Bezdarba rādītāji un.., 2021). The correlation analysis between the unemployment rate and the number of market participants in observed sectors revealed a weak negative, statistically insignificant relationship. No correlation was found between population and unemployment either (correlation coefficient: -0.06, statistically insignificant). Consequently, it is concluded that the unemployment rate and its interaction with the number of market participants and the population in cities and counties do not show a statistically significant effect.

In Latvia, the level of disposable income per ***household*** tends to increase, moreover, with a different amount in urban and rural areas. In state-cities, there are on average 50.6 thous. households, while in the rest of the country: 3.4 thous. (Privāto mājsaimniecību

Table 2

Consumption of food products on average per household member per year in Latvia in 2015, 2016, 2019

Product group, unit of measurement	2015		2016		2019		Cities, 2019/2015, %
	cities	counties	cities	counties	cities	counties	
Beef, kg	1.57	0.78	1.60	0.83	1.33	0.41	-15.3
Pork, kg	16.57	21.81	16.73	24.00	14.24	21.08	-14.1
Poultry meat, kg	12.65	8.79	13.25	10.27	12.27	9.56	-3.0
Eggs, pcs.	190.10	208.62	202.36	218.29	204.00	224.00	+7.3
Local garden fruits, kg	19.10	13.75	23.04	17.36	20.84	15.47	+9.1
Leaf and stem vegetables, kg	2.28	2.83	2.44	2.88	2.39	2.77	+4.8
Cucumbers, kg	9.72	10.24	10.13	10.03	10.09	10.83	+3.8
Tomatoes, kg	12.91	11.92	12.97	11.35	12.87	11.96	-0.3
Pumpkin seeds, courgettes, legumes, sweet peppers, kg	6.22	5.10	7.76	7.09	7.99	7.26	+28.5
Onions, kg	6.35	5.89	6.61	6.19	6.18	6.43	-2.7
Radish, etc. root crops, kg	1.09	1.04	1.27	0.90	1.29	1.14	+18.3
Potatoes, kg	56.14	82.04	54.19	78.87	41.81	61.13	-25.5
Honey, kg	0.74	0.88	0.92	0.62	0.73	0.67	-1.3

Source: authors' compilation on the bases of data from Pārtikas produktu patēriņš.., n.d.

kopējais.., n.d.), and in cities the average income in 2020 was 656.86 euros per person, but in rural areas – 573.24 euros (Mājsaimniecību rīcībā esošo.., n.d.). Data on individual cities and counties are not available, so correlation analysis is not possible. But the higher income level is often associated with changes in consumer habits, including the purchase of household products rather than growing them themselves. Therefore, household income trends can be assessed as a negative factor for the development of urban agriculture in Latvia. A stable economic and security situation, combined with agricultural subsidy payments, keeps food prices low in Europe, making food growing and saving money from urban agriculture practices secondary (Glavan *et al*., 2016).

Urban agriculture is most often associated with the cultivation of plant products, which are primarily affected by the availability of land resources and specific aspects of the urban environment that hinder livestock farming. Therefore, the affecting factor is the ***consumption of different food groups*** and its trends in terms of resource use.

Table 2 summarizes the information on the product groups that are most commonly grown in urban agriculture and those that affect their consumption: the consumption of meat products reduces the need for products most commonly grown in urban agriculture: vegetables, berries, herbs and others. The Central Statistical Bureau of Latvia has published consumption data for years 2015, 2016 and 2019. The average food consumption of the Latvian population shows a tendency that the urban population consumes more product groups such as beef and poultry, fruits, berries, cabbage, tomatoes, courgettes, legumes, sweet peppers and radishes compared to the rural population. With the exception of beef, other product groups can be produced in urban agriculture during the season, thus promoting the consumption of fresh products and reducing the resource burden on rural areas. In general, the share of household consumption expenditure in food and non-alcoholic beverages is declining (Mājsaimniecības patēriņa izdevumu.., n.d.). But this aspect does not negatively affect the development of urban agriculture, as the share of expenditure decreases, but not the volume. The correlation analysis revealed a statistically significant, close negative correlation (correlation coefficient: -0.87) between the level of household income and the share of expenditure on food – this means that as the level of income increases, the share of expenditure on food decreases.

Social factors often interact with other factors influencing urban agriculture. The most significant social factors influencing the development of urban agriculture in Latvia are:

- increase in the proportion of the urban population (S1);
- current trends in food growing among the urban population (S2);
- people's views and attitude towards urban food (S3).

Population number changes are one of the characteristics of the urbanization – the emigration of people from rural to urban areas, driven by economic motivation for higher employment, higher wages, social services, better infrastructure and other specific benefits from cities. According to UN's data, more than half of Latvia's population has lived in cities since 1960, in 2020 it was already 68.3% and in 2050 it is planned that 75.9% of Latvia's population will live in cities (World Urbanizations Prospects.., n.d.). In 2021, 49.09% of the population lived in 9 largest cities (Iedzīvotāju skaits un.., n.d.). The social factor of the population concentration in urban areas has a positive effect on the development of urban agriculture – urban population growth increases risks of the resource congestion and growing demand that emphasizes the topicality of the balance between the food consumption and production, the potential of wider, more populated and interactive communities and the transfer of the experience of the food growing from rural to urban areas.

Results of the survey of the population of Latvia, conducted in 2021, show that 65.4% of residents of state-cities are engaged in growing at least one type of food products in their households. This confirms the relevance of ***food growing traditions*** and the positive impact on the development of urban agriculture. However, in Latvia it is mostly practiced as micro-agriculture, as 86.5% of practitioners grow food for their own consumption, and 56.4% grow only up to 10% of the required food in the respective product group. The role of food growing traditions in the development of urban agriculture is also proved by the motivation aspects of the practice - one of the most important motivators for respondents is that food growing is a family tradition (significance coefficient: 0.78). In addition, 69.81% of practitioners gain knowledge of agriculture from the family. That makes cultivating traditions in the family as a contributing factor for the development of urban agriculture.

An important factor promoting the development is the ***population's views*** and ***attitude*** towards urban agriculture and the food produced in cities. Results of the population survey show that the population evaluates urban agriculture as a complementary aspect of the school programs (significance coefficient: 0.85) and as a promoting practice for additional education and knowledge (significance coefficient: 0.84). Equally important are views that urban agriculture diversifies, creates a greener urban environment (significance coefficient: 0.83) and is a way to minimize negative climate change (significance coefficient: 0.72).

Figure 1. Factors affecting the development of urban agriculture in Latvia.

Growing food in cities is recognized by the population as a modern trend (significance coefficient: 0.72) that encourages community's interaction (significance coefficient: 0.71). When evaluating food that is grown in cities, respondents have the impression that it is healthier compared to that bought in a store (significance coefficient: 0.72), potentially also more expensive (significance coefficient: 0.68). The correlation between views, attitudes and respondents' place of residence (a city or countryside) and opinion in urban agriculture shows no statistical significance. That allows to conclude that population's views on urban agriculture are sustainable and general, regardless of their place of residence or experience in urban agriculture.

The development of urban agriculture cannot be seen in isolation from **environmental factors**. The most important in Latvia's case are:

- topicality of urban environment diversification and issues of preservation and maintenance of ecosystem service (En1);
- waste management trends (En2).

Promoting ***urban biodiversity*** is becoming an increasingly important challenge of the development. Cities have long been considered to be not only 'not-green' but also anti-environmental, consuming much more resources than they are able to produce on their own (WinklerPrins, 2017b). Cities are characterized by over-exploitation of the environment beyond their potential for bio-capacity, which not only pollutes the air and soil, but also increases the air temperature in the urban environment and contributes to the risks of climate change. Conservation of the biodiversity is an essential aspect of environmental sustainability, as it helps to ensure the stability and protection of the ecosystem by redistributing environmental risks and stabilizing critical key points of fragility (White, 2017). Principles of diversification of the urban environment have a positive effect on the development of urban agriculture, as it diversifies the urban environment, both in terms of households and, in particular, the community and public gardens, while preserving and promoting its biodiversity. Also, urban agriculture can provide important ***ecosystem service*** functions that are related to: 1) microclimate conditions - reducing the urban heat island effect; 2) dust absorption and air purification; 3) conservation of biological diversity; 4) the use of biological waste for fertilizers; 5) reuse of water (Ferreira *et al*., 2018). Urban development planning with integrated, environmental and climate-neutral conditions has a positive effect on the development of urban agriculture, taking into account the potential of practices in the diversification and greening of the urban environment.

The circular economy in the EU is one of the preconditions for sustainable development. A separate implementation of the principles is envisaged in the field of ***waste management***, not only by reducing the amount of generated waste, but also by reusing sorted waste. Existing requirements and development plans have a positive impact on the development of urban agriculture and its topicality in two aspects: 1) self-grown food allows to reduce food waste, as food requires a short delivery time and is fresh for a longer period (Foodmetres.., 2015), 2) bio-waste can be used as compost for urban agriculture, thus reducing its amount by a process of reuse (Ferreira *et al*., 2018). Latvia's waste management plan envisages both the reduction of waste and the implementation of separate collection of bio-waste by 31 December 2023 (Par Atkritumu apsaimniekošanas.., 2021). The implementation of the waste management plan has a positive impact on the development of urban agriculture, as it has the potential of both - to reduce the amount of food waste and to reuse bio-waste, thus fitting into the principles of the plan.

Summarizing the impact of the most important factors of urban agriculture in Latvia and using the force field analysis, the sum of the impact of factors overall is positive (+16), which shows that urban agriculture in Latvia has wide development opportunities, justified by political, economic, social and environmental factors.

Conclusions

Urban agriculture is able to play a supporting role in a number of challenges of the sustainable development and urbanization, so its development is desirable and should be encouraged in the form of both urban planning and individual and community initiatives. However, development is influenced by a number of factors, which may vary in different countries and regions.

The development of urban agriculture in Latvia is mostly influenced by political, economic, social and environmental factors. The highest negative impact factor on the development is the cost of resources needed for agriculture compared to the practice in rural areas, thus making agricultural practice in cities less economically advantageous. The increase of the household income level, which allows consumers to switch to purchasing products by reducing the need to grow their own food, and the lack of a definition and regulation of urban agriculture in legislation documents, which hinders the attraction of agricultural support instruments, also have a negative impact.

However, mostly influencing factors are contributing the development, especially the goals of the sustainable development and urban sustainability strategies and food-growing habits and traditions in the society.

Urban agriculture in Latvia has both potential and high development opportunities, supporting and promoting the improvement of the urban environment and the quality of life of urban dwellers. But for more successful adaptation of practice in urban processes, the state and municipal support in the context of the regulation and support systems is required.

References

*Bezdarba rādī*tāji *un NVA aktivitātes 2020.gadā* (Unemployment indicators and SEA activities in 2020). (2021). Retrieved March 1, 2022, from https://www.nva.gov.lv/lv/2020gads. (in Latvian).

Boneta, A., Rufi-Salis, M., Ercilla-Montserrat, M., Gabarrell, X., & Rierdevall, J. (2019). Agronomic and Environmental Assessment of a Polyculture Rooftop Soilles Urban Home Garden in Mediterranean City. *Frontiers in Plant Science*, 10, Art. No. 341. DOI: 10.3389/fpls.2019.00341.

Dobele, M., & Zvirbule, A. (2020). The concept of urban agriculture – historical development and tendencies, *Rural Sustainability Research*, 43 (338), 20–26. DOI: 10.2478/plua-2020-0003.

Dobele, M., Zvirbule, A., & Dobele, A. (2021). A review of urban, peri-urban and rural agriculture concepts and role in sustainable development. In Proceedings of the International Scientific Conference Social Sciences for Regional Development 2020, 9-10. October 2020 (pp. 59–66). Daugavpils, Latvia: Daugavpils Universitāte, Sociālo zinātņu fakultāte, Humanitāro un sociālo zinātņu institūts. ISBN 9789984149318. ISSN 2255-8853.

Ferreira, A.J.D., Gulherme, R.I.M.M., Ferreira, C.S.S., & Oliveira, M.F.M.L. (2018). Urban agriculture, a tool towards more resilient urban communities? *Current Opinion in Environmental Science & Health*, 5, 93–97. DOI: 10.1016/j.coesh.2018.06.004.

Foodmetres. Food Planning and Innovation for Sustainable Metropolitan Regions. Synthesis report. (2015). Eds. Wascher, D., Kneafsey, M., Pintar, M., Piorr, A. Wageningen: Wageningen UR.

Glavan, M., Schmutz, U., Williams, S., Corsi, S., Monaco, F., Kneafsey, M., Rodriguez, P.A.G., Čenič-Istenič, M., & Pintar, M. (2016). The economic performance of urban gardening in three European cities-examples from Ljubljana, Milan and London. *Urban Forestry & Urban Greening*, 36, 100–122. DOI: 10.1016/j.ufug.2018.10.009.

Iedzīvotāju skaits un tā izmaiņas (Population and its changes). (n.d.). Retrieved March 2, 2022, from https://stat.gov.lv/lv/statistikas-temas/iedzivotaji/iedzivotaju-skaits/247-iedzivotaju-skaits-un-ta-izmainas. (in Latvian).

Kadastrālo vērtību bāze (Base of cadastral values). (2020). Retrieved March 1, 2022, from https://www.vzd.gov.lv/lv/KVB. (in Latvian).

Latvija2030. Sustainable Development Strategy of Latvia until 2030. (2010). Retrieved February 4, 2022, from https://pkc.gov.lv/sites/default/files/inline-files/LIAS_2030_en_1.pdf.

On Agriculture and Rural Development: the law. (2004). Retrieved March 1, 2022, from https://likumi.lv/ta/en/en/id/87480-on-agriculture-and-rural-development.

Mājsaimniecību patēriņa izdevumu struktūra (%) (Structure of household consumption expenditure (%)). (n.d.). Retrieved March 1, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__POP__MB__MBI/MBI010/table/tableViewLayout1/. (in Latvian).

Mājsaimniecību rīcībā esošo ienākumu sastāvs vidēji uz vienu mājsaimniecības locekli (eiro mēnesī) (Composition of disposable income of households on average per household member (euro per month)). (n.d.). Retrieved March 1, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__POP__MI__MIS/MIS020/table/tableViewLayout1. (in Latvian).

Par Atkritumu apsaimniekošanas valsts plānu 2021.-2028.gadam (On the National Waste Management Plan for 2021-2028): Cabinet of Ministers Order No. 45. (2021). Retrieved March 1, 2022, from https://likumi.lv/ta/id/320476-par-atkritumu-apsaimniekosanas-valsts-planu-20212028-gadam. (in Latvian).

Pārtikas produktu patēriņš vidēji uz vienu mājsaimniecības locekli gadā (Food consumption on average per household member per year). (n.d.). Retrieved March 1, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__POP__MB__MBP/MBP010/table/tableViewLayout1/. (in Latvian).

Privāto mājsaimniecību kopējais skaits un mājsaimniecības vidējais lielums reģionos, republikas pilsētās, novados, laukos un pilsētās gada sākumā (*Total number of private households and average household size in regions, cities, counties, rural areas and cities at the beginning of the year*). (n.d.). Retrieved March 1, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__POP__MV__MVS/MVS010/table/tableViewLayout1/. (in Latvian).

Rethinking the future of cities. (2018). Retrieved February 22, 2022, from http://www.fao.org/fao-stories/article/en/c/1106849/.

European Commission. (2020). *A Farm to Fork Strategy.* Retrieved March 1, 2022, from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0381&from=LV.

Tirgus sektora ekonomiski aktīvi uzņēmumi reģionos, republikas pilsētās un novados sadalījumā pa uzņēmumu lieluma grupām pēc nodarbināto skaita un galvenajiem darbības veidiem (Economically active enterprises of the market sector in regions, cities and counties by size groups of enterprises by number of employees and main types of activity). (n.d.). Retrieved March 1, 2022, from https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__ENT__UZ__UZS/UZS030/table/tableViewLayout1/. (in Latvian).

United Nations. (n.d.). *Goal 11: Make cities inclusive, safe, resilient and sustainable*. Retrieved February 2, 2022, from https://www.un.org/sustainabledevelopment/cities/.

White, S.A. (2017). Urban Agriculture as Adaptive Capacity: An Example from Senegal. In: A.M.G.A. WinklerPrins (Ed.), *Global urban agriculture: convergence of theory and practice between North and South* (pp. 134–145). UK: CPI Group Ltd., CABI.

WinklerPrins, A.M.G.A. (2017). Global Urban Agriculture into the Future: Urban Cultivation as Accepted Practice. In: A.M.G.A. WinklerPrins (Ed.), *Global urban agriculture: convergence of theory and practice between North and South* (pp. 242–248). UK: CPI Group Ltd., CABI.

World Urbanizations Prospects 2018. (n.d.). Retrieved March 1, 2022, from https://population.un.org/wup/.

 DOI: 10.22616/rrd.28.2022.024

SOCIAL ENTREPRENEURSHIP DEFINITION AND ESSENCE IN THE LATVIA CONTEXT

***Dana Gintere, Lasma Licite-Kurbe**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: dana.gintere@gmail.com

Abstract
Inconsistencies, overlapping concepts, and contradictions appear in the developing literature on social entrepreneurship and its role in economic development and social value creation. However, the theoretical and practical importance of developing and applying social entrepreneurship to sustain social development and enhance human well-being in rapidly changing environments has catapulted this issue to the forefront of the research agendas of many scholars. This article examines the historical backdrop of social entrepreneurship, as well as the contexts of Latvia and the Nordic and Baltic countries. The study examines how the definition of social entrepreneurship has changed through time in various studies. Different scientists' definitions are compared, and the issues with a common definition barrier are discussed. The definitions of social entrepreneurship are examined in the Latvian context between M. Yunus' concept, the European Commission's definition, and the Social Enterprise Law. Finally, the definitions of social entrepreneurship in the Nordic and Baltic nations that have legalized social entrepreneurship are examined to see where there are similarities and discrepancies.
Key words: social entrepreneurship, social enterprise, the Nordic and Baltic region, systematic review.

Introduction

Social entrepreneurship is one of the recent business concepts. Social entrepreneurship has an important role in society. This is clear both at the national level, where the promotion of social entrepreneurship is included in various strategic documents, and at the local level, where countries are implementing various support systems for social enterprise development. Despite the fact that social entrepreneurship is becoming more prominent in society, scholars, scientists, and politicians cannot agree on a shared definition of social entrepreneurship or what makes a social enterprise. Each country has its own definition. Each scholar defines the concept of 'social entrepreneurship' differently (Martin & Osberg, 2007; Light, 2006; Mair, 2006; Nicholls, 2006; Hockerts, 2006) (Robinson, 2006). Nicholls emphasizes the importance of precisely defining the terms 'social entrepreneurship,' which are made up of two seemingly simple terms: 'social' and 'entrepreneurship' (Nicholls, 2006). These phrases are complex, both combined and independently, with various perspectives and interpretations that further complicate the term 'social entrepreneurship'. Johnson points out that defining social entrepreneurship is as tough as establishing its conceptual limits (Johnson, 2002). The researcher claims that in the year 2002 the reason of difficulties was lack of literature on this issue, which is still a current obstacle 20 years later. But Braunerhjelm indicates that lack of scientific definition of the concept is the importance of various social entrepreneurship activities for people in different parts of the world, each understanding social entrepreneurship differently, within their own geographical and cultural context (Braunerhjelm *et al*., 2012). The lack of a universal definition makes it difficult to collect statistics on social entrepreneurs, social enterprises and their impact on social issues, both locally and globally.

Primarily, the term 'social entrepreneurship' is defined as a combination of the terms 'social' and 'entrepreneurship' (Mulgan, 2006). It is correctly regarded as combining the 'commercial' process and profit-making tools from the standpoint of charities, as well as the purpose of a 'social' mission (Nicholls, 2006; Peredo & McLean, 2006). It is appropriately interpreted as linked to the goal of a 'social' mission from the perspective of charities and to linking the 'business' process and profit-making tools (Nicholls, 2006; Peredo & McLean, 2006). Entrepreneurship is a term that has been given various definitions in the literature, including entrepreneurship, intrapreneurship, commercial entrepreneurship, and, most recently, social entrepreneurship. In the 18th century, the French economist Jean-Baptiste Say was the first to popularize the term 'entrepreneur,' defining it as 'a person who devotes resources to higher regions of productivity and yield'. Scientists have characterized the ethical and mission values of social entrepreneurship and social entrepreneurship in similar way.

Other scholars argue that McClelland (1961), who focused on the need for accomplishment incentive, brought a psychological explanation of 'who entrepreneurs are', was one of the first to define entrepreneurship. In keeping with Schumpeter's (1934) theories on the role of entrepreneurs in economic development, risk-taking, proactiveness, and innovativeness are three of the most commonly stated attributes cultivated as a means of creating market opportunities (Stevenson & Jarillo, 1990). These qualities are and are also needed by social entrepreneurs to achieve both business and social goals. Despite the fact that there has been a lot

of discussion about social entrepreneurship in recent years, agreement on what constitutes social entrepreneurship remains elusive. There are numerous definitions of social entrepreneurship.

The aim of the paper is to look at and analyse the definition of social entrepreneurship in a historical context. The following specific research tasks have been established in order to achieve the aim:1) to examine social entrepreneurship in a historical framework from a social entrepreneurship definition perspective; 2) to analyse the main social entrepreneurship definitions; 3) to compare the definitions of regulatory enactments for social entrepreneurship in Nordic and Baltic countries. The study of social entrepreneurship in the world has been studied by D. Bornstein (2010), focusing on a key innovation that underlies much of the recognition of the role played by entrepreneurs in advancing positive social changes, A. Nicholls (2006), who emphasized the role of social entrepreneurship in socio-economic development, and G. Dees (2002), referred to as the father of social entrepreneurship education, founder of the Center for Social Entrepreneurship Development of Duke University. Social entrepreneurship has been studied by several scientists in the Baltic States, including L. Līcīte-Ķurbe (2013), E. Butkevičiene (2008), J. Grebļikaitė (2012), L. Pērkūne (2019), D. Gintere (2020).

Materials and Methods

Various methods were used in the research of the article to achieve the goal and perform the tasks. The paper was conducted as a systematic review of the literature. To conduct a theoretical debate and evaluate the study's results based on scientific theories and findings on social entrepreneurship, monographic and descriptive methods were employed. The theoretical results and legal documents in various policies employed analysis and synthesis to investigate the elements of the problems and define the regularities. The induction method was used to make scientific assumptions and identify links based on specific pieces or facts. The logical systematization and interpretation of literary data has been done using deduction.

Results and Discussion

Social entrepreneurship definition in historical framework

The development of social entrepreneurship can be divided into three stages: philanthropy, global social movements, and current times. A period of philanthropy preceded the beginning of social entrepreneurship (18th century – early 20th century) (Dobele, 2013). During this time, numerous charities and religious organizations became more involved in resolving socio-economic issues. Initially, forms of social entrepreneurship manifested themselves in philanthropy and religious movements, as a result of which social entrepreneurs were called humanists, reformers, and philanthropists (Bornstrein & Davis, 2010). Although research on social entrepreneurship is not considered to have emerged during the philanthropic period, Ms. Parker-Folleta wrote in her publications on the interaction between the entrepreneur and the social system around 1915 that every firm is part of a man-made system that makes up society and everyone should be aware. She was one of the first to emphasize that the mechanisms of action of the state and local governments are often too cumbersome, and the courage, activity and search for innovative solutions characteristic of entrepreneurs are essential in solving social problems (Stimms, 2009).

As a result of the development of society in the global period of social movements (early 50s – 90s), socio-economic problems related to discrimination against various groups also continued to grow, with representatives of various political and social movements actively involved in the problems of these groups.

The first appearance of the term's social enterprise and social entrepreneur in the literature is indicated by H. Boven in the book 'Social Responsibilities of the Businessman' in 1953. Later these terms were widely used in the 1980s and 1990s, and were advertised by B. Drayton, C. Leeds and others (Defining the 'Social', 2005). However, other researchers Nicholls and Trivedi point out that the term social entrepreneurship for the first time was used twenty years later in 1972 by J Banks in the book 'The Sociology of Social Movements'. The book emphasizes the importance of using a management strategy to address social issues that are still important 50 years later form book publishing. The time of the global period of social movements and the period of modern social entrepreneurship overlap, several representatives of social and political spheres began to update the term social entrepreneurship in the 20th century.

In the early 1990s, and beyond, this concept developed more and more widely as we understand it now. The period of modern social entrepreneurship (from the early 1990s to the present), when a business model is used to solve a social problem, began in the early 1990s and is still evolving today. The emergence of modern social entrepreneurship is linked to the activities of M. Young, who created more than 60 organizations around the world between 1950 and 1990, including several schools of social entrepreneurship in the UK (Dobele, 2013). In the 2000s, the concept of social entrepreneurship became more popular in society and in academic research, especially after the publication of Charles Leeds book

'The Rise of the Social Entrepreneur'. A set of authors (Mair *et al*., 2006) provided ten definitions of social entrepreneurship in the introductory chapter of 'Social Entrepreneurship', in another article Mair (2006) identified three meanings for social entrepreneurship. Scholar Hockert identified only five different uses of 'social entrepreneurship'. That many definitions reveal a flaw in various definitions of the word collocations 'social enterprise' and 'social entrepreneurship'. The long-term lack of a common definition threatens the further scientific development of a particular entrepreneurship study. The most referenced definition of a social enterprise is mentioned by M. Yunus (founder of social entrepreneurship and Nobel Laureate) that a social enterprise is a loss-making and non-profit enterprise owner created to solve a social problem. Profits are used to expand the company or improve the product / service (Yunus, 2007). Although this definition is taken as the basis for the definition of social entrepreneurship in policy documents and researchers, the result of social enterprise definition is different for each interpreter.

There are various components on which researchers focus on the essence of social entrepreneurship. Some scientists consider the mission to be the most important part of the definition for social entrepreneurship. For instance, Dees (2001) points to the mission of social entrepreneurs to maintain not only private but also social value. This mission, according to the researcher, is manifested through innovation, the unrestricted availability of existing resources, and the responsibility for the results achieved and places served (Dees & Economy, 2001). Scholar Mort also believed that social entrepreneurship leads to continuous innovation in business. Adding that social entrepreneurship forms itself more through a multidimensional construct that incorporates entrepreneurial methods to achieve social mission in a context of moral complexity (Mort *et al*., 2003). Roberts and Woods emphasized that social entrepreneurship is 'the creation, evaluation, and exploration of opportunities for transformative social change by passionate individuals' – embedding this concept in changing the world through social entrepreneurship (Roberts & Woods, 2005). Mair and Martı view social entrepreneurship as a process that involves the innovative combination of existing resources to meet social change and social needs (Mair & Martı, 2006). Social entrepreneurs are creative, resourceful and goal-oriented people who combine the best ideas from the corporate and non-profit world to create strategies that have the greatest social impact. Although each researcher points to a different 'importance' of social entrepreneurship, the unifying factor is the search for innovative approaches to social enterprise with existing resources and addressing the social issues and their different concepts.

Social entrepreneurship in context of Latvia

The Ministry of Welfare in Latvia points out that there is currently no universal definition of social entrepreneurship in the European Union (MoW, [w.y.]). Although there is no uniform definition in the European Union, the European Commission 2011 report on the 'Social Business Initiative: Creating the right conditions for social enterprises – the basis for the social economy and social innovation' stated: a social enterprise that is a participant in the social economy is an enterprise whose main purpose is to have a social impact and not to benefit its owners or partners. It operates in a marketplace, producing goods and services in a business-like and innovative way, and uses the revenue mainly for social purposes. These companies are managed responsibly and transparently, by involving the company's employees, customers and stakeholders in its economic activities.

The concept was clarified so that the Member States of the European Union have uniform information on what a social enterprise is. Taking into account the definitions of different authors, three definitions of social enterprise were chosen for the analysis of the work – M. Yunus, the definition of the European Commission statement and the definition in the Social Enterprise Law. A comparison of the definitions of social entrepreneurship is shown in Table 1.

Although the definitions are different, they have common features that characterize a social enterprise. Common features for social entrepreneurship definitions are:

- The aim is to create a measurable, positive social impact – The European Commission states in its report that the primary goal of a social enterprise is to create social impact, also in the Social Enterprise Law and M. Yunus in his definition that the goal of a social enterprise must be to solve a social problem. This goal is the most important thing that distinguishes a social enterprise from other types of enterprises. Although various companies have been trying to be socially responsible in recent years, their primary goal is not to solve social problems.
- It provides a service or sells a product to socially disadvantaged groups – social enterprises can solve social problems in various ways, for example, by offering their services as the final product of their enterprise. Another way to do this is to sell or return your product to socially disadvantaged groups, such as a 'second breath', which allows you to buy your product at a reduced price and then continue to divert your profits to various social purposes. Both the report of the European Commission and the Social Enterprise Law indicate that

Table 1

Comparison of the definitions of social entrepreneurship

Author	Definitions	Keywords
M. Yunus (2007)	A social enterprise is a loss-making and non-profit business owner created to solve a social problem. Profits are used to expand the business or improve the product / service.	- designable, beneficial social impact, - provides a service or sells a product to socially disadvantaged groups, - profits are used to achieve primary objectives, - the company is managed in an accountable and transparent manner.
European Commission (European Commission Report, 2012; EESC, 2011)	A social enterprise is an enterprise which, regardless of its legal form: a) has set itself the primary objective of achieving a measurable, positive social impact, in accordance with its statutes or any other instrument of incorporation, where that undertaking: - provides services or sells goods to vulnerable, disadvantaged or marginalized people; - is provided with goods or services using a production method; b) the profits are used primarily for the purpose of achieving the primary objectives rather than being distributed and have established pre-approved procedures and rules for any circumstances in which the profits are distributed to shareholders and owners, ensuring that any such distribution does not adversely affect the primary objectives; c) is managed in an accountable and transparent manner, in particular involving employees, customers and / or stakeholders involved in its business.	
Social Enterprise Law. Social Enterprise Law, 2017)	1) A social enterprise is a limited liability company which in accordance with the procedures laid down in this Law has been granted the status of a social enterprise and which conducts an economic activity that creates a positive social impact (e.g., provision of social services, formation of an inclusive civil society, promotion of education, support for science, protection and preservation of the environment, animal protection, or ensuring of cultural diversity). 2) The status of a social enterprise may be acquired by a limited liability company where one or several public persons jointly do not have the majority of votes if the objective defined in the articles of association of the social enterprise is employment of the target groups.	

Source: author's own compilation based on Yunus, 2007; Dobele, 2013; European Commission Report, 2012; EESC, 2011; Social Enterprise Law, 2017.

this indicator is important in defining social entrepreneurship.

- The profits are used for primary purposes – the fact that the profits of a social enterprise cannot be obtained by its owner or investor, in the definition of what a social enterprise states, Yunus and the European Commission report. A for-profit social enterprise can invest in expanding the enterprise and improving a product or service, but primarily to achieve its primary goals. In order to make the investment of profits as transparent as possible, the European Commission calls for the introduction of pre-approved procedures for channelling profits to a positive social impact. Although the Social Enterprise Law does not specify that the profit is not distributed among the owners, it is indicated in Section 5, Paragraph 3 of the Law that the status of a social enterprise can be obtained only if the obtained profit is not distributed, in order to achieve the objective, set out in the statutes. The non-distribution of profits between owners or investors has created a misconception in society that in this case the owner of the company may not receive a salary for his work, but this is not the case - the owner of a social enterprise indicates the salary for running the company and pays employees according to the labour market, if possible, from the company's revenue.
- The company is managed in a responsible and transparent way – the definition of the European Commission states that the company must be managed responsibly and transparently, in the definitions of M. Yunus and the Social Enterprise Law this is not indicated. However, law states that before receiving the status of a social enterprise, the Ministry of Welfare examines the application for obtaining the status of each social enterprise in a specially established commission, to which the company presents its further activities and submits all documents transparent operation of the company.

Table 2

Comparison of the definitions of social entrepreneurship in Nordic and Baltic countries

Country	Definition	Keywords
Finland (Finlex, 2003)	A social enterprise is a registered trader who is entered in the register of social enterprises.	- registered trader/ legal person/ an enterprise - status of a social enterprise - socio-economic enterprise purpose - special form of enterprise - for the disabled
Lithuania (Law on Social Enterprise (2020)	1. A social enterprise is a legal person or a subdivision thereof which has acquired the status of a social enterprise in accordance with the procedure established by this Law and has at least the number of employees belonging to the target groups of persons employed in social enterprises. 2. A social enterprise for the disabled is a legal person or a subdivision thereof which has acquired the status of a social enterprise for the disabled in accordance with the procedure established by this Law.	
Denmark (Folketinget, 2014)	A socio-economic enterprise is an enterprise whose primary purpose is not to generate a profit that creates growth in the enterprise or is pulled out of the owners' private fortunes. The purpose is instead to promote social and socially beneficial causes through the income generated in the business. It is thus not a special form of enterprise, but instead a 'label' that can be used by the socio-economic enterprises.	
Latvia (Social Enterprise Law, 2017)	1. A social enterprise is a limited liability company which in accordance with the procedures laid down in this Law has been granted the status of a social enterprise and which conducts an economic activity that creates a positive social impact (e.g., provision of social services, formation of an inclusive civil society, promotion of education, support for science, protection and preservation of the environment, animal protection, or ensuring of cultural diversity). 2. The status of a social enterprise may be acquired by a limited liability company where one or several public persons jointly do not have the majority of votes, if the objective defined in the articles of association of the social enterprise is employment of the target groups.	

Source: author's own compilation based on Finlex, 2003; Law on Social Enterprise, 2020; Folketinget, 2014; Social Enterprise Law, 2017.

M. Yunus defines social enterprise in general, but the European Commission and the Social Enterprise Law define social enterprise by supplementing it with specific legal limits.

Prior to the adoption of the Social Enterprise Law in Latvia in 2018, there was no specific restriction that distinguishes a social enterprise from foundations, associations or various charities, and a report from the European Commission in 2011 also states that a social enterprise may be one that meets the definition of a social enterprise, regardless of its legal form. The study 'Latvia on the Road to Social Entrepreneurship' concludes: In fact, social entrepreneurship is a synthesis of philanthropy and business (Les inska *et al*., 2012). Social entrepreneurship refers to the establishment of new social values that should take place in the public, private and non-profit sectors (Austin *et al*., 2006). At the same time, other researchers point out that social entrepreneurship is a way for society to find a solution where state and local authorities cannot. Researchers who conducted the research 'Individual in Social Entrepreneurship: Systematic Analysis of Social Entrepreneurship Personality' concluded that it is critical to pay close attention to the operationalization of the concept of social entrepreneur – how to more precisely define and measure the concepts of 'social' and 'entrepreneurship' (Stephan & Drencheva, 2017). The authors believe that there is still a public confusion between social enterprises and charities. The purpose, advantages and limitations of a social enterprise are different from the aims, advantages and limitations of foundations, associations and other similar organizations.

Definition between Latvia and Lithuania, other Nordic countries

Given the ambiguity of the worldwide concept of social entrepreneurship, it is vital to establish whether the meaning of social entrepreneurship in a specific context is the same. In this case, whether the definition of social entrepreneurship between the Nordic and Baltic countries – Lithuania, Estonia, Finland, Denmark, Norway and Iceland is the same.

Among the Nordic and Baltic countries, Latvia, Lithuania, Finland and Denmark are the only ones to have adopted specific laws on social entrepreneurship, where a specific definition of social entrepreneurship also appears. A comparison of the definitions of social entrepreneurship in Nordic and Baltic countries is shown in Table 2.

The definition of social entrepreneurship is also not uniform among the Nordic and Baltic countries. Social entrepreneurship is defined differently in each country. The basis of these definitions is the one established by law, or the purpose of the definition is to regulate entrepreneurship and, accordingly, to provide support to social entrepreneurs within the framework of the law. Common to all definitions is the fact that a social enterprise is a legal form – a registered trader, legal person or an enterprise – limited in its activities. The goal of social entrepreneurship is also unifying: it must be specific and measurable. Unlike the theoretical literature, the definition in the law clearly indicates that social enterprises are given the state title – social enterprise – this is different from non-profit organizations or ordinary business. Denmark is the only one to point out that a social enterprise is not a special form of enterprise, but instead a 'label' that can be used by socio-economic enterprises, stating that entrepreneurship must be the basis for achieving a social goal. Researchers from the European Association of Social Company Law (ESELA; from November 2018 called ESELA) notes that even if we look at only one legal form in one country, one can see differences in the way the legal form is drafted (ESELA, 2015), which is also reflected in different definitions. For example, other aspects (which influence stakeholders, decision-making and the distribution of profits, etc.) may be relevant to different social objectives. Lithuanian social entrepreneurship has historically been based on support for a social group with a disability, and since 2020, social entrepreneurship has been defined more broadly, while leaving important guidance on the proportions of target group employees in the company. The definitions of other countries are less restrictive to the specific target groups that must be the 'field' of the social entrepreneurship mission. Although the Nordic and Baltic countries are geographically closer to Latvia's position, such as the European support instruments for social entrepreneurship, each country has its own definition of social entrepreneurship. These differences in the definition of social entrepreneurship continue to hamper researchers' databases for international research. While there are significant differences in the definitions of social entrepreneurship, there will be limitations in research to social entrepreneurship.

Conclusions

1. The development of social entrepreneurship can be divided into three stages: the period of philanthropy, the period of global social movements and the modern period. The greatest contribution to the definition of social entrepreneurship and the development of the concept is made in the modern period. The time of modern social entrepreneurship, several representatives of social and political spheres began to update the term social entrepreneurship in the late 20th century and beginning of 21th century strengthening the concept of social entrepreneurship as we understand it now.
2. Although the Nordic and Baltic countries are geographically closer to Latvia's position, each country has its own definition of social entrepreneurship and its purpose. Common to all country definitions is that a social enterprise is a legal form limited in its activities. The goal of social entrepreneurship is also unifying, all social entrepreneurship purpose must be specific and measurable.
3. In Latvia, the context a social enterprise is an enterprise that has been granted the status of a social enterprise determined by the Ministry of Welfare and which solves socio-economic problems with an entrepreneurship mechanism.
4. While there are significant differences in the definitions of social entrepreneurship between scholars and law makers, there will be limitations in research to social entrepreneurship, which will obstruct the development of social entrepreneurship concept in the academic field and globally. Therefore, it is necessary to agree on a specific definition of social entrepreneurship before further research is developed.

References

Austin, J.E., Stevenson, H., & Wei-Skillern, J. (2006). *Social and Commercial Entrepreneurship: Same, Different, or Both? Entrepreneurship*. *Theory and Practice*, January, pp. 1–22. DOI: 10.1111/j.1540-6520.2006.00107.x.

Bornstein, D., & Davis, S. (2010). *Social entrepreneurship: What everyone needs to know*. Oxford University Press. ISBN-10: 0195396332.

Braunerhjelm, P., & Stuart Hamilton, U. (2012, February). Social entrepreneurship–a survey of current research. In *Swedish Entrepreneurship Forum Working Papers* (No. 2012: 9).

Chell, E. (2007). Social enterprise and entrepreneurship: Towards a convergent theory of the entrepreneurial process. *International small business journal*, *25*(1), 5–26. DOI: 10.1177/0266242607071779.

Dees, J.G., & Economy, P. (2001). Social entrepreneurship. *Enterprising nonprofits: A toolkit for social entrepreneurs*, *128*, 1–18. ISBN-10: 9780471397359.

Dobele, L. (2013). *Social Entrepreneurship Development Possibilities in Latvia.* Summary of the Doctoral thesis for the scientific degree of Dr.oec. Latvia University of Life Sciences and Technologies, Jelgava, Latvia.

European Economic and Social Committee. (2012). *Social Entrepreneurship and Social Enterprise* (exploratory opinion). *Official Journal of the European Union*. Retrieved March 5, 2022, from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1551685692245&uri=CELEX%3A52011AE1584.

ESELA. (2015). *Social enterprise in Europe. Developing legal systems which support social enterprise growth*. Retrieved March 6, 2019, from https://esela.eu/wp-content/uploads/2015/11/legal_mapping_publication_051015_web.pdf.

Finlex. (2003). *Act No. 1351/2003 on Social Enterprises*. Retrieved March 5, 2022, from http://www.finlex.fi/en/laki/kaannokset/2003/en20031351.pdf.

Folketinget. (2014). L 148 *Forslag til lov om registrerede socialøkonomiske virksomheder* (Proposal for a law on registered socio-economic enterprises). Retrieved March 7, 2019, from https://www.ft.dk/samling/20131/lovforslag/l148/20131_l148_som_vedtaget.htm. (in Danish).

Johnson, S. (2002). *Social Entrepreneurship Literature Review*. Retrieved March 4, 2022, from www.bus.ualberta.ca.

Law on Social Enterprises. (2007). Retrieved March 6, 2019, from https://eseimas.lrs.lt/portal/legalActPrint/lt?jfwid=1cdz0hg6oa&documentId=TAIS.312453&category=TAD.

Lešinska, A., Litvins, G., Pīpiķe, R., Šimanska, I., Kupcis, O., & Bušēvica, K. (2012). Latvija ceļā uz sociālo uzņēmējdarbību (Latvia on the way to social entrepreneurship). Retrieved March 5, 2022, from http://providus.lv/article_files/2265/original/SU_gala_9nov.pdf?1352889758. (in Latvian).

Light, P.C. (2006). Reshaping social entrepreneurship. *Stanford Social Innovation Review*, *4*(3), 47–51. Retrieved March 5, 2022, from https://wagner.nyu.edu/files/performance/ReshapingSE.pdf.

Mair, J., & Noboa, E. (2006). Social entrepreneurship: How intentions to create a social venture are formed. In *Social entrepreneurship* (pp. 121–135). Palgrave Macmillan, London. DOI: 10.1057/9780230625655_8.

Mair, J., Robinson, Jeffrey, & Hockerts, K. (Eds.) (2006). *Social Entrepreneurship*. London: Palgrave Macmillan. Retrieved March 6, 2022, from https://jeffreyrobinsonphd.com/wp-content/uploads/2017/06/Social-Entrepreneurship-Palgrave-Macmillan-1.pdf.

Martí, I. (2006). Introduction to part I-Setting a research agenda for an emerging field. In *Social entrepreneurship* (pp. 17–21). Palgrave Macmillan, London. DOI: 10.1057/9780230625655_2.

Martin, R.L., & Osberg, S. (2007). *Social Entrepreneurship: The Case for Definition*. In *Stanford Social Innovation Review*. Spring, pp. 29–39. DOI: 10.48558/TSAV-FG11.

Ministry of Welfare. (2022). *Social enterprise register*. Retrieved March 6, 2022, from https://www.lm.gov.lv/lv/socialo-uznemumu-registrs.

Mulgan, G. (2006). Cultivating the other invisible hand of social entrepreneurship: Comparative advantage, public policy, and future research priorities. *Social entrepreneurship: New models of sustainable social change*, 74-96. ISBN 0-19-928387-7.

Nicholls, A. (Ed.). (2008). *Social entrepreneurship: New models of sustainable social change*. Oxford: Oxford University Press. ISBN-10: 0199283885.

Peredo, A.M., & McLean, M. (2006). Social entrepreneurship: A critical review of the concept. *Journal of world business*, *41*(1), 56–65. DOI: 10.1016/j.jwb.

Roberts, D., & Woods, C. (2005). Changing the world on a shoestring: The concept of social entrepreneurship. *University of Auckland business review*, *7*(1), 45–51. Retrieved March 5, 2022, from http://www.thebookshelf.auckland.ac.nz/docs/UABusReview/2005_07_i01-05-asd.pdf.

Robinson, J. (2006). Navigating social and institutional barriers to markets: How social entrepreneurs identify and evaluate opportunities. In *Social entrepreneurship* (pp. 95–120). Palgrave Macmillan, London. Retrieved March 5, 2022, from http://jeffreyrobinsonphd.com/wp-content/uploads/2017/06/Navigating-Social-and-Institutional-Robinson2006-1.pdf.

Simms, M. (2009). Insights from a management prophet: Mary Parker Follett on social entrepreneurship. *Business and Society Review*, *114*(3), 349–363. DOI: 10.1111/j.1467-8594.2009.00346.x.

Social Enterprise Law. (2018). Retrieved March 5, 2022, from https://likumi.lv/ta/en/en/id/294484-social-enterprise-law.

Sociālais uzņēmums – darīt labu un pretī iegūt kvalitāti (Business Network. Social enterprise – do good and get quality in return). *Swedbank*. Retrieved March 5, 2022, from https://businessnetwork.lv/ievads/izaugsme/socialais-uznemums-visi-var-52915. (in Latvian).

Stephan, U., & Drencheva, A. (2017). The person in social entrepreneurship: A systematic review of research on the social entrepreneurial personality. *The Wiley handbook of entrepreneurship*, 205–229. DOI: 10.1002/9781118970812.ch10.

Stevenson Howard, H., & Carlos Jarillo, J. (1990). *A paradigm of entrepreneurship*. In *Entrepreneurial management Strategic Management Journal*. Vol. 11, pp. 17–27. Retrieved March 4, 2022, from https://www.jstor.org/stable/2486667.

Sullivan Mort, G., Weerawardena, J., & Carnegie, K. (2003). Social entrepreneurship: Towards conceptualisation. *International journal of nonprofit and voluntary sector marketing*, *8*(1), 76–88. DOI: 10.1002/nvsm.202.

Tan, W.L., Williams, J., & Tan, T.M. (2005). Defining the 'social'in 'social entrepreneurship': Altruism and entrepreneurship. *The International Entrepreneurship and Management Journal*, *1*(3), 353–365. DOI: 10.1007/s11365-005-2600-x.

Trivedi, C. (2010). Towards a social ecological framework for social entrepreneurship. *The Journal of entrepreneurship*, *19*(1), 63–80. DOI: 10.1177/097135570901900105.

Yunus, M. (2007). *Social business.* Retrieved March 5, 2022, from http://www.muhammadyunus.org/index.php/social-business/social-business Access: 19.02.2021.

 DOI: 10.22616/rrd.28.2022.025

EU FUNDING AS A DETERMINANT OF FOREIGN DIRECT INVESTMENTS IN RURAL AREAS - POLICY IMPLICATIONS

***Juris Hazners[1], Andra Zvirbule[2]**
[1]Institute of Agricultural Resources and Economics, Latvia
[2]Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: juris.hazners@arei.lv

Abstract
This paper analyzes the direct impact of the EU funding on the spatial distribution of Foreign Direct Investment (FDI) inflows in Latvian rural districts. While the determinants of inflows of FDI are often analysed at the regional and national level, the impact of the EU funding on the spatial distribution of FDI between the administrative entities within a single country is not extensively studied. The research objective is to assess the possible net impact of the EU funding on FDI inflows in Latvian rural districts, thus enabling the more targeted policy decisions with respect to the structure in future EU funding. To evaluate this impact, Instrumental Variables method is applied using the panel data on Latvian rural districts. The research results confirm that positive direct impact of the EU funding on the FDI inflows in Latvian rural districts exists, and it is substantial and statistically significant. At the same time, confounded 'third factors' might exist with negative impact on FDI inflows. While the spatial distribution of the FDI inflows in several regional aspects is rather uneven, the respective differences in the EU funding are less pronounced confirming the existence of negative 'third factors'. Hence, the structure of the support by EU funds has to be revised to improve the local potential determinants of the FDI inflows with emphasis on infrastructure and human capital.
Key words: rural areas, foreign direct investments, EU funding, instrumental variable, policy implications.

Introduction

The gains and losses from Foreign Direct Investment (FDI) inflows in the country are described by Czinkota et al. (2015). On the one hand, there are economic benefits like increase in capital flows, new technologies, increased competition that benefits the economy, improvements in balance of payments, new jobs created, improved access to global markets. Also, the standards of living might improve. On the other hand, risks arise in a longer term of increase in capital outflows in cases when the shortage of local suppliers induces larger imported supplies. Often FDI inflows bring changes in the lifestyles of consumers in the host country by introducing new products and services. Studies abound on country level determinants of FDI, especially in large Asian economies like China and India. Zheng (2009) employs statistical models for China and India showing ambiguous results. For both countries market growth, imports, labour costs, and the country political risk and policy liberalization are the FDI determinants. While exports, market size, and borrowing costs are important to China, geographical and cultural distance factors are important to India. Panel data analysis of Brazil, Russia, India, China and South Africa (BRICS) by Vijayakumar et al. (2010) identifies market size, labour cost, infrastructure, exchange rate and gross capital formation as the potential determinants of FDI inflows while the economic stability, growth prospects trade openness seem to be the insignificant factors. Liargovas and Skandalis (2012) tested the causality between FDI inflows and several factors in the developing countries by analyzing panel data. They prove that in a longer term the inflows of FDI are associated with the openness to trade. Procher (2011) finds that since the very beginning French investments in Europe, North America and North Africa are positively affected by higher market demand and former colonial ties with France, while higher labour cost and distance are deterring factors. Eastern Europe as a region is attractive location for manufacturers and established companies. Agglomerations and clusters of companies are important. Cleeve et al. (2015) assessed the role of human capital (HK) measured by several indicators of educational attainment on FDI inflows to sub-Saharan Africa. The research results show that all measures of HK have a significant influence on FDI. Katsaitis and Doulos (2009) investigated the impact of the funding from EU Structural Funds on the volume of FDI inflows in EU-15 countries using a variety of econometric techniques yielding robust empirical findings. The results indicate that the institutional quality of the receiving countries is crucial. Breuss et al. (2010) proved that the EU enlargement in 2004 with a redistribution of funds towards the new member states has made the accession countries even more attractive as a location of FDI. Dumciuviene and Paleviciene (2017) analyzed the impact of the support form EU structural funds on FDI inflows. Fewer papers focus on the spatial distribution of the FDI within a single country. Hoškova (2001) states that since joining the EU, the distribution of FDI inflows in Slovakia have been uneven with more than half of FDI being made in a close proximity to state or regional capitals. The larger distance from an industrial centre means less foreign investment. She finds that the main factors behind this are associated with the infrastructure of transport and communications (especially access to highways and the airport), skilled labour and easily accessible relevant state institutions. Previous experience with the

foreign investors also affects new inflows positively. By analyzing input-output linkages in Hungary, Bekes (2005) suggests that there is an agglomeration effect and access to suppliers and markets is crucial for selecting the location. The closeness of companies in the same industry is important pointing towards a role of already established clusters. Castro et al. (2007) analyzes regional patterns in Argentine with the regression based on spatial error model and spatial lag model. The results suggest that among other proxies of infrastructure the increase in paved roads per capita provides for FDI growth. The overall results from the analysis in Sweden by Falck and Colin (2014) indicate that regions with a relatively diverse economy, good access to international airport and qualified labour force appear to be the most attractive destinations for FDI ventures. Furthermore, the importance of information and knowledge spillovers is emphasized. Kersan-Škabič and Tijanič (2014) by performing static and dynamic panel data analysis identified a number of factors that influence the unequal distribution of FDI inflows. The results show that education, location at the areas of special state concern and capital city region have positive and statistically significant influences, while unemployment and location at the regions bordering with the EU show negative statistically significant influences. The agglomeration effect also is stressed. The research results obtained at the county level in Poland by Nazarczuk and Krajewska (2018) are similar to other findings in other countries at the regional level. The FDI inflows depend on road quality, availability of skilled labour, overall economic situation and proximity of markets. Steenbergen and Tran (2020) have addressed the scarcity of research on the impact of FDI on employment and welfare in developing countries. Moreover, the influence of FDI on income inequality also is not extensively studied. The results obtained prove that FDI has a positive impact on employment and growth in wages, helping to reduce poverty as FDI-induced wage increases occur mainly at the lower side of the income spectrum. However, at the same time FDI raises the income gap because workers with poorer education and lower skills are less affected. The negative impact of FDI on income distribution should be addressed in labour market and education policies. In the EU countries, Hunady and Orviska (2014) found that FDI inflows are larger when labour costs and the risks of incurring additional costs from firing are lower. At the macro level, the openness of the economy is important along with the lower public debt and higher GDP per capita.

Materials and Methods

The instrumental variables (IV) method is a quasi-experimental design technique. Similarly to propensity score matching, instrumental variables provide an adjustment for confounding factors. Imbens and Angrist (1994) state that while the evaluation of treatment effects in healthcare and medical programs is usually based on the data collected from randomly assigned treatment and control groups, the use of random assignment in socio-economic programs is controversial. They introduce the local average treatment effect concept. The framework for estimation of causal effects with instrumental variables is proposed by Angrist, Imbens and Rubin (1996). They address the problems arising when assignment to a binary treatment is ignorable while the receipt of treatment is non-ignorable. The instrumental variables approach is used in a number of impact analyses of specifically designed programmes in labour market policy area. Carling and Pastore (1999) analyzed two Swedish employment programs. They find that the engagement of the unemployed in the subsidized elaborated special programs increases the risks for the person to be repeatedly unemployed more than twice if compared to the program designed for the encouraging the self-employment. By using non-parametric methods Forslund et al. (2004) found that Swedish employment subsidy programme has a positive treatment effect for the participants. Frolich and Lechner (2004) evaluated the effects of active labour market policies (ALMP) such as training on chances for the participant to get an employment and improvement in earnings by non-parametric instrumental variables. Their results show that in the short term the participation in a program raises probability to get a job by approximately 15%. Winter-Ebmer (2006) use the microeconometric evaluation methods to assess the treatment effects of a specialized non-managerial training program in Austria on workers who lost their jobs due to a decline in the metalworking industry. The results show that in the short and even medium term after the completing the program graduates have far better employment opportunities with higher labour compensations. Usually, FDI is not a variable targeted in broader national or specifically designed programs as it is not suitable for measuring the impact in terms of economic growth, productivity, employment and income. Hence, there are no studies available on the impact of public support on FDI.

In a matrix form, with a simple regression with one independent variable, the cause-result relationship between the dependent variable and independent variable can be indicated as follows:

$$Y = \alpha + \beta X + E, \quad (1)$$

where:
α – regression constant,
β – regression slope coefficient,
$Y = (y_1 \dots y_n)$ – vector of dependent variable,

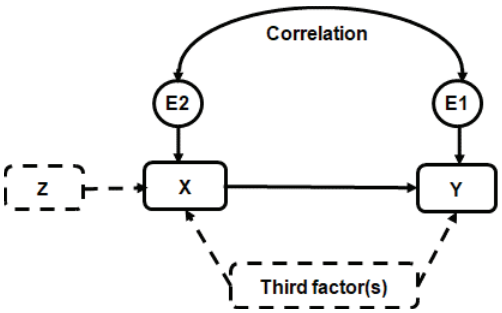

Figure 1. The layout of the instrumental variables method.

$X = (x_1 \dots x_n)$ – vector of independent variable,
$E = (e_1 \dots e_n)$ – vector of error terms (residuals).

However, the possibility of existence of so-called 'third factor(s)' or confounded variables is not considered. The simultaneous increase in dependent and independent variables might be affected by the same single factor or several factors. Likewise, the increase in independent variable might occur when dependent variable decreases due to 'third factor(s)'. If the expected value of independent variable from the regression can be regressed by some other variable and other independent variable(s) added, the effect caused by 'third factor(s)' can be separated and explained as correlation between the errors (residuals) from two regressions. The approach used can be illustrated by the following layout (Figure 1).

Two conditions have to be satisfied. First, there a correlation between both errors (residuals) exists. Second, correlation does not exist between the instrumental variable and both errors (residuals). The suitability of selected instruments has to be empirically tested. In practice, variables which satisfy those two conditions can rarely be found, and this is often the main reason why instrumental variables method is not applicable. The coefficients in both regressions have to be statistically significant.

The data panel used in this study contains information on 110 Latvian rural districts according to the territorial division before the territorial reform coming into force in June, 2021. Four variables are selected – total support received from EU funds over the period from 2015 to 2019 (for calculations, vector is denoted as 'funds'), aggregated FDI inflows from 2015 to 2021 ('fdi'), district budgets in 2015 ('budget') and number of commercial healthcare providers in 2015 ('health'). The selection of the last two variables is determined by their empirically proven suitability for use as instruments. The data on EU funds, FDI inflows and district budgets are extracted from the Regional Development Indicators Module database (RAIM, 2022). The data on healthcare providers are extracted from the National Statistics databases (CSP, 2022).

Results and Discussion

The calculations start with the first regression - 'funds' are regressed on 'budget' and 'health'. By inserting the obtained values of the regression coefficients, the expected value of funds (denoted 'funds_hat') is calculated. By extracting the expected value from the actual value, the first residual vector e1 is calculated. Then, the second regression follows – 'fdi' is regressed on 'health' and 'funds_hat'. By inserting the obtained values of the regression coefficients, the expected value of 'fdi' (denoted 'fdi_hat') is calculated. By extracting the expected value from the actual value, the second residual vector e2 is calculated. The results of two regressions are shown in Table 1.

All coefficients in both regressions are statistically significant. The last calculation step is a correlations matrix. The correlations between 'budget' and both residuals are shown in Table 2.

Neither of residuals correlates with 'budget' and there exists a moderate statistically significant correlation between the residuals. Thus, the two conditions mentioned above are met and 'budget' can be considered a valid instrument. The coefficient of the 'funds_hat' variable in the second regression characterizes the direct impact of the EU funding on FDI inflows. Increase in one currency unit of EU funding causes increase in FDI inflows by 4.96 currency units. The impact is rather high.

To confirm the plausibility of these findings, ivreg2 procedure was performed with Stata13 software yielding the same results.

Correlation between FDI and EU funding was negative, weak and statistically insignificant, $r(108) = -0.140$, $p = 0.856$. Simple linear regression was used to test if EU funding significantly predict FDI. The fitted regression model was: (fdi) = 16270507 - 0.213 * (funds). The overall regression was not statistically significant (R-squared = 0.02, $F_{(1,108)} = 2.17$, $p = 0.144$). It was found that EU funding can not significantly predict FDI ($\beta = -0.213$, $p = 0.144$). These two calculations are used only to check whether the findings of positive high impact of EU funding on FDI are in line with the expected direction of the relationship

Table 1

Results of two instrumental variable regressions

		β	SE	Beta
Coefficients – 1st regression				
	Intercept	15109516***	2979513	
	Budget	1.07*	0.631	0.216
	Health	221024**	112629	0.250
Model summary				
	R-squared	0.188		
	Adjusted *R*-squared	0.173		
	F statistic	12.39***		
Coefficients – 2nd regression				
	Intercept	-82089947***	14859640	
	Health	-1461039***	319362	-1.091
	Funds_hat	4.96***	0.833	1.419
Model summary				
	R-squared	0.293		
	Adjusted *R*-squared	0.28		
	F statistic	22.19***		

** p<0.1, ** p<0.05, *** p<0.01*

Table 2

Pairwise correlations matrix between the instrumental variable and residuals

Correlations	budget	e1	e2
budget	1.000	-0.000	-0.000
e1	-0.000	1.000	-0.410***
e2	-0.000	-0.410***	1.000

** p<0.1, ** p<0.05, *** p<0.01*

between two variables. The contradictions between the results of these two simple calculations with the empirically strong results obtained with instrumental variable regressions point towards the existence of "third factors" that have negative impact on FDI. A comparison of spatial distributions of EU funding and FDI might lead to conclusions about the impact of EU funding on FDI in various spatial segments.

The distributions of the aggregate FDI and EU funding are shown in Figure 2.

Distribution of aggregated FDI is shown on the left side of the picture. In regional breakdown, it shows marked differences between regions with majority of inflows to Central Region. In Eastern Region, the inflows are the smallest. At the same time, the EU funding is distributed rather evenly. Referring to the studies mentioned above, an agglomeration effect on FDI inflows is clearly visible with capital city and vicinities being a dominating factor. Similarly marked differences do exist between inland and border districts or districts closer to the State capital and remote districts while the differences in EU funding are less pronounced. In distance breakdown, remote districts receive even more EU funding. These findings are also in line with previous research pointing towards a dominance of border and distance as factors with negative influence on FDI inflows. Thus, the superficial conclusion from the instrumental variable regressions about targeting larger inflows of FDI with unstructured increasing of EU funding would be erroneous. The 'third factors' mentioned above from the research on the determinants of FDI inflows should be considered for modifying the structure of funding accordingly to be enclosed in future rural development policies. These might include elaboration of policy measures that target the improvements in human capital and infrastructure in 'vulnerable' spatial segments. By examining the EU support for small and medium-sized enterprises in the Czech Republic and Slovakia Šipikal et al. (2013) have detected a substantial deadweight representing more

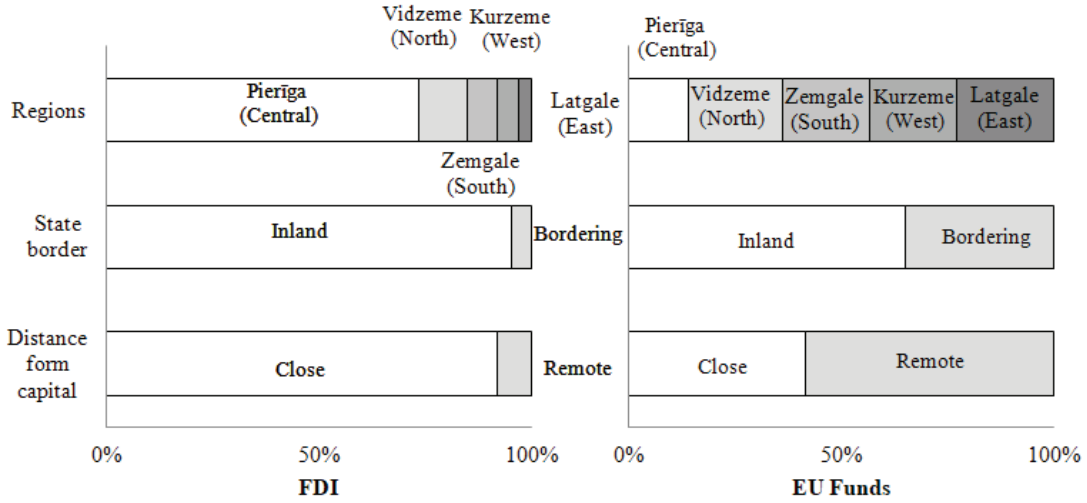

Figure 2. Distribution of aggregated FDI and EU funding, 2015-2019, by spatial characteristics.

than 35% of public subsidies. The activities within the measures designed for education and creation of job opportunities have lower deadweight effect than support for investments. The share of the support for investments in Latvian Rural Development Programme amounts to 46% of total public financing. Meanwhile, the support for infrastructure and knowledge transfer combined has only 14% share in total financing. However, as previously conducted evaluations suggest (Benga & Hāzners, 2016), there is no deadweight effect detected from farm modernization support measure which consumes the majority of investment support in the total public financing. Hence, the redistribution of public support by redirecting funding from investments to other activities can not be recommended as there are no investments which would have been made without programme support. Instead, the restructuring of funding less favourable areas in terms of FDI inflows with emphasis on infrastructure, human capital and other spatial determinants of FDI like manufacturing clusters has to be considered.

Conclusions

1. The FDI inflows in the host country brings economic benefits like increased capital flows, technology transfer, increased competition, favourable balance of payments, increased employment opportunities, improved access to global markets and improved standards of living. New products and services are often introduced.
2. The long-term risks arising with the FDI inflows are associated with possible capital outflows due to larger imported supplies. The adverse effects include also inequality created by disproportionate benefits for better educated and higher-skilled workers.
3. The main country level determinants of FDI inflows are economic stability, trade openness, policy liberalization, institutional qualities, market size, market growth rate, labour costs, geographical and cultural proximity, infrastructure, exchange rate and gross capital formation. In the EU, redistribution of funds towards the new member states has had a positive impact on the attractiveness of accession countries with respect to a location of FDI.
4. The main spatial determinants of FDI inflows within a single country are agglomeration factors such as vicinity of capital city and a few regional centres, especially driven by a good transport and communications infrastructure, distance from the economic centre of the country, skilled workforce, past experience with the foreign investors, industrial clustering and proximity of potential customers.
5. Due to a scarcity of research on the impact of the EU funding on the spatial distribution of FDI inflows within a single country, there is no evidence mentioned on the possible direct impact of the EU funding.
6. The research results bring the evidence that the direct impact of the EU funding on the FDI inflows in Latvian rural districts is substantial and statistically significant. At the same time, confounded ‘third factors’ might exist with a negative impact on FDI inflows.
7. While the spatial distribution of the FDI inflows in several regional aspects is rather uneven, the respective differences in the EU funding are less pronounced confirming the existence of negative ‘third factors’. Hence, the structure of the support by EU funds has to be revised to improve local potential determinants of the FDI inflows with emphasis on infrastructure, human capital and clusters.

References

Angrist, J.D., Imbens, G.W., & Rubin, D.B. (1996). Identification of Causal Effects Using Instrumental Variables, *Journal of the American Statistical Association*, 91:434, 444–455.

Békés, G. (2005). *Location of manufacturing FDI in Hungary: How important are inter-company relationships?* (No. 2005/7). MNB Working Papers.

Benga, E., & Hāzners, J. (2016). *Counterfactual evaluation of farm modernization measure of Latvian RDP 2007-2013 with propensity score matching.* Good Practice Workshop 'Methods for Assessing Impacts of Rural Development Programmes 2007-2013', 4-5 July 2016, Palermo, Italy. Retrieved April 14, 2022, from https://enrd.ec.europa.eu/sites/default/files/gpw-03_3-1_latvia_hazners.rev_.pdf.

Breuss, F., Egger, P., & Pfaffermayr, M. (2010). Structural funds, EU enlargement, and the redistribution of FDI in Europe. *Rev World Econ* 146, 469–494.

Carling, K., & Pastore, F. (1999). *Self-employment grants vs. subsidized employment: Is there a difference in the re-unemployment risk?* IFAU Working Paper 1999: 6, Uppsala. Retrieved April 15, 2022, from http://www.ifau.se/upload/pdf/se/to2000/wp99-6.pdf.

Castro, L., Regis, P., & Saslavsky, D. (2007). *Infrastructure and the Location of Foreign Direct Investment. A Regional Analysis.* MPRA Paper No. 6736. Retrieved April 14, 2022, from https://mpra.ub.uni-muenchen.de/6736/.

Cleeve, E.A., Debrah, Y., & Yiheyis, Z. (2015). Human capital and FDI inflow: An assessment of the African case. *World Development*, 74, 1–14.

CSP (2022). Retrieved April 14, 2022, from https://data.stat.gov.lv/pxweb/en/OSP_PUB/START__ENT__UZ__UZS/UZS030.

Czinkota, M.R., Ronkainen, I.A., & Moffett, M.H. (2015). *Fundamentals of International Business*. New York: Wessex, 2015, 60.

Dumciuviene, D., & Paleviciene, A. (2017). Finding the Determinants of FDI Inflows to EU Member States. In: Bilgin M., Danis H., Demir E., Can U. (eds) Country Experiences in Economic Development, Management and Entrepreneurship. Eurasian Studies in Business and Economics, Vol. 5. Springer, Cham. DOI: 10.1007/978-3-319-46319-3_8.

Falck, S., & Colin, A. (2014). Location of Foreign Direct Investment in Services: some Cross-industrial evidence from Sweden. *Revue d'Économie Régionale & Urbaine*, 2014/2 Septembre, 285–314.

Forslund, A., Johansson, P., & Lindqvist, L. (2004). *Employment subsidies – A fast lane from unemployment to work?* IFAU Working Paper 2004, n. 18, Uppsala. Retrieved April 14, 2022, from http://www.ifau.se/upload/pdf/se/2004/wp04-18.pdf.

Frölich, M., & Lechner, M. (2004). *Regional treatment intensity as an instrument for the evaluation of labour market policies.* Discussion Paper n. 1095, Bonn, IZA. Retrieved April 14, 2022, from http://repec.iza.org/dp1095.pdf.

Hoškova, A. (2001). *Impact of foreign direct investment on the economy of Slovakia.* National Bank of Slovakia, Institure of Monetary and Financial Studies, 2001.

Hunady, J., & Orviska, M. (2014). Determinants of foreign direct investment in EU countries – do corporate taxes really matter? *Procedia Economics and Finance*, 12, 243–250.

Imbens, G.W., & Angrist, J. (1994). Identification and Estimation of Local Average Treatment Effects. *Econometrica*, 62, 467–475.

Katsaitis, O., & Doulos, D. (2012). The impact of EU structural funds on FDI. *Kyklos* 62.4 (2009): 563–578.

Kersan-Škabič, I., & Tijanič, L. (2014). The Influence of Foreign Direct Investments on Regional Development in Croatia. *Croatian Economic Survey*, 2014, Vol. 16, issue 2, 59–90.

Liargovas, P.G., & Skandalis, K.S. (2012). Foreign direct investment and trade openness: The case of developing economies. *Social indicators research* 106.2 (2012): 323–331.

Nazarczuk, J.M., & Krajewska, A. (2018). Local determinants of foreign direct investment in Poland: the role of relative distance. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 13(1), 73–88.

Procher, V. (2011). Agglomeration effects and the location of FDI: evidence from French first-time movers. *Ann Reg Sci* 46, 295–312.

RAIM (2022). Regional development indicators module. Retrieved April 14, 2022, from https://raim.gov.lv/MicroStrategy/asp/Main.aspx.

Steenbergen, V., & Tran, T.T. (2020). The Distributional Effects of FDI: Evidence from Ethiopia, Vietnam, and Turkey. *Global Investment Competitiveness Report 2019/2020: Rebuilding Investor Confidence in Times of Uncertainty.*

Šipikal, M., Pisar, P., & Labudova, V. (2013). Are subsidies really needed? The case of EU regional policy in the Czech and Slovak Republics. *E+ M Economics & Management* 2013 (4).

Vijayakumar, N., Sridharan, P., & Rao, K.C.S. (2010). Determinants of FDI in BRICS Countries: A panel analysis. *International Journal of Business Science & Applied Management (IJBSAM)* 5.3 (2010): 1–13.

Winter-Ebmer, R., (2006). Coping with a structural crisis: evaluating an innovative redundancy-retraining project. *International Journal of Manpower*. 2006 Dec 1.

Zheng, P. (2009). A comparison of FDI determinants in China and India. *Thunderbird International Business Review*, 51.3 (2009): 263–279.

 DOI: 10.22616/rrd.28.2022.026

EFFECTIVENESS OF ACTIVE LABOR MARKET POLICY MEASURES IN LATVIA

***Vera Hohlova**, **Baiba Rivza**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: veragaidai@gmail.com

Abstract
The impact of the Covid-19 pandemic on the world of work has been both devastating and far-reaching. In order to reduce the unemployment rate, it is necessary to increase motivation and incentives to look for a job, to improve readiness for work and help to find a suitable job, as well as to expand employment opportunities. Public employment services have become an important point for jobseekers, giving workers and employers access to a number of passive and active labour market support mechanisms. Active labour market policies are a key tool through which welfare states seek to improve the employment prospects of the unemployed. Ongoing monitoring and evaluation of the impact of active labour market policies and programs are needed to strengthen the effectiveness and efficiency of policies in responding to the needs of different groups. This study analyzes the data obtained from the survey of the unemployed with the aim of finding out how actively the unemployed cooperate with the state employment service and use services offered by it, as well as to reveal the possible shortcomings and shortcomings of this society, so that it is possible to eliminate them and increase the efficiency of this cooperation.
Key words: unemployed, Covid-19, unemployment, unemployed women, employment services, unemployment reduction measures.

Introduction

The International Labour Organization (ILO) has called for global action to bring about an inclusive, sustainable and lasting recovery from the Covid-19 crisis. According to the ILO, the impact of the pandemic on the world of work has been both devastating and far-reaching. There has been a loss of working hours, an increase in unemployment, inactivity and underemployment. Labour and business incomes have declined, including an increase in bankruptcies, especially among small businesses. New challenges have emerged in the areas of occupational health, safety and fundamental rights. And all of the above has exacerbated poverty as well as gender, economic and social inequalities (ILO, 2021).

Effective activation policies aim to ensure that as many people as possible have access to the workforce and good employment. To ensure this, it is necessary to increase motivation and incentives to look for work, to improve readiness for work and to help find a suitable job, as well as to expand employment opportunities. The implementation of these key elements needs to be managed by an efficient and well-coordinated labour market, as well as by social institutions and policies. Ongoing monitoring and evaluation of the impact of policies and programs is needed to strengthen policy effectiveness and efficiency in responding to the needs of different groups (OECD, 2021).

International empirical evidence suggests that employment services are one of the most cost-effective active labour market interventions aimed at facilitating the transition of workers and enterprises to the labour market. Since the global economic and financial downturn of 2008-2009, public employment services have become an important point for jobseekers, giving workers and employers access to a number of passive and active labour market support mechanisms. In the current crisis, PES have played a key role in assisting workers and employers with redundancies, leave or reduced working hours (OECD, 2020).

The future of work poses new challenges for public employment services across the OECD. Automation suppresses and changes the skills needed to work in certain occupations, forcing employment services to deal with more complex job transitions. At the same time, digitalisation is promoting the development of new forms of work, such as platforms and remote work. The Covid-19 crisis is likely to accelerate these trends, as certain workplaces may prolong remote work, and companies are automating production processes at reduced margins. Public employment services will need to step up digital training for their staff and jobseekers, and the digitalisation of services has the potential to improve job search, speed up recruitment and devote more time to vulnerable jobseekers and employers (OECD Library, 2020).

Materials and Methods

Participants and Recruitment

In order to find out the impact of the Covid-19 pandemic on the unemployment rate in Latvia, a study has been conducted, during which Latvian unemployed people were interviewed.

The survey was conducted by the research centre SKDS, which has been represented in E.S.O.M.A.R (European Society for Opinion and Market Research) since 2000 and operates in accordance with all the ethical and methodological rules and standards, set by this organization for public opinion and market research institutes. Since 2014, SKDS research centre has been represented in the WIN network of research companies (SKDS, 2020).

The survey was completed by 216 unemployed people aged 18 and over. Data were collected from

October 29, 2020 to November 2, 2020 (Hohlova & Rivža, 2021).

In accordance with the regulations of the Cabinet of Ministers of the Republic of Latvia "Regulations on the Procedure for Organizing and Financing Active Employment Measures and Preventive Unemployment Reduction Measures and the Principles for Selecting Implementers", the State Employment Agency (SEA) organizes active employment measures and preventive unemployment reduction measures, as well as physical and legal entities and associations of such persons. The measures are financed from the state budget, the European Union structural funds and other sources of funding (Cabinet Regulations, 2011).

In the 2020 report, the SEA issued an opinion that in order to overcome the consequences of the Covid-19 pandemic, the SEA promptly developed and implemented support measures, including wage subsidy measures, which provided employers with wage subsidies for the first three months for SEA-registered unemployed (SEAL, 2021).

The survey was conducted at a time when the number of people with Covid-19 in Latvia began to increase significantly. At the beginning of September 2020, the number of people infected with Covid-19 was 1428, but already at the beginning of October 2020, 3450 people had the disease, and at the beginning of November, 8095 (COVID-19, 2022). An increase in unemployment was also inevitable; if in the fourth quarter of 2019 the unemployment rate in Latvia was 6%, then in the fourth quarter of 2020 the unemployment rate reached 7.9% (Eurostat, 2022). The registered unemployment rate at the end of December 2020 was 7.7% (SEA, 2020), which had also increased compared to the unemployment rate of 6.2% at the end of December 2019 (SEA, 2019).

Survey development

Prior to the survey, the existing solutions on the unemployed and unemployment indicators were studied, only information on employment agencies and the measures implemented by them was collected, as well as informal conversations with the unemployed provided information on the actual situation, problems and possible problems. The survey started with finding out the demographic information, and only the unemployed were selected using filters. Only both registered and unregistered unemployed were surveyed, which was important because the State Employment Agency, like agencies in other countries, offers statistics only on registered unemployment. This article will cover both the data obtained and the national official statistics that are relevant and the objectives of the study.

Demographics included age, gender, marital status, level of education, income, nationality and region of residence. When answering the questions, the respondents could choose from the suggested specific answer options, and only one question was an open question.

Three questions of the survey were aimed at clarifying the circumstances regarding the cooperation of the unemployed with the SEA and their involvement in active employment measures or preventive measures to reduce unemployment. Respondents were asked whether they plan to work with the SEA to find a job, and whether the unemployed person also applied for an active employment measure when applying for the status of an unemployed person, and if the answer to this question was positive, he / she was asked to name exactly what event the unemployed had applied for.

Results and Discussion

At the macroeconomic level, the problem of unemployment is most often addressed by pointing to business cycle conditions or excessive labour market regulations. Employment and training programs, as well as other active unemployment reduction measures, are much less frequently evaluated to assess their effectiveness in reducing the duration of unemployment or guaranteeing new jobs with a decent income (Vassiliev *et al*., 2005).

Active labour market policies are a key tool through which welfare states seek to improve the employment prospects of the unemployed. Active labour market policies consist of a variety of interventions: public employment services that promote the link between jobseekers and employers, training programs that increase employment opportunities by accumulating human capital, the creation of public jobs that create additional jobs in the public sector, and subsidized employment that includes recruitment incentives for employers, such as wage subsidies (Fredriksson, 2020).

In most countries, public employment services inform the unemployed about available job vacancies, and the services they provide are usually free of charge for both employers and the unemployed. Unemployed people usually use two job search strategies. The first is to use the services of a public employment service, where the public employment service acts as an intermediary between employers offering vacancies and the unemployed. The second strategy is to use the private or active search methods of the unemployed, including advertisements in newspapers and databases, as well as direct contacts with employers and indirect contacts through friends and relatives (Fougére, Pradel, & Roger, 2009).

By registering with the public employment service, an unemployed person acquires not only rights but also obligations. When registering with the Latvian SEA, the unemployed have the following obligations:

to search for a job independently and with the help of the SEA and immediately after receiving the SEA individual job search plan, to visit the SEA on the day specified in the individual job search plan and to present within working days from the day of receipt of the invitation, to participate in the activities provided for in the individual job search plan, including filling in the job search diary (SEA, 2022).

The study involved 216 unemployed people aged 18 to 63. The age group most represented in the study is from 55 to 63 years (27.8%), followed by the group of respondents from 35 to 44 years (25.9%), while the least represented age group is from 18 to 24 years (7.9%). %). 27.3% of men and 72.7% of women participated in the survey. 49.1% of respondents have secondary or secondary special education, 43.1% of respondents have higher education, while 7.9% of respondents have only basic education.

When asked if the respondent had ever been in paid employment, 100% of the answers were 'yes'.

The majority of the unemployed surveyed (57.86%) are not registered unemployed, while the registered unemployed are 42.13%.

The largest number of unregistered unemployed is in the age group from 35 to 44 years, while the largest number of registered unemployed is in the age group from 55 to 64 (persons of pre-retirement age).

Unregistered unemployed are those who have chosen not to co-operate with the employment service, and therefore do not receive its services, which tend to make the unemployed establish an employment relationship as soon as possible.

Studies in previous years have found that unemployed people from particular countries have been denied the status of registered unemployed, such as in countries where the sick unemployed person was not currently available for work or in countries where they were not registered because they were seeking part-time employment. Various restrictions on obtaining registered unemployment directly affected young people, such as young people who were in search of their first job, so they were not eligible for unemployment benefits, young people who were full-time or even part-time students and looking for part-time work, or even young people who were part-time students and were available for work (European Commission, 2006).

Young people also take part in this study, but the number of respondents aged 18 to 24 is only 7.9% of all respondents. In addition, according to the Latvian regulations, a young person who has reached the age of 15 and has not been enrolled in a primary or secondary education program (Support for Unemployed, 2002) can become unemployed, which is also the only restriction for a young person to obtain the status of a registered unemployed person.

The largest number of respondents in the study is in the age group from 55 to 63 years – 27.8%. Persons of pre-retirement age are singled out as a risk group, which may, for example, be a participant in the active employment measure 'Measures for certain groups of persons', i.e., the employer may participate in the measure and receive a subsidy for this unemployed person, but only if the unemployed person has no more than two years left until reaching the retirement age (SEA, 2020, Subsided work places).

Respondents were asked whether they intended to cooperate with the SEA, and four possible answers to this question were offered. When processing the obtained data, the author performed a cross-tabulation analysis to compare the positions of men and women. 20.3% of men and 10.8% of women admitted that they are forced to cooperate with the SEA. This answer option was offered to the respondents because in informal conversations with the unemployed the author found out that many unemployed people acquire the status of registered unemployed only to receive unemployment benefits, and these unemployed are not open to employment and formally meet the SEA requirements for as long as possible.

The majority of respondents indicate that they plan to find a job on their own or with the help of friends and relatives, and for this reason do not cooperate with the SEA. This answer option was marked by 40.7% of men and 43.9% of women.

Of course, there are also respondents who admit that they plan to cooperate with the SEA and get involved in the proposed activities. 16.9% of men and 21.7% of women admitted that they will cooperate or are already cooperating with the SEA.

However, there are also respondents who do not cooperate with the SEA because they do not plan to enter into an employment relationship. 22% of men and 23.6% of women do not plan to enter employment.

In summary, it can be concluded that the majority of the unemployed surveyed do not want to cooperate with the SEA and that only 16.9% of men and 21.7% of women consider this cooperation useful.

In order to find out whether there is a significant difference between the sexes regarding the attitude of not cooperating with the SEA, we performed a Chi-square test and clarified that such a difference does not exist

($x^2=3.5<x^2_{0.05}=7.82$, df=3, sign=0.030, n=216); therefore, it is not necessary to develop a special approach to promoting the cooperation of the unemployed depending on gender.

The study found that a fairly large number of unemployed people do not plan to enter employment at all; most likely they are current or future long-term unemployed. The negative impact of long-term unemployment on the country's economy

Table 1

Do you plan to cooperate with the State Employment Agency to find a job?

			Your gender		Total
			Male	Female	
Do you plan to cooperate with the State Employment Agency to find a job?	Yes, I plan to actively cooperate with SEA representatives and get involved in the proposed activities	Count	10	34	44
		% within Do you plan to cooperate with the State Employment Agency to find a job?	23%	77%	100%
		% within your gender	17%	22%	20%
		% of Total	5%	16%	20%
	No, I plan on my own (including with the help of relatives and friends)	Count	24	69	93
		% within Do you plan to cooperate with the State Employment Agency to find a job?	26%	74%	100%
		% within your gender	41%	44%	43%
		% of Total	11%	32%	43%
	I am forced to cooperate with the SEA	Count	12	17	29
		% within Do you plan to cooperate with the State Employment Agency to find a job?	41%	59%	100%
		% within your gender	20%	11%	13%
		% of Total	6%	8%	13%
	I do not plan to enter into an employment relationship	Count	13	37	50
		% within Do you plan to cooperate with the State Employment Agency to find a job?	26%	74%	100%
		% within your gender	22%	24%	23%
		% of Total	6%	17%	23%
Total		Count	59	157	216
		% within Do you plan to cooperate with the State Employment Agency to find a job?	27%	73%	100%
		% within your gender	100%	100%	100%
		% of Total	27%	73%	100%

grows especially in times of crisis. The recording of unregistered unemployment plays an important role. It is not just the long-term unemployed who become unregistered precisely because they lose their entitlement to benefits that need to be counted; the unregistered unemployed are also those who have no entitlement to unemployment benefits at all, such as workers with too short length of service. Particular attention should also be paid to the increase in short-term unemployment, which more often affects women and young people who do not apply for registered unemployment, as they often agree to work in short-term or temporary jobs as well as part-time jobs (Lafuente, 2019).

However, it is important to find out the reasons for the position of the unemployed not to cooperate with the SEA.

In order to find out whether the level of education of the unemployed person can be singled out as a factor of non-cooperation with the SEA, we performed a cross-tabulation analysis. The results show that 11.3% of the unemployed with higher education and 18.3% with secondary education have confirmed that they are forced to cooperate with the SEA, but no unemployed person with primary education has chosen this answer option. At the same time, 64.7% of unemployed people with basic education confirmed that they do not plan to cooperate with SEA and plan to find work independently (including with the help of relatives and friends). A large number of unemployed people with secondary education (40.6%) and with higher education (41.9%) also chose this answer option.

In order to find out whether the interest to cooperate with SEA differs significantly depending on the level of education, we performed a Chi-square test and found out that there are no significant differences ($x^2=8.32<x^2_{0.05}=12.59$, sign=0.032, n=216). This proves that it is necessary to stimulate the unemployed of all

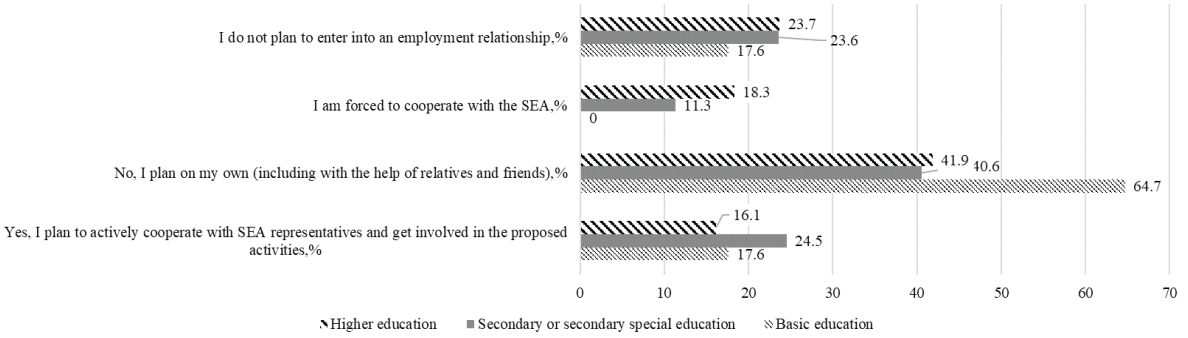

Figure 1. Answers to questions 'Do you plan to cooperate with the State Employment Agency to find a job?' and 'Your level of education?'

educational levels to cooperate more actively with SEA and that a specialized approach is not necessary for the unemployed of a certain educational level.

Employment agencies have a heterogeneous set of functions, including: mediation services to facilitate the link between supply and demand; providing up-to-date information on the situation in the labour market for employers and jobseekers - this function is implemented by compiling data on job vacancies and potential applicants; provision of active employment measures and preventive measures to reduce unemployment; management and coordination of labour migration. Unemployment teaching programs must provide the unemployed with the skills they need, making them more attractive to employers. In addition, training programs must be in line with market requirements. Subsidized employment mainly refers to wage subsidies, where part of labour costs are covered by public funds to encourage employers to hire the unemployed, often focusing on certain groups, such as the long-term unemployed (Fredrikson, 2020).

The Latvian SEA "Measures for Certain Groups of Persons" offers to subsidize jobs: for the unemployed with disability, for the unemployed over the age of 55 but who have no more than two years left until retirement, for the unemployed who have been unemployed for at least 12 months, for the unemployed with refugee or alternative status and unemployed under the age of 29 (State Employment Agency, 2022; Subsidized Jobs).

Respondents who participated in the survey and answered that they had applied for active employment measures offered by the SEA were asked to indicate exactly which measure the unemployed person had applied for. Virtually all of the unemployed who answered this question indicated that they had applied for various types of courses and training; a couple of respondents answered that they had applied for paid temporary public works.

According to SEA statistics, career counselling was most often provided to the unemployed in 2021 – 28,702, however, career counselling is one of the mandatory measures that a registered unemployed person must attend in order to maintain the status of a registered unemployed person. The unemployed themselves most often applied for paid temporary public works – 5762 unemployed. 4074 unemployed participated in non-formal training, 936 unemployed applied for vocational training, retraining and qualification improvement, 577 unemployed were involved in the measure for certain groups of persons (subsidized jobs), 295 unemployed participated in the development of skills required for work, 141 unemployed received training at the employer, 132 unemployed people took part in events to start a business or self-employment, and 50 unemployed people received support in the event for people with addiction problems (State Employment Agency, 2022; SEA activities).

One of the reasons why the unemployed may refuse to cooperate with the SEA is the close link between the SEA and the fulfilment of minimum requirements within a certain period of time; such pressures and formal rules are burdensome for many unemployed and contrary to their individual characteristics (Kerschbaumer & Boost, 2020).

Recent studies by the ILO show that worldwide it is much more difficult for women to find work than for men, and that women tend to work in low-quality jobs in vulnerable conditions, with no improvement expected in the near future (International Labour Organization, 2022).

Also in this study, we found that there is a fairly large predominance of unemployed women, and most of them do not want to cooperate with the SEA because they do not see the point. The Latvian SEA does not offer special active employment measures or preventive measures to reduce unemployment, the target group of which would be women.

Women are one of the groups most affected by Covid-19, so special programs should be set up specifically for women. This is the case, for example, in Spain, whose employment service Lanbide runs 11 programs targeting women (OECD Library, 2020).

Conclusions

1. It is necessary to continue work in order to find out and minimize the causes that are the basis for the unemployed choosing not to cooperate with SEA, taking into account the results obtained in the study that no specific approach is needed depending on the unemployed person's gender or education level.
2. Active employment measures and preventive measures to reduce unemployment targeting women need to be introduced, as women are one of the groups most affected by the Covid-19 pandemic, and a specialized approach is needed to address these negative effects.
3. In the process of implementation of active employment measures and preventive measures to reduce unemployment, it is also necessary to provide for the possibility to deviate from formal requirements, so that, taking into account the characteristics and requirements of the individual, it is possible to grant exemptions for the fulfilment of the minimum requirements in general or for the fulfilment within a certain period of time.

Acknowledgements

The research was supported by the National Research Program 'Latvian Heritage and Future Challenges for the Sustainability of the State' project 'Challenges for the Latvian State and Society and the Solutions in International Context – INTERFRAME-LV'. No VPP-IZM-2018/1-0005.

References

COVID-19. (2022, February). *Distribution of Covid-19 in Latvia.* Retrieved March 2, 2022, from https://covid19.gov.lv/covid-19/covid-19-statistika/covid-19-izplatiba-latvija.

European Commission. (2006). Registered unemployment (RU) compared with harmonised unemployed (LFS). Retrieved February 10, 2022, from https://ec.europa.eu/eurostat/documents/3888793/5834669/KS-CC-06-001-EN.PDF/bdde7b22-1eca-408d-8ba1-26005af93932.

Eurostat Statistics Explained (2022, March). *Harmonised unemployment by sex.* Retrieved March 3, 2022, from https://ec.europa.eu/eurostat/web/products-datasets/-/teilm010.

Eurostat Statistics Explained. (2022, February). *Unemployment rates by sex, age and educational attainment level (%).* Retrieved February 26, 2022, from https://ec.europa.eu/eurostat/databrowser/view/lfsq_urgaed/default/table?lang=en.

International Labour Organization. (2020, August). *COVID-19: Public employment services and labour market policy responses.* Retrieved January 8, 2022, from https://www.ilo.org/emppolicy/areas/covid/WCMS_753404/lang--en/index.htm.

International Labour Organization. (2022, February). *The gender gap in employment: What's holding women back?* Retrieved March 7, 2022, from https://www.ilo.org/infostories/en-GB/Stories/Employment/barriers-women#intro.

Fougère, D., Pradel, J., & Roger, M. (2009, March). Does the public employment service affect search effort and outcomes? *European Economic Review.* 2009, 53 (7) 846–869. DOI: 10.1016/j.euroecorev.2009.01.006.

Fredriksson, D. (2020, May). Reducing unemployment? Examining the interplay between active labour market policies. *Social Policy & Administration.* 2021, 55 (1) 1–17. DOI: 10.1111/spol.12606.

Hohlova, V., & Rivža, B. (2021, May). The impact of the Covid-19 pandemic on the unemployment rate in Latvia. *RESEARCH FOR RURAL DEVELOPMENT.* 2021, (36) 137–143. DOI: 10.22616/rrd.27.2021.020.

International Labour Organizationa. (2021, October). *Global Call to Action for a Human-centred Recovery from the COVID-19 crisis.* Retrieved February 20, 2022, from https://www.ilo.org/infostories/en-GB/Campaigns/covid19/globalcall#intro.

Kerschbaumer, L., & Boost, M. (2020, October). The German Employment Agency's measures for integrating the long-term unemployed with multiple constraints into the labour market: Some individual experiences. *Social Policy & Administration.* 2020, 55 (4) 702–715. DOI: 10.1111/spol.12652.

Lafuente, C. (2019, July). Unemployment in administrative data using survey data as a benchmark. *Springer Link.* Retrieved March 5, 2022, from https://link.springer.com/article/10.1007/s13209-019-0200-1.

Organisation for Economic Co-operation and Development. (2021). *Active Labour Market Policies: Connecting People with Jobs.* Retrieved February 2, 2022, from https://www.oecd.org/employment/activation.htm.

OECDiLibrary. (2020). *3. Designing responsive employment services to help people into good jobs.* Retrieved January 10, 2022, from https://www.oecd-ilibrary.org/sites/7223d6e4-en/index.html?itemId=/content/component/7223d6e4-en#abstract-d1e4127.

Republic of Latvia Cabinet Regulation. (2011). Republic of Latvia Cabinet Order No. 75. Regulations Regarding the Procedures for the Organising and Financing of Active Employment Measures and Preventative Measures for Unemployment Reduction and Principles for the Selection of Implementers of Measures. Latvia.

State Employment Agency of Latvia (2019). *Unemployment indicators and SEA activities in 2019.* Retrieved February 5, 2022, from https://www.nva.gov.lv/lv/2019gads.

State Employment Agency of Latvia (2020). *Unemployment indicators and SEA activities in 2020.* Retrieved February 5, 2022, from https://www.nva.gov.lv/lv/2020gads.

State Employment Agency of Latvia (2020). Subsided work places. Retrieved February 5, 2022, from https://www.nva.gov.lv/en/subsided-work-places.

State Employment Agency of Latvia (2021). *Public review 2020.* Retrieved January 10, 2022, from https://www.nva.gov.lv/lv/media/12377/download.

State Employment Agency of Latvia (2022, January). *Rights and duties.* Retrieved January 10, 2022, from https://www.nva.gov.lv/lv/tiesibas-un-pienakumi.

State Employment Agency of Latvia (2022, February). *Subsidized jobs (Aid for the employment of the unemployed).* Retrieved February 28, 2022, from https://www.nva.gov.lv/lv/subsidetas-darba-vietas-atbalsts-bezdarbnieka-nodarbinasanai.

State Employment Agency of Latvia. (2022, March). *NVA aktivitātes – 2021. (SEA activities – 2021).* Retrieved March 8, 2022, from https://www.nva.gov.lv/lv/2021gads. (in Latvian).

SKDS. (2022). About us. Retrieved February 9, 2022, from https://www.skds.lv/about-us.

Support for Unemployed Persons and Persons Seeking Employment Law. (2002). Latvia.

Vassiliev, A., Giovanni, F.L., Flückiger, Y., & Ramirez, J.V. (2005, May). Unemployment and employment offices efficiency: What can be done? *Socio-Economic Planning Sciences.* 2006, 40 (3) 169–186. DOI: 10.1016/j.seps.2004.10.007.

 DOI: 10.22616/rrd.28.2022.027

CHANGES IN HEALTH LITERACY ASSESSMENT OF VIDZEME STATISTICAL REGION IN LATVIA

***Baiba Kodrica[1], Tamara Grizane[2]**
[1]Latvia University, Latvia
[2]Turiba University, Latvia
*Corresponding author's email: baibakondrica@inbox.lv

Abstract
The ability to find, understand, evaluate and use information about an individual's health during the Covid-19 pandemic has become crucial. Therefore, health literacy (HL) skills development in Latvia, also in other OECD countries, is a priority area. Insufficient HL information base in Latvia is a fundamental basis for the research goal: to determine factors influencing HL and their changes among the population of Vidzeme statistical region (LV008) in Latvia. The study compares the authors' 2020 study based on the European Health Literacy Questionnaire (HLS-EU-Q47). The study includes survey of respondents (n = 383) using pen-and-paper interviewing (PAPI) and telephone interview approach. Various methods and tests were used: Principal axis factor analysis (PFA) with varimax rotation, Confirmatory factor analysis (CFA), Compare means Independent-sample T-test, Anova, Kaiser-Mayer-Olkin (KMO), Bartlett's test and Chi-squared test, Cronbach's and Spearman-Brown methods, correlations (Pearson and Spearman's) and Multiple linear regression (MLR) with Assumption Testing analysis, and Cronbach's test. The study identified four factors influencing health literacy: access, understanding, evaluation, and use. Compared to the study conducted by the authors in 2020, which determined that education has a positive impact on factor – access, the HL has increased more strongly in the age groups 18-19, 20-29 and 30-39. However, among women the HL level has decreased compared to the previous study by authors and HLS-EU, the proportion of people with sufficient and excellent HL in the European Union has increased overall by 13.5%, while the proportion of people with limited HL decreased by 24.4%.
Key words: health literacy, socioeconomics factors; demographic factors.

Introduction

Health literacy (HL) is an important factor determining the health of individuals and society in large (Nutbeam, 2008). Limited HL can impact health of society during health crisis such as COVID-19 pandemic (Abdel-Latif, 2020). A European HL survey found that, on average, 47% of respondents have problems with health management (Sorensen *et al*., 2015). HL problems are mainly related to people's lack of knowledge and competences, which hinders proper understanding and decision-making about their health, care, disease prevention and health promotion (Sorensen, 2012; Altin, 2014; Connor, Mantwill, & Schulz, 2014; Guzys, Kenny, & Dickson-Swift, 2015). For instance, there is a connection between low HL and insufficient knowledge about ones health and increased expenditures on health services (Rowlands *et al*., 2014; Wallace *et al*., 2016). However, there are also different HL impacting factors, such as, gender, education, occupation, income, etc. (Protheroe *et al*., 2017; Cho *et al*., 2020; Chiu *et al*., 2020). The International Health Literacy Association (IHLA) pointed to the need to promote HL and its importance (IHLA, 2021). The HL skills in Latvia, as well as in other OECD countries, has been identified as one of the priority fields of skills to be increased. The HL research in Latvia has been aimed at research on patients' health satisfaction, health care, HL skills development (Rasnaca, Vibane, & Nikisins, 2017; Onose *et al*., 2017; Silkane, Davidsone, & Veliverronena, 2018). Authors agree that research in this area has been limited compared to other EU member states (Heijmans *et al*., 2015). Previously the lack of information on HL in Latvia has been indicated in European Commission research (Heijmans *et al*., 2015). Based on topicality of HL, authors continued the research conducted in 2020-2021 (Kodrica & Grizane, 2021) and chose the **aim of the research**: determination of changes in HL influencing factors in Vidzeme statistical region of Latvia (LV008). **Tasks of the research**: (1) to carry out a review of the scientific literature on the health literacy survey (HLS-Q) on the methods used to determine the factors; (2) to determine the sample size for Vidzeme statistical region, to conduct a survey, to determine and evaluate the factors influencing HL; (3) to compare changes in HL sample in Vidzeme statistical region; (4) to determine the HL index; (5) to compare the HL of Vidzeme statistical region with the data of other EU countries.

Materials and Methods

The research was compared with a similar study by the authors in 2020 (Research_1), based on the European Health Literacy Survey (HLS-EU-Q47) (Sorensen *et al*., 2013; Kodrica & Grizane, 2021). Research_2 47 questions were rated on a 4-point Likert scale (1 = very difficult, 2 = difficult, 3 = easy and 4 = very easy), which identified 4 competencies related to health information management *access*, *understand*, *evaluate* and *apply* information. The rating allows the calculation of both the overall HL index and the

HL index for each of these four competencies. The formula used allowed the standardization of HL indices to uniform values from 0 to 50 (HLS-EU Consortium, 2012):

$$index = (M-1)\times(50/n), \quad (1)$$

where

index – was the specific index calculated;

M – the mean of all participating items for each person;

1 – was the minimal possible value of the mean (leading to a minimum value of the index of 0);

n – was the range of the mean;

50 – was the chosen maximum value of the new metric.

The obtained HL index was grouped, similarly to Resarch_1, according to the value in 3 groups from inappropriate and problematic (0-33), to sufficient (> 33-42) and excellent HL (> 42-50), to assess the HL of respondents by gender, age, education and GIM (EUR) and comparisons with other countries (Kodrica & Grizane, 2021). The frequency and percentage of HL was calculated, based on the gender, age, education (educational level), GIM (EUR) of respondents.

Research place: Vidzeme statistical region (LV 008) in Latvia. *Research period:* from January till December 2021. The calculated sample size, 383 respondents was based on the number of active working age population (Official statistic portal, 2021), proportionally to each gender. Due to the limitations caused by Covid-19 a mixed survey approach was conducted: pen-and-paper interviewing (PAPI) and telephone interviews. *Research method:* PFA with varimax rotation, CFA, KMO, while determining the HL impacting factors and values. An Independent-sample T-test was used to compare the means of the two gender groups. Multiple linear regression (MLR) with assumption testing analysis was used to predict the role of gender, education, age and GIM (EUR) in HL.

Results and Discussion

An analysis of 11 studies in Europe and Asia from 2015 to 2021 revealed that HL is relevant in many countries. The studies differentiate in sheer number of respondents from 383 to 10,024; number of survey questions 12 to 86 and their content, geographical or administrative location – from a given country to a block of countries, such as the EU. In these surveys, different methods and tests have been utilised: Anova, Kaiser-Mayer-Olkin (KMO), Bartlett's test and Chi-squared test, Cronbach's and Spearman-Brown methods, Confirmatory factor analysis (CFA), Factor analysis, Principle component analysis (PCA), correlations (Pearson and Spearman's) and regressions (Multiple linear) (Solar & Irwin, 2010; Sorensen *et al*., 2012, 2013, 2015; Wallace *et al*., 2016; Bodur, Filiz, & Kalkan, 2017; Macleod *et al*., 2017). Taking into concern the previous research concept, similar methods and tests were conducted (Kodrica & Grizane, 2021).

The second research collected the demographical and socioeconomic data of respondents as follows: (Table 1).

The internal consistency test showed that the alpha factor for 47 units is 0.983, $\alpha > 09$, indicating that the units have a high internal consistency.

PFA with varimax rotation identified 4 factors: *access*, *understand*, *evaluate*, and *apply*, associated with health information management. The value of Kaiser Meyer Olkin (KMO) is $\alpha > 0.8$, which according to Kaiser (1974) is a positive trend.

For construct validity, CFA was conducted with Extracted method: Principal Axis and Rotation Method: Varimax Factoring with Kaiser Normalization. Rotation convergence in 9 iterations. After the rotation factor *access* accounted for 27.48% of the variance, factor *understand* for 23.2%, factor *estimation* for 13.5%, and the factor *apply* for 9.4% of the variance. Table 2. displays the items and factor loadings for the rotated factors, with loadings less than 0.4 omitted to improve clarity. The factor that indexes *access*, the factor that *understands* the index,

Table 1

The profile of the respondents (n = 383)

Category	Profile
Gender	female – 50.1 %; male – 49.9 %
Age	18-19 – 33.2%; 20-29 – 29%; 30 -39 – 31.9%; 40-49 – 2.6%; 50-59 – 2.3%; 60> – 1.0%
Education (Educatiol level)	higher – 12%; vocational or vocational secondary – 45.4%; general secondary – 35.8; primary or lower than primary – 6.8%
Gross income per month (EUR)	<400 – 4.4%; 400-700 – 19.6%; 700-1000 – 49.1; 1000-1500 – 21.9%; 1500> – 5%

Source: author's calculations.

put a heavy load on 21 items. The factor *appraise* was a heavy load of 14 units, but factor *apply* to 13 units.

Thereby four factors were determined: *access*, *understand*, *appraise* and *apply*. The eigenvalues 34.92 of the First factor *access* explains the largest quantity of observed variables common dispersion, for 64-85% of the variance. However, factors *understand* and *appraise* explain half the variables, while the fourth factors' *apply* eigenvalues are just 8.10, i.e., the factor explains the smallest quantity common variance of the observed variables.

MLR in SPSS with Assumption Testing analysis was performed to determine the role of gender**,** education**,** age and GIM (EUR) in HL predicting by ***access***, ***understand***, ***appraise*** and ***apply*.**

Access. Compare means Independent-sample T-test tool indicates that there was not a statistically significant difference between male and female on *access*: Levene's test is not statistically significant, because its p = 0.13: we do not reject its null hypothesis of equal gender for men and women variances, t (381) = - 0.853, p = 0.39, males (M = 2.41, SD = 0.54, but females (M = 2.46, SD = 0.59). The confidence interval for the difference between the means was 2.37±2.54 for women and 2.33±2.49 for men indicating that the difference could be as small as one point, which is probably not a practically import difference.

MLR correlation matrix of HL factor *access* scores predictors gender, education, age and GIM (EUR) indicated, that among predictors age un education r = 0.398, age and GIM (EUR) r = -139, gender and GIM (EUR) r = -0.373, which is a weak and insignificant relationship between gender and GIM (EUR). The relationship is functional and diminishing. Therefore, a moderate correlation exists; however, it is not significant enough, so that trend correcting steps would be justified. The tolerance level is above 0.2, i.e. 0.8, but the VIF scores are well below 10, i.e., 1.17 predictor gender to 1.24 education. Therefore, the assumption to be met was fulfilled. The assumption of homoscedasticity is fulfilled. Durbin-Watson = 1.74.

MLR was carried out to investigate the relationship between HL factors *access* scores and predictors gender, education, age and GIM (EUR). Obtained results: gender (β = -0.008, p = 0.899), age (β = 0.04, p = 0.880), education (β = 0.131, p = 0.01), GIM (EUR) (β = -0.061, p <0.084), F (4, 38) = 4.82, p < 0.001, with all four variables significantly contributing to the prediction. Taken into account that **F-test value is less than 0.05, then the null hypothesis has to be rejected: regression equation statistically significantly explain the change of resulting indications.** The adjusted R squared value was 0.38. This indicates that 38% of the variance can be explained with the MLR model, in which factor interaction effect is included and that gender, education, age and gross income per month (EUR) can impact the factor *access*. The beta weights, suggest that education has a positive impact on factor *access*, negatively associated with predictor GIM (EUR). In the meantime, in Research_1, the data were evident of the contrary.

Understand. Compare means Independent- sample T-test tool indicates that, there was not a statistically significant difference between **gender group** male and female on *undestand*: Levene's test is not statistically significant, because its p = 0.63, t (381) = -0.308, p = 0.76, males (M = 2.50, SD = 0.59, but females (M = 2.48, SD = 0.57). Levene's test is not statistically significant, because its p = 0.63 for men and women variances, t (381) = -0.31. The confidence interval for the difference between the means was analogic to -0.14±0.10 for women and for men indicating that there is no significant difference.

MLR correlation matrix of HL factor *understand* scores predictors gender, education, age and GIM (EUR) indicated, that among predictors age and education r = 0.398, education and GIM (EUR) r = -139, gender and GIM (EUR) r = -0.373, that is a weak and insignificant correlation, while between gender and GIM (EUR) relation is functional and diminishing. Therefore, a moderate correlation exists; however, it is not significant enough, so that trend correcting steps would be justified. Tolerance level is significantly above 0.2, i.e. 0.8, but VIF scores are significantly below 10, i.e. 1.17 predictor gender until 1.24 education. Therefore, the assumption to be met was fulfilled. The Durbin-Watson statistic showed that the assumption about homoscedasticity is met (Durbin-Watson = 1.55).

MLR was carried out to investigate the relationship between HL factor *understand* scores predictors gender, education, age and GIM (EUR) and factor access. Acquired results: gender (β = 0.043, p = 0.502), age (β = -0.86, p = 0.005), education (β = 0.057, p = 0.172), GIM (EUR) (β = 0.031, p = 0.399), F (4,378) = 2.05, p = 0.09, with all four variables is not significantly contributing to the prediction. **Since the value of F-test is >0.05, then H0 hypothesis was confirmed: regression equation cannot statistically significantly explain change of resultative indicators.** The adjusted R squared value was 0.02. This indicates that only 2% of the variance can be explained by a MLR model, in which factor interaction effect and the gender, education, age and GIM (EUR) impact factor *understand.* Meanwhile the Research_1 indicated 31%.

Appraise. Compare means Independent- sample T-test tool indicates, that there was not a statistically significant difference between **gender group** male and female on *appraise*: Levene's test is not statistically significant, because its p = 0.12, t (381) = -0.23, males (M = 2.43, SD = 0.53), but females (M = 2.42,

SD = 0.53). The confidence interval for the difference between the means was anologic -0.13±0.01 for women and for men indicating that there is no difference.

MLR correlation matrix indicated that among factor *appraise* scores predictors age and education r = 0.398, age and GIM (EUR) r = -139, gender and GIM (EUR) r = -0.373, that is weak and insignificant, in addition the relation between the gender and GIM (EUR) is functional and diminishing. Therefore, a moderate correlation exists. Tolerance is above 0.2, i.e. 0.8, but VIF scores are below 10, i.e. 1.17 predictor gender till 1.24 for *education.* Therefore, the assumption to be met is fulfilled. An assumption of homoscedasticity has been met (Durbin-Watson = 1.60).

MLR was carried out to investigate the relationship between predictors gender, education, age and GIM (EUR) and HL factor *appraise*. The acquired results: gender (β = 0.015, p = 0.811), age (β = -0.006, p = 0.834), education (β = -0.024, p = 0.548), GIM (EUR) (β = 0.002, p = 0.949), F (4,378) = 0.17, p = 0.95. Since the F-test value is p > 0.05, the **H0 hypothesis is confirmed: regression equation does not explain statistically significantly the change of resulting indications.** The adjusted R squared value was 0.02. This indicates that 2% of the variance can be explained with MLR model, in which factor interaction effect and the impact of gender, education, age and GIM (EUR) on factor *appraise* is indicated. Compared to the Research_1 it indicates that 30% of the variance in *appraise* was by model.

Apply. Compare means Independent - sample T-test tool indicates that there not a statistically significant difference between gender group, male and female, on *appraise*: Levene's test is not statistically significant, because its p = 0.39, t (381) = -0.39, males (M = 2.46, SD = 0.60), but females (M = 2.43, SD = 060). The confidence interval for the difference between the means was similar -0.14±0.09 for women and for men indicating that there was practically no difference.

MLR correlation matrix indicates that among predictors age and education r = 0.398, age and GIM (EUR) r = -139, gender and gross income per month (EUR) r = -0.373, which is a weak and insignificant relationship. In addition the relationship between gender and GIM (EUR) is functional and diminishing. Therefore, a moderate correlation exists. Tolerance is high above 0.2, to 0.8, but the VIF score is under 10, i.e. 1.17 predictor gender until 1.24 for education. Therefore, the assumption to be met was met. The assumption of homoscedasticity is fulfilled (Durbin-Watson = 1.54).

MLR was carried out to investigate the relationship between HL factor *apply* scores predictors gender, education, age and GIM (EUR) and factor *access.* The acquired results: gender (β = 0.023, p = 0.727), age (β = -0.019, p = 0.533), education (β = -0.004, p = 0.931), GIM (EUR) (β = 0.003 p = 0.810), F (4,378) = 0.15, p = 0.963. Since the F-test value was larger than 0.05, H0 **hypothesis was affirmed: regression equation did not explain statistically significant resulting indications.** The adjusted R squared value was 0.02. This indicates that 2% of the variance can be explained with MLR model, in which factor interaction effect has been applied and that gender, education, age and GIM (EUR) impact factor *apply,* but Research_1 indicate that 30% of the variance in appraise was by model.

HL index division according to gender indicates that out of 192 respondents 63.5% for women and out from 191 respondents for 61.3% for men is a limited HL (*inadequate* + *problematic*). HL *excellent* evaluation is relatively similar in percentage 36.5% for women and 37.7% for man. HL excellent has been indicated by 49% respondents, who receive salary in the range of 700-1000 gross income per month (EUR), 52.5% respondents with higher and vocational or vocational secondary education. Contrary to Research_1 the evaluation dominant *excellent* HL value was in an age group 18-19, 20-29 and 30-39. Although 59.8% of these age groups were respondents with limited

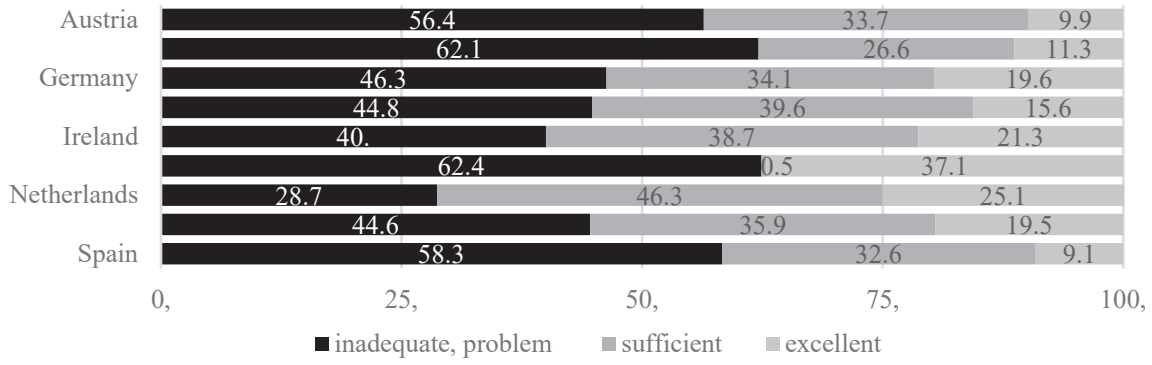

Figure 1. Levels of health literacy index by country and LV008.

Source: author's calculations based on Sorensen *et al*., 2015.

HL, the 40.2% with excellent HL are the reason for further research. Authors have made assumption that the achievements are based on computer literacy, more pronounced among men. Thereby the positive impact of predictor education on factor *access* can be explained. Overall 73.1% respondents of age groups 50-59 and 60> with primary or lower than primary education indicated limited HL. Thereby previous research on HL of elderly people groups can be confirmed (Macleod *et al*., 2017). However, the actual HL skills, according to (DeWalt & Pignone, 2005), can vary. In this study, for instance, in the age group 60> it was determined that 50% have HL at *excellent* level. Similarly to previous Research_1 differences in the HL level were observed between people of different education level, indicating increased HL among senior age group of women. Authors put forward assumption that men with higher computer literacy tend to have higher HL, which should be further studied. Further research on improvements to HL in age groups 50-59 and 60> with primary or lower than primary education is required, because 73.1% respondents of this group had limited HL.

Levels of HL index by country and LV008 in Latvia in Research_2 are showed in Figure 1, where Bulgaria and Spain have the largest HL index.

The number of respondents with HL *excellent* has increased by 24.4%, compared to research of period 2020-2021. It is by 20.7% greater than that of other countries (Figure 1); however, lack of comparable data should be taken into account.

Conclusions

1. Four factors influencing HL were identified in the study: access, understanding, evaluation and application in the Vidzeme statistical region of Latvia (LV008)
2. Compared to 2021 HL research (Research_2) of inhabitants of Vidzeme statistical region in Latvia, the following changes were observed: education is positively impacted by factor *access*, and is negatively associated with predictor GIM (EUR).
3. Compared to the study of 2021 (Researh_2) with the study of 2021 (Research_1), the factor *access* (Study_2) has a positive effect on education and negatively affects GIM (EUR), while (Study_1) the factor *access* is negatively related to the education of forecasters, but positively forecaster GIM (EUR).
4. The research (Research_2) indicated, that 38% of the variance can be explained with MLR model with predictors gender, education, age and GIM (EUR), that impacts factor *access*, only 2% of the variance, that impacts factors *understand*, *appraise* and *apply*. However, (Research_1) indicated factors *access* 30%, *understand* 31%, *appraise* and *apply* 30% of the variance can be explained with MLR model with these predictors.
5. 63.5% for women and for 61.3% for men is a limited HL, but HL excellent evaluation is 36.5% for women and 37.7% for men. Contrary to (Research_1) the evaluation dominant excellent HL value was in the age groups 18-19, 20-29 and 30-39. However, 73.1% respondents of age groups 50-59 and 60> with primary or lower than primary education indicated limited HL.
6. Comparing to the limited HL index of the respondents of Vidzeme statistical region (LV008) in research (Research_1) and the results of HLS-EU research concerning the EU member states, the proportion of people with limited HL has decreased by 24.4% and the proportion of those with sufficient and excellent HL skills have increased by 13.5%.

References

Abdel-Latif, M.M.M. (2020). The enigma of health literacy and COVID-19 pandemic. Public Health, 185, 95–96. DOI: 10.1016/j.puhe.2020.06.030.

Altin, S.V., Finke, I., Kautz-Freimuth, S., & Stock, S. (2014). The evolution of health literacy assessment tools: a systematic review. BMC Public Health 14, 1207. DOI: 10.1186/1471-2458-14-1207.

Bodur, A.S., Filiz, E., & Kalkan, I. (2017). Factors Affecting Health Literacy in Adults: A Community Based Study in Konya, Turkey. *International Journal of Caring Sciences*, January– April 2017, 10(1), 100–109.

Chiu, H.T., Tsai, H.W., Kuo, K.N., Leung, A.Y.M., Chang, Y.M., Lee, P.H., & Hou, W.H. (2020). Exploring the Influencing Factors of Health Literacy among Older Adults: A Cross-Sectional Survey. Medicina (Kaunas), 56(7):330, DOI: 10.3390/medicina56070330.

Cho, M., Lee, Y.M., Lim, S.J., & Lee, H. (2020). Factors Associated with the Health Literacy on Social Determinants of Health: A Focus on Socioeconomic Position and Work Environment. International Journal of Environmental Research and Public Health, 17(18), 6663. DOI: 10.3390/ijerph17186663.

Connor, M., Mantwill, S., & Schulz, P.J. (2013). Functional health literacy in Switzerland: Validation of a German, Italian, and French health literacy test. Patient Education and Counseling, 90(1), 12–17. DOI: 10.1016/j.pec.2012.08.018.

DeWalt, D.A., & Pignone, M.P. (2005). Reading is fundamental: the relationship between literacy and health. Archives of Internal Medicine, 165(17), 1943–44. DOI: 10.1001/archinte.165.17.1943.

Gordon, R.A. (2015). Regression Analysis for the Social Sciences. New York and London: Routledge.

Guzys, D., Kenny, A., Dickson-Swift, V., & Threlkeld, G. (2015). A critical review of population health literacy assessment. BMC Public Health 15, 215. DOI: 10.1186/s12889-015-1551-6.

Hair, J.F., Black, W.C., Babin, B.J., & Anderson, R.E. (2013). Multivariate data analysis: Advanced diagnostics for multiple regression. Retrieved February 12, 2022, from http://www.mvstats.com/Downloads/Supplements/Advanced_Regression_Diagnostics.pdf.

Heijmans, M., Uiters, E., Rose, T., Hofstede, J., Deville, W., van der Heide, I., … Rademakers, J. (2015). Study on sound evidence for a better understanding of health literacy in the European Union. Final Report, RfS Chafea/2014/health/01. Brussels: European Commission.

IHLA (International Health Literacy Association). (2021, October). 2021 IHLA Global Health Literacy Summit Press Realize Final 29 sep.2021… For immediate press release. Retrieved February 21, 2022, from https://i-hla.org/wp-content/uploads/2021/09/IHLA-Global-Health-Literacy-Summit-Press-Release_FINAL_29Sep2021.pdf.

Kaiser, H.F. (1974). An index of factorial simplicity. Psychometrika, 39(1), 31–36. DOI: 10.1007/BF02291575.

Kondrica, B., & Grizane, T. (2021). Health literacy Assessment of Vidzeme Statistical Region. In Revelling in Reference: 22nd International Scientific Conference. 'Economic Science for Rural Development 2021', 1-14 May 2021, (pp.461–469). Jelgava, Latvia: Latvia University of Life Sciences and Technologies. DOI: 10.22616/ESRD.2021.55.047.

MacLeod, S., Musich, S., Gulyas, S., Cheng, Y., Tkatch, R., Cempellin, D., … Yeh, C.S. (2017). The impact of inadequate health literacy on patient satification, healtcare utilization, and expenditures among older adults. Geriatric Nursing, 38(4), 334–341. DOI: 10.1016/j.gerinurse.2016.12.003.

Nutbeam, D. (2008). The evolving concept of health literacy. Soc Sci Med., 67, 2072–8. DOI: 10.1016/j.socscimed.2008.09.050.

Official statistic portal. (2021, June). RIG060. Urban and rural population in regions, cities, municipalities, towns and rural territories (experimental statistics) 2011-2021. Retrieved February 2, 2022, from https://data.stat.gov.lv/pxweb/en/OSP_PUB/START__POP__IR__IRS/RIG060/.

Onose, G., Ancane, G., & Capisizu, M. (2017). Doctors' and older patients' Health Literacy of functional decline and frailty. Results from Latvia and Romania. Biophiia 2017. 1(21), 21–27. DOI: 10.14813/ibra.2017.21.

Protheroe, J., Whittle, R., Bartlam, B., Estacio, E.V., Clark, L., & Kurth, J. (2017). Health literacy, associated lifestyle and demographic factors in adult population of an English city: a cross-sectional survey. Health expect 2017. 20, 112–119. DOI: 10.1111/HEX.12440.

Rasnaca, L., Vibane, K., & Nikisins, J. (2017). How proficiently do we take care of our health? How to become more skillful? In: Latvia. Human Development Report 2015/2016. Mastery of Life and Information Literacy. Edited by Baiba Holma. Riga: Advanced Social and Political Research Institute of the University of Latvia. DOI: 10.22364/lvhdr.2015.2016.

Rowlands, G., Protheroe, J., Price, H., Gann, B., & Raf, I. (2014). *Health Literacy: Report from an RCGP-led health literacy workshop*. London: Royal College of General Practitioners.

Silkane, V., Davidsone, A., & Veliverronena, L. (2018). The Role of Health Literacy in Predicting Patient satisfaction with health care. Society. Integration. Education. In Revelling in Reference: Proceedings of the International Scientific Conference. Vol. VII, 25-26, May 2018 (pp. 240–50). Valmiera: Vidzeme University of Applied Sciences. DOI: 10.17770/SIE2018VOL1.3223.

Solar, O., & Irwin, A. (2010). *A conceptual Framework for Action on the Social Determinants of Health: Social Determinants of Health Discussion Paper 2*. World Health Organization 2010. Geneva: WHO Press.

Sorensen, K., Pelikan, J. M. Rothlin, F., Ganahl, K. Slonska, Z. Doyle, G., … Brand, H. (2015). Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU). The European Journal of Public Health, 25(6), 1053–1058. DOI: 10.1093/eurpub/ckv043.

Sorensen, K., Van den Broucke, S., Fullam, J., Doyle, G., Pelikan, J., Slonska, Z., & Brand, H. (2012). Health literacy and public health: a systematic review and integration of definitions and models. BMC Public Health. 12(1), 80. DOI: 10.1186/1471-2458-12-80.

Sorensen, K., Van den Broucke, S., Pelikan, J., Fullam, J., Doyle, G., Slonska, Z., & Brand, H. (2013). Measuring health literacy in populations: Illuminating the design and development process of the European Health Literacy Survey Questionnaire (HLS-EU-Q). BMC Public Health, 13(1), 948. DOI: 10.1186/1471-2458-13-948.

Wallace, A.S., Perkhounkova, Y., Bohr, N.L., & Chung, S.J. (2016). Readiness for hospital discharge, health literacy, and social living status. *Clinical Nursing Research*, 25(5), 494.

 DOI: 10.22616/rrd.28.2022.028

EXAMINATION OF THE EXPERIENCE OF WORK INTEGRATION SOCIAL ENTERPRISES IN LATVIA

***Lasma Licite-Kurbe**, **Liva Sevcuna**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: lasma.licite@llu.lv

Abstract
In Latvia, the employment of persons with disability is two times lower than the European Union average, which indicates a marked social and income inequality in the country, as well as the dependence of such persons on national and local government support. One of the solutions for increasing the employment of people with disability is social entrepreneurship. In Latvia, 28% of a total of 189 social enterprises are work integration social enterprises, which mostly employ persons with disability. The research aims to examine the experience of work integration social enterprises in Latvia. To achieve the aim, the research performed a case study of three work integration social enterprises. It was found that the main goal of all the enterprises was to integrate people with disability into the labour market through their training and skills development. The main challenges of employing the target group were their insufficient level of education and poor professional skills, as well as the need to adapt the working environment and equipment. Depending on the degree and kind of disability, the workloads for such persons are also adapted. National, local government and other available support instruments for social enterprises are used to expand their operation, the most important of which are the grants administered by the Ministry of Welfare and the finance institution Altum, as well as a tax credit – a lower employer mandatory state social insurance contribution rate if employing people with disability.
Key words: work integration social enterprise, social entrepreneurship, social enterprise, persons with disability.

Introduction

Employment is an important component of an adult's life, which develops skills and competences, provides socialization and incomes, as well as can contribute to the individual's self-confidence. The United Nations Convention states that 'everyone has the right to work, to free choice of employment, to just and favourable conditions of work and to protection against unemployment' (UN Universal Declaration of Human Rights, 1948). However, access to the labour market for people with disability is constrained. In 2020 in Latvia, 26.6% adults with disability were employed (compared with 64.2% persons without disability); moreover, this figure was almost two times lower than the EU average (50.8% in 2017), indicating a marked social and income inequality in the country. In addition, the low employment rate and low incomes contribute to the dependence of individuals on national and municipal support.

An alternative to promoting the employment of persons with disability is a relatively new kind of business – social entrepreneurship – which is governed by the Social Enterprise Law in Latvia. One of the kinds of social enterprises is work integration social enterprises (hereinafter WISE), the main goal of which is the integration of population groups at risk of social exclusion into the labour market, incl. persons with disability. The main focus of such enterprises is placed on the creation of social benefits and employment of target population groups, thereby raising their standard of living rather than making as much profit as possible; therefore, the enterprises more often need additional support to achieve their social goals.

The role of social entrepreneurship has increased in Latvia in recent years, incl. the number of research studies conducted in this field. Researchers analyse the role of current support for social enterprises (Measure 'Support for Social ..., 2021; Licite-Kurbe & Gintere, 2021), the process of becoming a social enterprise (Bale & Auzina, 2020). Research studies on the possibilities of integrating people with disability in specific enterprises have also been conducted (Laizāns *et al*., 2005). Several research studies on WISEs have been conducted in Europe, incl. Defourny and Nyssens (2008) have analysed WISEs in Europe, while Chieaf and Giacomini (2009) have focused on theoretical aspects of WISEs. Researches on WISEs have been done in various countries: Ireland (O'Shaughnessy & O'Hara, 2016), Greece (Adam, 2014), Croatia and Slovenia (Majetic *et al*., 2019), Denmark (Hulgard & Bisballe, 2008) etc. In Latvia, there are few researches on WISEs available (Anca & Sloka, 2020; Casno & Sloka, 2021); however, it is important to examine their role in promoting employment for a specific target group by analysing the complex of their activities. Namely, the experience of and assessments by WISE representatives are important, as they come into contact with the specific target group daily and can better understand the real situation, as well as suggest the necessary kinds of support. As a result, this allows examining and identifying the main employment-related aspects that hinder the integration of people with disability into the labour market, as well as coming up with potential solutions. Therefore, the aim of the research is to examine the experience of WISEs in Latvia. To achieve the aim, the following specific research tasks have been set: 1) to describe

the situation of WISEs in Latvia; 2) to perform a case study of WISEs, describing the motivation of entrepreneurs to create WISEs and identifying challenges for employing people with disability; 3) to examine the economic performance of and support instruments for WISEs.

Materials and Methods

The research employed the case study method. Yin points out that the case study method is employed if the research relates to the desire to understand the phenomenon in depth. The application of this method enables the researcher to maintain holistic and real-life characteristics (Yin, 2013). To examine the experience of WISEs in Latvia, it is necessary to explore an enterprise from different perspectives, in depth and inseparably from the environment in which they operate; therefore, the case study method was applied in the present research. It allows to obtain more information on the experience of WISEs in employing people with disability – the challenges, the motivation of social entrepreneurs to start this kind of enterprise, as well as the current and necessary kinds of support.

Any case study consists of 5 research stages. At the first stage, the aim was identified – to examine the experience of WISEs in employing people with disability. The following research questions were set: 1) Why entrepreneurs establish WISEs; 2) What are the specifics and challenges of employing persons with disability; 3) What are the support mechanisms available and necessary to promote the employment of persons with disability. At the second stage, a semi-structured interview protocol was developed based on the questions raised by the research. The selection of cases was based on the following criteria: 1) a WISE, which is registered in the Register of Social Enterprises; 2) the enterprise is active; 3) one of the target groups employed by the enterprise is persons with disability; 4) the enterprise employs persons with various kinds of disability and/or the owner of the enterprise is a person with disability. The selection was based on information available in the Register of Social Enterprises provided and maintained by the Ministry of Welfare. Given the limited number of WISEs, the experience of three WISEs was analysed by the research. At the third stage, interviews were conducted with WISE owners. Before the interviews, secondary data were collected – information on the performance of the enterprises available in the register and provided by the Lursoft company (annual reports). At the fourth stage, the information was systematized, analysed and the performance was compared. At the last stage of the case study, conclusions were drawn about WISEs in Latvia.

The present research also analysed papers from international journals on social entrepreneurship, data on social enterprises collected by the Ministry of Welfare, as well as the legal framework of the Republic of Latvia governing the field of social entrepreneurship in Latvia.

Results and Discussion

Characteristics of WISEs in Latvia. The target group of WISEs is most often people with disability, while other groups at risk of social exclusion are also integrated into the WISEs, e.g. persons before retirement age, persons after imprisonment etc. In Latvia, in accordance with Cabinet Regulation No. 173 (effective from 27 March 2018), 13 groups exposed to the risk of social exclusion have been defined, considering the socio-economic situation of the country and its impact on certain groups in society. In 2021, 189 social enterprises operated in Latvia; of the total, 28% were WISEs.

Although social enterprises become popular and visible, their goals are different from those of traditional companies, and they are more likely to need support to ensure their viability. To promote the expansion of social entrepreneurship in Latvia, the Social Enterprise Law prescribes various support mechanisms available to all social enterprises, incl. WISEs (Section 8). The most important kind of support for social enterprises is the grants administered by Altum and the Ministry of Welfare (hereinafter Altum grants); however, it should be mentioned that this kind of support has ended in the second half of 2021, and the financial resources allocated have been used up.

In Latvia, few specific support mechanisms or tax relief for WISEs are available. From 1 January 2021, social enterprises have an opportunity to apply for a tax credit – the social enterprises that employ disabled or mentally handicapped persons (hereinafter MHP) are entitled to a lower employer mandatory state social insurance contribution (MSSIC) rate (21.94%). In addition, a one-time salary to be paid by the government has also been introduced – if a person with disability or an MHP has been unemployed, the enterprise is entitled to apply for the one-time salary for the first month of the employment. Overall, the national government works on promoting the integration of people with disability into the labour market by applying support mechanisms to social enterprises, including WISEs, yet actually there are few specific support mechanisms for WISEs available; therefore, the WISEs seek other kinds of support – they participate in the programmes administered by the State Employment Agency (SEA) etc.

Characteristics of the enterprises selected for the case study. The main goal of all the WISEs selected relates to the integration of persons with disability and other target groups into the labour market. The other social goals also involve training and developing

skills, breaking stereotypes in society, raising the quality of life of the target groups, etc.

4 vēji Ltd was registered as a WISE on 29 April 2021. It is a manufacturing enterprise engaged in the production of corrugated paper and board as well as paper and cardboard packaging. The enterprise is located in the village of Kalnciems, Jelgava municipality. It employs MHPs and closely cooperates with the multifunctional social services centre Laipa where the MHPs live and which is located in the same village. The enterprise began hiring MHPs at the suggestion of the municipality and the multifunctional centre to involve MHPs in the enterprise.

Sonido Ltd has been operating as a WISE since 1 February 2019. The enterprise is located in Riga and operates as a call centre. It has two departments – one is responsible for outsourcing calls or telemarketing activities to other companies, and the other is a helpline for people who need support or just want to talk. Both departments employ people with disability (mostly people with functional disorders). Before becoming a social enterprise, the enterprise already provided outsourcing and telemarketing services, and it gradually evolved into a WISE.

OWA Ltd was registered as a social enterprise on 28 September 2018. The enterprise was established for a specific purpose – the owner, who was himself a person with disability, wanted to show other people with disability, as well as the public, that disability was not a barrier to enter the labour market. The enterprise is engaged in the production of knitted products as well as their sale in a shop (in Riga) and via an online shop. All the persons with and without disability employed by the enterprise have appropriate education, knowledge and skills to perform their responsibilities. It could be concluded that the social enterprises selected operated in different fields of economic activity and employed people with different kinds of disability, thereby giving an insight into the performance of different WISEs. Also, it could be concluded that there were various reasons that contributed to the establishment of the WISEs. It related to the personal factors of entrepreneurs, their entrepreneurial ability, willingness to help, as well as it emerged as cooperation with the municipality.

Characteristics of and employment challenges for employees. 4 vēji Ltd employs MHPs. The employees are assigned specific responsibilities, depending on their abilities and skills. Some of the employees are employed in low-skilled jobs – cleaning of premises, arrangement of materials, etc. The most capable employees are involved in the direct production process, where they are partially supervised as well. The employees' knowledge and skills are constrained, and there are disability-related restrictions that require more resources to enable an employee to perform the responsibilities. An important factor is the job trainer (the person assigned to the employee), as it is necessary to provide support when the employee starts the responsibilities, as well as it is necessary to remind and repeat the already built-up knowledge. Since this is the first work experience for many, they are not used to the workload. Individuals have poor reading and writing skills that constrain their performance of certain responsibilities. Given this fact, the enterprise management encourages their employees to learn. The employee turnover is low, yet some employees have repeatedly terminated and resumed their employment because of some kind of indecision. Currently, the number of employees in the enterprise is sufficient, the enterprise is known in the surrounding area, and the number of people who want to be employed by the enterprise is larger than it needs. Most employees appreciate the opportunity to work and be paid for their work.

Sonido Ltd employs mostly persons with functional disorders. Depending on the department in which the person works, there are certain criteria to be met to assure the quality of the work. To start an employment relationship, individuals need to be able to speak, as well as perceive and process information quickly. The significance of soft skills become more important (Zvirbule, Dobele, & Grinberga-Zalite, 2019). A certain constraint in the performance of work responsibilities is the low computer skills of employees, which hinders both the training process and the ability to perform work responsibilities at high quality. The employee turnover varies by department. The work in the call centre is more intensive, and the employee turnover is higher. Working as an operator on the helpline is less stressful, customers often call to talk about everyday situations, employee stress levels are lower, and the employee turnover is lower. For the most part, the employees perceive their work as an important part of their daily lives, as well as appreciate the opportunity to be employed and earn extra incomes. In some cases, it has been observed that the employee's willingness to work is greater than the ability to do so, i.e. the employee is not always critical enough to be able to invest the extra energy to do the job properly. To promote a professional attitude towards work, the management regularly carries out various activities, in which both the enterprise's values are emphasised and employee recommendations on various enterprise-related processes are considered. The management is open to building up their employees' knowledge and encourages them to apply for various continuing education courses or seminars.

OWA Ltd employs people with various kinds of disability (mostly with functional disorders). All the persons employed by the enterprise have appropriate education, skills or previous experience

in the specified job position. Persons with disability are engaged in the production process, the shop and marketing activities. No special training is provided for those engaged in the production process. The employee turnover is moderately low, with a low turnover among those engaged in the production process, yet a higher turnover is among salespeople due to their job responsibilities, personal factors and the COVID-19 situation as well as job insecurity. The persons employed by the enterprise are both those who have found this job themselves and those who are involved through the SEA programme. The employees have different attitudes towards their work, they do their jobs at different speeds and quality; some accept their work as part of everyday life, others view it as an opportunity, while for some it is a short-term activity. The employment challenges for the WISE target group included in the case study are summarized in Figure 1.

Overall, it could be concluded that each enterprise has individual circumstances, and each employee has specific needs. It is most often observed that the qualification of employees is the factor that causes the largest challenges. Attitudes towards work are not directly associated with the consequences of disability, but with personal aspects. MHPs are more likely to need additional support to perform their responsibilities, while employees with functional disorders are more likely to have a higher turnover rate and need an adapted working environment and adapted equipment.

Workloads and the working environment. Sonido Ltd employees are given an opportunity to set their own work schedule and the number of working hours adapted to their abilities. Most employees in the helpline department work an average of 4 hours a day, while in the call department – 4 hours or more. The employees also have an opportunity to work from home, which can make their daily lives easier, for example, there is no need to get to the workplace. As regards the working environment, the enterprise rents premises in a building that was initially accessible to people with reduced mobility. In relation to the performance of direct work responsibilities, the enterprise has invested its resources in providing employees with appropriate office equipment: height-adjustable desks, appropriate ergonomic computer chairs, mouse pads etc.; there are adapted hygiene rooms, as well as a partially adapted resting room. The working environment, its accessibility and flexible working conditions are good motivators for doing the job.

At OWA Ltd, mostly all its employees work full-time, except for a part-time marketer due to a lack of resources. The working hours are set and include rest breaks. The employees engaged in the production process and in the shop perform their responsibilities at their workplaces, while the marketing specialist works both on site and from home. In the course of time, the enterprise has purchased height-adjustable tables for both the employees involved in the production process and in the shop. Special ergonomic chairs have also been purchased, as well as a sofa on which the employee must periodically lie down due to due to the constraints caused by the disability. The resting room and hygiene rooms are also adapted and accessible to all the personnel. The shop personnel use the adapted hygiene rooms available in the supermarket.

At 4 vēji Ltd, the employees work certain numbers of hours, which depend on their responsibilities and abilities. The working time is individually set for each employee, varying from 2 to 4 days/week to 4 to 6 hours/day. Low-skilled employees work fewer days and hours, while those engaged in the production process work longer hours and more often. Besides, if an employee proves that s/he is able to learn and acquire new skills, the job responsibilities could

Figure 1. Mind map of employment challenges for the WISE target group included in the case study.
Source: authors' own compilation.

Table 1

Economic performances of OWA Ltd and Sonido Ltd

Indicator	OWA Ltd			Sonido Ltd	
	2018	2019	2020	2019	2020
Net turnover, EUR	12 539	39 922	66 345	203 092	184 262
Total cost, EUR	29 629	31 224	61 867	231 152	254 160
Revenue from other main economic activities, EUR	1 000	-	-	51 577	70 388
Net profit or loss, EUR	-17 971	8 695	4 478	23 402	355
Gross profit margin, %	0.17	0.64	0.61	1	1
Net profit margin, %	-	21.78	6.75	11.52	0.19

Source: authors' calculations based on enterprise annual reports.

change or the workload could increase, and the employee's income changes accordingly.

It could be concluded that the workloads in each enterprise are different, which is due to both the specifics of work and the availability of work and resources.

Characteristics of the financial situation. 4 vēji Ltd began its operation as a WISE in 2021; therefore, no annual report on its performance is available. For this reason, the financial performances of OWA Ltd and Sonido Ltd (Table 1) were compared for the period the enterprises operated as WISEs.

An analysis of the annual reports of OWA Ltd reveals that in 2018 it suffered a loss; however, the enterprise has been able to make a profit in 2019 and 2020. An analysis of operational efficiency reveals a similar trend, as the gross profit margin was 0.17% in 2018 and increased considerably in the coming years, reaching 0.64% and 0.61%. The situation is similar regarding net profits. The low efficiency and profit of the enterprise in 2018 related to the purchase of premises for the shop, which required additional financial resources. This also partly explains the considerable increase in the performance indicators in 2019. In 2020, the indicators were impacted by the COVID-19 pandemic.

Sonido Ltd began its operation on the basis of an existing Ltd, which is also evidenced by the fact that it has finished the first year of operation (2018) with a profit. The overall operating efficiency of the enterprise in 2019 reached 11.52% a year, yet it declined considerably in 2020. The enterprise's representative explains this by the impact of the pandemic, as the demand for the service decreased considerably; the companies with which they had previously cooperated did not need the service for some time.

It could be concluded that the financial situations of the enterprises compared were quite different; however, the enterprises were able to operate with a profit, indicating a self-sufficient situation in the enterprises. Although the restrictions caused by the pandemic affected the enterprises, they have been able to continue operating.

Support instruments. All the enterprises interviewed have used or use some of the available national or other kinds of support for social enterprises.

OWA Ltd was established using the owner's own financial resources. The enterprise has also received funding from NewDoor, which is an international social innovation platform and a direct support mechanism for social entrepreneurs aimed at developing sustainable social enterprises through providing knowledge, support and opportunities for cooperation with local and foreign mentors and other specialists. To begin operating, the enterprise received financial support from the local government of Riga city by participating in public procurement, which was significant support at the initial stage of entrepreneurship for the purchase of equipment, premises and other needs. During its operation, the enterprise has received an Altum grant, which was used for long-term investments, the expansion of the enterprise, as well as the purchase of premises for the shop. The enterprise also tries to establish cooperation with various national institutions, for example, by participating in the SEA programme and providing a subsidized job. The high bureaucratic burden was referred to as a negative aspect of cooperation with the SEA, as it was necessary to fill in a large number of various documents related to the involvement in the project, personal employment characteristics and other criteria. Efforts have also been made to cooperate with the Social Integration State Agency, which provides vocational training for people with disability, yet the skills and knowledge acquired have not met the needs of the enterprise. This indicates a certain problem – the enterprise wants to employ qualified employees, yet the knowledge and skills of the individuals do not meet the needs of the labour market. The manager of the enterprise also actively participates in various continuing education activities, providing additional services, e.g. delivering master classes, which are implemented together with the employees, thereby promoting the enterprise and the equipment used in textile processing. In relation to the

tax relief, the enterprise has used the reduced MSSIC rate throughout the period of operation; however, it was noted that the reduction of the rate was insignificant and was not significant relief for the enterprise. The reimbursement of the MSSIC paid by the employer, which was introduced in 2021, was indicated as significant relief for the enterprise. This was particularly important during the COVID-19 pandemic when the shop was closed. The enterprise regularly seeks new ways to attract funding, as well as establish cooperation with various private entrepreneurs and online shopping platforms. For example, in cooperation with Omniva Ltd, customers could receive their shipments free of charge at Omniva parcel terminals for a certain period.

Sonido Ltd has already started its operation as a WISE on the basis of an existing enterprise. The advantage of the enterprise is that it rents premises in a building that is accessible to people with disability, and the enterprise was already partially provided with the necessary equipment for daily operations. The enterprise has received three Altum grants, which were invested in adapting the working environment and providing technical resources to its employees, as well as covering labour costs. The reduced MSSIC rate, which was indicated as minor relief, was also used. The enterprise also benefited from the reimbursement of the MSSIC paid by the employer, which was indicated as quite substantial relief. The company has also involved volunteers during its operation, but this is a rare practice. The enterprise cooperates with the SEA in providing subsidized jobs and receiving the relief specified in the programme; however, this kind of support creates some administrative burden. The management actively participates in the activities held by the Social Entrepreneurship Association of Latvia, thereby trying to improve the social entrepreneurship environment at the national level. In addition, the representatives of the enterprise are also often involved in various educational activities, where they inform the public about social entrepreneurship, as well as participate in discussions and make proposals directly to the representatives of the Ministry of Welfare about WISEs.

4 vēji Ltd has recently begun its operation as a WISE, and the founder of the enterprise owns a manufacturing company and appropriate equipment. To date, the enterprise has benefited from the reimbursement of the MSSIC paid by the employer, which was referred to as an important support mechanism. Besides, the enterprise cooperates with the government of Jelgava municipality, which has granted the enterprise immovable property tax rebates, as well as with the multifunctional centre Laipa whose employees provide advice and support to the enterprise's manager regarding the employment of MHPs. The support given by Jelgava municipality, which provided informative lectures related to the business environment, was also appreciated. As regards the involvement of volunteers, it was pointed out that this was done rarely, as it takes time for the volunteers to learn their job responsibilities, and there is no guarantee that the quality of the work is adequate if the work is not paid for.

Overall, it could be concluded that the support mechanisms used by the enterprises are important and affect their performance. Each enterprise has an individual need for certain support mechanisms, which depend on various factors. What the enterprises had in common was the use of the reduced MSSIC rate, as well as the reimbursement of the MSSIC paid by the employer. Altum grants represented also important financial support, thereby creating opportunities for development and providing employees with adequate equipment and working conditions. Cooperation with the SEA was also a common practice for the enterprises; however, the number of documents to be filled in represented a hindrance to more cooperation. All the enterprises pointed out that they were members of the Social Entrepreneurship Association of Latvia that provided significant support concerning the latest amendments to the relevant legal framework and advice and support regarding entrepreneurship.

Necessary support mechanisms/instruments. All the entrepreneurs involved in the case study indicated that their enterprises were created both to employ people with disability and to be able to operate in the current market by producing goods or services that meet market requirements, while constantly seeking ways to compete in the market rather than waiting for a specific kind of support.

The representative of Sonido Ltd pointed out that, given the current situation in the enterprise, there was no need for additional kinds of support for WISEs. The enterprise was to some extent self-sufficient, able to successfully perform certain functions, as well as generate profits. In view of the above-mentioned problem – poor computer skills – additional measures would be needed to build up personal computer skills. Both the SEA and municipalities periodically organize such courses; however, as observed, the courses do not always reach the groups who would really need this knowledge.

4 vēji Ltd appreciated the amount of support that was already available. An effective kind of additional support, especially if employing MHPs, would be salaries partially subsidised by the national or local governments for a period comparable to the period of support provided in Lithuania. This would facilitate the initial stage of employment, as well as give the employer more motivation to invest resources and acquire a more knowledgeable employee in the long term. Besides, although the representative of the enterprise appreciated the involvement of the local

government and its support to the enterprise, all municipalities would need to provide more support to social enterprises. It would also be important to educate current enterprises, as well as to work together with them to jointly tackle various social problems in the region.

As one of the negative aspects, the representative of OWA Ltd mentioned that although the remuneration was in line with the market situation, the potential employees rejected their job opportunities due to the low remuneration. This is due to the fact that potential employees have long had low incomes and qualified as low-income or needy persons. The Law on Social Services and Social Assistance (2002) stipulates that if a person is a low-income or needy person, the municipality provides income in the amount of the guaranteed minimum income (GMI), which is EUR 109 for the first person in the household and EUR 76 for each additional person in the household, as well as pays a housing allowance. Although the salary paid by the enterprise is higher than the GMI, the person loses social benefits provided by the law and has to cover the expenses him/herself; as a result, the real amount of money is smaller than if the person were not employed. This is consistent with the finding in the literature that individuals have become dependent on benefits (Kitching, 2014). The representative of the enterprise also pointed out that there was some difficulty in finding a qualified workforce, and it should be necessary to align training programmes with the requirements of the labour market. It could finally be concluded that overall the need for support is mainly emphasized with regard to knowledge and skills related to the performance of national and local authorities.

Conclusions

1. In 2021, 189 social enterprises operated in Latvia, and most of them (28%) were WISEs. The target group of WISEs is most often people with disability, while other groups at risk of social exclusion are also integrated into the social enterprises (13 groups at risk of social exclusion are defined in Latvia).
2. In Latvia, the Social Enterprise Law provides for various support mechanisms for social enterprises; however, there are few specific support mechanisms for WISEs. From 1 January 2021, social enterprises have an opportunity to apply for a tax credit – the social enterprises that employ disabled or mentally handicapped persons are entitled to a lower MSSIC rate (21.94%), as well as a one-time salary is paid by the government.
3. The case study described three WISEs that operated in different fields of economic activity and employed people with different kinds of disability, thereby giving an insight into the performance of different WISEs. The research concluded that there were various factors that contributed to the emergence of WISEs, e.g. the personal motives of entrepreneurs, as well as it was the result of successful cooperation with the municipality.
4. The largest challenge of employing people with disability is low skills and qualifications of the target group. Mentally handicapped people more often need additional support to perform their job responsibilities, while people with functional disorders need an adapted working environment and adapted equipment. Their workloads are affected by the specifics of the jobs, the kind and degree of disability and the availability of resources.
5. The financial situation of the WISEs examined showed that they were able to operate profitably, yet national and municipal support was important. All the enterprises examined used a tax credit – the reimbursement of the MSSIC paid by the employer. Altum grants were also important financial support, thereby creating opportunities for development and providing employees with adequate equipment and working conditions. Cooperation with the SEA was also a common practice for the enterprises, yet the administrative burden could be a hindering factor.

References

Adam, S. (2014). Social exclusion and work integration: Social cooperatives for people with mental health problems in Greece. Ciriec Working Papers, 1408, 1–25.

Anca, E., & Sloka, B. (2020). Social entrepreneurship and employment challenges of persons with mental disabilities. In Proceedings of New Challenges in Economic and Business Development – 2020: Economic Inequality and Well-Being, 2 October 2020 (pp. 9–16). Riga, Latvia: University of Latvia, Faculty of Business, Management and Economics.

ANO vispārējā cilvēktiesību deklarācija (UN Universal Declaration of Human Rights) (1948). Retrieved January 2, 2022, from https://www.tiesibsargs.lv/lv/pages/tiesibu-akti/ano-dokumenti/ano-vispareja-cilvektiesibu-deklaracija (in Latvian).

Bale, I., & Auzina, A. (2020). Social entrepreneurship as an instrument for the development of non-government organization's activities: A case study of the association 'Oranzais Stars'. In Proceedings of the 2020 International Conference 'Economic Science for Rural Development', No 54, 12-15 May 2020 (pp. 141–150). Jelgava, Latvia: LLU ESAF. DOI: 10.22626/ESRD.2020.53.016.

Casno, K., & Sloka, B. (2021). Reducing social stratification via digital skills improvement: the case of social enterprises in Latvia. In Proceedings of FEB Zagreb 12th International Odyssey Conference on Economics and Business, 3(1), 9-12 June 2021 (pp. 879–891). Šibenik, Croatia.

Chieaf, E., & Giacomini, D. (2009). The evaluation in work integration social enterprises: a literature review. In 2nd EMES International Conference on Social Enterprise at Trento, 1-4 July 2009 (1–23). Trento, Italy.

Defourny, J., & Nyssens, M. (2008). Social enterprises in Europe: recent trends and developments. *Social Enterprise Journal,* 4(3), 202–228. DOI: 10.1108/17508610810922703.

Hulgard, L., & Bisballe, T. (2008). Work integration social enterprises in Denmark. *EMES Working Paper*, 04/08, 1–49.

Kitching, J. (2014). *Entrepreneurship and self-employment by people with disabilities*. Kingston University.

Laizāns, A., Mičule, B., Cālīte, D., & Rubenis, A. (2005). *Cilvēku ar invaliditāti kā neizmantota darbaspēka potenciāla efektīva iesaiste Latvijas elektronikas un elektrotehnikas nozares ražošanas uzņēmumos* (Effective involvement of people with disabilities as untapped labor potential in Latvian electronics and electrical engineering manufacturing companies). Retrieved January 2, 2022, from https://providus.lv/petijumi/cilveku-ar-invaliditati-ka-neizmantota-darbaspeka-potenciala-efektiva-iesaiste-latvijas-elektronikas-un-elektrotehnikas-nozares-razosanas-uznemumos/ (in Latvian).

Licite-Kurbe, L., & Gintere, D. (2021). Analysis of financial support instruments for social enterprises in Latvia. *Rural Sustainability Research*. 45 (340), 76–84. DOI: 10.2478/plua-2021-0009.

Majetic, F., Makarovič, M., Šimleša, D., & Golub, T. (2019). Performance of work integration social enterprises in Croatia, Slovenia, and Italian regions of Lombardy and Trentino. *Economics and Sociology*. 12(1), 286–301. DOI: 10.14254/2071-789X.2019/12-1/17.

O'Shaughnessy, M., & O'Hara, P. (2016). Social enterprise in Ireland – Why work integration social enterprises (WISEs) dominate the discourse. *Nonprofit Policy Forum*. 7(4), 461–485. DOI: 10.1515/npf-2016-0015.

Pasākuma 'Atbalsts sociālajai uzņēmējdarbībai' starprezultātu novērtēšana un priekšlikumu izstrāde tiesiskā ietvara un atbalsta pilnveidošanai (Interim Assessment of the Measure 'Support for Social Entrepreneurship' and the Development of Proposals for Improving the Legal Framework and Support). (2021). Riga: Oxford Research Baltics Ltd. (in Latvian).

Zvirbule, A., Dobele, A., & Grinberga-Zalite, G. (2019). The role of soft skills in life sciences education in the context of a digitalized working environment. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management. 19(5.4), 341–347. DOI: 10.5593/sgem2019/5.4/S22.046.

Yin, R.K. (2013). *Case study research: design and methods.* Thousand Oaks, CA; London; New Delhi: SAGE Publications.

 DOI: 10.22616/rrd.28.2022.029

FINANCIAL PLATFORMS AS ALTERNATIVE FINANCIAL INSTRUMENT TO CREDITING IN EUROPE

***Gunita Mazure**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: Gunita.Mazure@llu.lv

Abstract
The significance of financial technologies constantly grows as they have become a part of national economies. Sharing economy or alternative financing includes various digital financial activities outside the traditional banking system like crowdfunding, peer-to-peer lending and other alternatives. The research aim is to evaluate alternative finance trends in Europe. The research results show that peer-to-peer platforms mainly ensuring a high return rate have recently become very popular allowing to invest resources in various projects including real estate, loans, invoice trading and businesses. The main significant drawback of these platforms is that they are risky. The alternative finance market volumes continue to increase steadily year by year reaching USD 22.60 billion in 2020 and the United Kingdom has the largest market share of 59.35% (USD 12.6 billion) in 2020. At the beginning of 2022, there are 315 alternative finance platforms in Europe, the largest number of alternative finance platforms operate in the UK, and peer-to-peer lending (both consumer and business) and invoice trading are three the most widespread types of alternative finance in Europe covering 68% of the entire market size. The rest types of alternative finance occupy considerably lower market shares, i.e. 3-7% each. The decrease in P2P lending volumes in 2020 might be directly related with the Covid pandemic and change in consumer priorities; though, the dynamics of P2P business lending shows a constant moderate increase in the lending volumes.
Key words: alternative finance, peer-to-peer, platforms, lending, crowdfunding, FinTech.

Introduction

The concept of *collaborative* or *sharing economy* has been increasingly discussed in the society in recent years. Sharing economy refers to business models where business activities are promoted by sharing a service or collaborating with multiple participants. In general, the operation of sharing economy bases on three players: service provider, user and intermediary which connects the service provider and a user through on-line platforms, mobile applications or applying other solutions. In Europe, the sharing economy has most developed in the spheres of co-financing services (such as Mintos, Twino), passenger car services (Bolt, Uber) and short-term guest accommodation platforms (Airnb.com. booking.com). The operation of alternative finance platforms is based on the principle that lending is provided to a borrower from several or even many individual lenders. The platform evaluates the credit worthiness of a borrower and transfers the loan to it. After the repayment of the loan to the platform, repaid resources are transferred back to investors. This means that financial platforms ensure the performance of financial analysis of the loan applicator, decide on the interest rate and select the suitable loan possibility.

Alternative financing includes various digital financial activities outside the traditional banking system like crowdfunding, crowdsourcing, equity crowdfunding, peer-to-peer lending, revenue-based financing and other alternatives. Crowdfunding is based on the initiative of a large number of people to support ideas and projects of other people by raising money (Mazure, 2017). In contrast, in crowdsourcing model persons obtain either goods or services from a large, open and fast developing group of participants. As cited in Nevo D. and Kotlarsky J. research, Estelles-Arolas and Gonzalez-Ladron-de-Guevara in their literature review have performed textual analysis of 36 definitions of crowdsourcing profoundly analysing the terms like crowd, crowsourcer and process (Nevo & Kotlarsky, 2020). Equity crowdfunding is considered to be one of the most popular financing forms to support start-ups or early-stage businesses by matching entrepreneurs with investors (Schwienbacher, 2019), while peer-to-peer lending is the most popular type of crowdfunding (Lenz, 2016). Peer-to-peer lending is a means of alternative finance having gained relatively high popularity in the recent years and many research articles are dedicated to this theme. According to Bachmann A. et al. study of 2011 it involves lending process between individuals, basically, private ones (Bachmann, 2011). The role of financial institutions is only to provide services of intermediator. Siaulyte R. and Lakstutiene A. in their research on P2P lending platforms conclude that financial technology or FinTech as an integral part of financial services is an innovative tool to efficiently design and perform financial services (Siaulyte & Lakstutiene, 2021). Revenue-based financing often referred to as royalty-based financing is a type of financing suitable for companies with stable revenue flows and payments are based on a percentage of monthly business revenue (Tetreault, 2019). Lately, several researchers have contributed to the studies of real estate crowdfunding (Montgomery et al., 2018; Battisti et al., 2020) due to emerging interest in investing capital in real estate funding projects. Estonia, among the Baltic States,

is very active providing real estate crowdfunding platforms and operating in real estate projects.

The performed literature review allows formulating the research **hypothesis**: demand for alternative finance types increases; hence, the research **aim** is to evaluate alternative finance trends in Europe. The following research **tasks** are advanced to reach the set aim: 1) to characterise different models of alternative finance; 2) to evaluate peer-to-peer platforms and 3) to analyse volumes and types of alternative finance market. The analysis covers the period of 2013-2020 with a more detailed analysis related to 2020.

Materials and Methods

Scientific publications of different authors describing and analysing various types of alternative finance market and statistical data provided by internet portals dealing with statistics for market data as well as analytical reviews and reports of Cambridge Centre of Alternative Finance have been used for the purpose of the study. The research is mainly based on the monographic descriptive method as well as the methods of analysis and synthesis are used to study the problem elements and synthesise coherencies or formulate regularities.

Results and Discussion

Alternative finance models

Online alternative finance platforms may be divided into platforms that allow borrowers receiving loans directly from creditors (peer-to-peer or P2P platforms) and platforms that are used to raise money on different conditions (crowdfunding) based on various types of remuneration, either financial or non-financial (Bilan *et al*., 2019). Table 1 summarises the information on various categories and models of alternative financing briefly describing model return aspects and their market share.

Table 1

Description and market share of global alternative finance models

Category	Business model	Lenders	Borrowers	Return	Market share %, excl. China	
					2019	2020
Peer-to-peer lending	Consumer lending	Individuals or institutional funders	Consumers	Money will be repaid with interest	37	31
	Business lending		Companies		8	14
	Property lending		Consumers or companies – property is used as pledge		4	3
Balance sheet lending	Consumer lending	Platform company	Consumer	Money will be repaid with interest	12	11
	Business lending		Companies		21	25
	Property lending		Consumers or companies – property is used as pledge		4	2
Invoice trading	Invoice trading	Individuals or institutional funders	Invoices or receivables are bought from a company at a discount	Money (invoices are held as collaterals)	4	3
Real estate crowdfunding	Real estate	Individuals or companies	Individuals or companies	Money will be repaid with interest or becoming a co-owner of estate	3	2
Equity crowdfunding	Equity (stocks, shares)	Business	Investors	Investment	1	1
Reward-based crowdfunding	Ideas (projects)	Individuals	Project or business	Non-financial reward (goods, services)	1	1
Donation-based crowdfunding	Donations	Individuals	Charity (charitable projects)	None	3	6
Hybrid models	Combination of elements of more than one crowdfunding type				-	-

Source: author's construction based on Cambridge Centre for Alternative Finance, 2021.
Note: not all categories of alternative financing models are included in Table 1; thus, the total market does not equal to 100%.

Balance sheet lending is closer to bank lending due to its requirement that a platform providing this type of lending has a banking licence. In addition, loans are liabilities of the balance sheet lender resulting in possible money losses of the lender if a borrower is not able to repay the loan. Invoice trading is basically used by companies to improve their working capital; thus, allowing to free up financial resources (cash) and pay expenses or settle short-term liabilities. Though, there is a risk that a company may not be able to repay the loan and lenders are involved in long and complicated activities to receive back the lent money.

In 2020, the market share of China in alternative finance system has substantially decreased (by around 20 percentage points in peer-to-peer lending) compared with the previous years; thus, the exclusion of Chinese market allows drawing comparable basis for the analysis. The largest alternative finance market share (almost 50%) is constituted by peer-to-peer lending, of which more than 30% belong to P2P consumer lending. Minor shifting changes have occurred between the market shares of consumer and business lending in P2P lending model, where the market size declined from 37% to 31%, while business lending increased its position from 8% to 14%. According to Cambridge Centre for Alternative Finance, P2P model has not reached the pre-Covid growth rates; however, the lending under this model has increased in absolute figures (Cambridge Centre for …, 2021). Business lending under the balance sheet lending is another model which has experienced 4 percentage points increase in the market share of alternative finance. In 2020, balance sheet business lending ranks in the 2nd position with 25% of market share. Analysing the types of crowdfunding, here the market share of donation-based crowdfunding has grown from 3% to 6%. Charity, social and health fund raising activities related to the Covid pandemic might be some of the reasons explaining the increase. Another aspect which is worth mentioning is the annual growth rate of donation-based crowdfunding volumes by 160% in 2020 compared with 2019 (Cambridge Centre for …, 2021). The share of other alternative finance models like equity crowdfunding and reward-based crowdfunding is very small, i.e. 1% each.

Since 2015 the Cambridge Centre of Alternative Finance and the University of Agder's School of Business publish a report on the development of the European online alternative finance market. Hence, the 2019 report included the review of 321 locally-based platforms operating in 45 European countries (including the UK) showing a steady growth in alternative finance activities (Cambridge Centre for …, 2019).

The alternative finance market volumes continue to increase steadily year by year reaching USD 22.60 billion in 2020. These figures refer to Europe including the UK where the growth is USD 21.1 billion or 1407% (15.1 times) compared with the base year 2013. The average annual growth equals to 52.94% for the entire period analysed; however, the fastest increases were seen in 2014 and 2015 (153.33% and 57.89% respectively). In 2020, the market volumes dropped by 2.59% compared with the previous year; yet, the decrease excluding the UK is more substantial (18.85%). This was the first decline in the overall market volume since 2013. According to Cambridge Centre of Alternative Finance, the decrease may be partly related to a number of alternative financing platforms which did not respond and submit their data on market volumes (Cambridge Centre for …, 2021). The Covid-19 pandemic might be another reason explaining the decline. The share of the UK alternative finance market volumes has fluctuated in

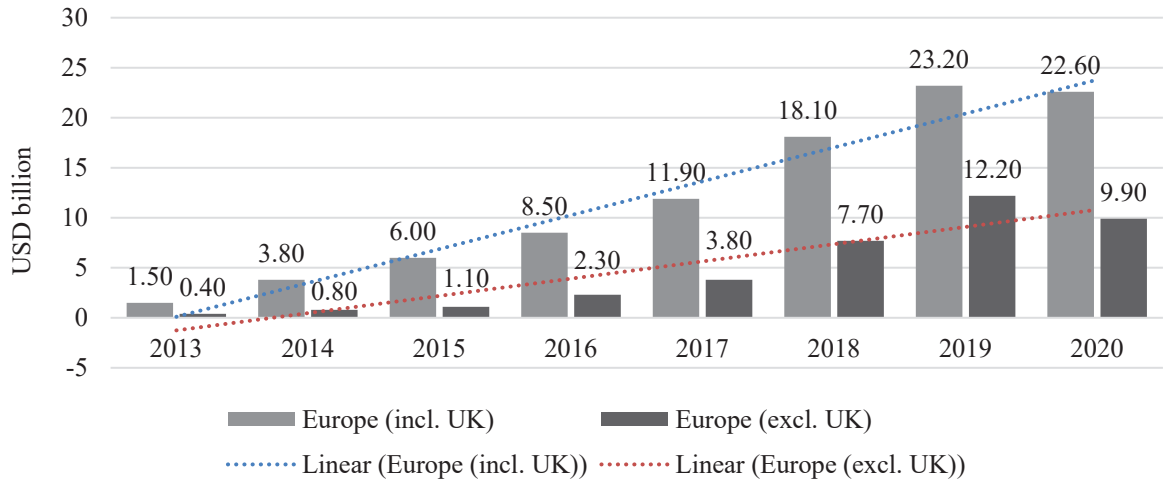

Figure 1. European alternative finance market volumes between 2013 and 2020, USD billion.
Source: author's construction based on Statista, 2021.

Table 2

Ten largest P2P lending platforms in the world on 31 January 2022

Platform	Country	Year	Market share, %	Total funding, EUR bln	Min. invest., EUR	Average annual interest, %	Regul. entity	Type of lending
Mintos	Latvia	2015	42.19	7.81	10	11.34	Country	Various
Credimi	Italy	2016	10.35	1.92	Only institutional		Bank of Italy	Business
PeerBerry	Latvia	2017	5.55	1.03	10	10.5	No	Personal, business, real estate
Twino	Latvia	2015	5.18	0.96	10	10.46	Country	Personal, business, real estate, invoices
Fellow Finance	Finland	2013	5.03	0.93	25; 100	3-8	Country	Personal, business
October	France	2015	3.32	0.70	20	5.82	Country	Business
Opyn	Italy	2015	2.74	0.56			Bank of Italy	Business
Bondora	Estonia	2008	2.64	0.56	1	8.4	Country	Personal
EstateGuru	Estonia	2014	2.76	0.51	50	9.94	Country	Real estate
Robocash	Croatia	2017	2.02	0.37	10	12	No	Consumers

Source: author's construction based on P2P market data, 2022.

the range of 81.67% (in 2015) to 47.41% (in 2019). The average share of the UK market has been around 67% within the period and it is considered to be the largest market in 2020.

Peer-to-peer platforms

Mutual lending or peer-to-peer (P2P) lending started with Zopa, a UK based personal peer-to-per lending company, and Prosper, a US based marketplace. Both companies started their operation and provision of lending services from 2005. Platforms specialising in corporate lending such as Funding Circle (UK) have also been established and operating from 2010. Peer-to-peer companies can offer lower interest rates, wider availability and fewer restrictions compared with loans provided by commercial banks. Therefore, these platforms have become a new source of alternative finance offering higher returns and having less volatility (Galland, 2017).

At the beginning of 2022, there are 315 alternative finance platforms in Europe, the largest number of alternative finance platforms operate in the UK (50) followed by Spain (36), France (32), Estonia (28) and Germany (25), while there are only 4 locally-based and 6 foreign-based platforms operating in Latvia and 11 platforms in Lithuania. Table 2 provides the information on 10 largest peer-to-peer lending platforms in Europe, where the primary criterion for ranking platforms is their market share.

In Latvia, the beginning of peer-to-peer lending dates back to 2015 with the establishment of the first two platforms Mintos and Twino, which seven years later have ranked among the TOP 5 platforms in the world. Mintos is the leading alternative finance platform worldwide offering various types of services like personal and business loans, car and agricultural loans, invoice trading and others. Mintos serves only lenders, so it is impossible to apply directly on the platform for a loan. In January 2022, the market share of Mintos is 42.19% with total funding exceeding EUR 7.81 billion. In these terms, Mintos is an absolute market leader leaving behind an Italian platform Credimi which has 4 times smaller market share and total funding volumes. Mintos is a platform operating with the largest diversity of currencies (EUR, USD, DKK, PLN, GBP, SEK, RUB, KZT, MXN and CZK). The minimum investment is EUR10 or equivalent in other mentioned currencies. The main currency for other platforms is EUR; yet, Twino offers services also in GBP.

In August 2021, the Board of the Financial and Capital Market Commission of the Republic of Latvia issued a licence to Mintos (registered as AS 'Mintos Marketplace' and SIA 'Mintos Payments') for the provision of investment and operation of electronic money institution (Financial and Capital Market…, 2021). This means that Mintos will provide legally regulated financial instruments through its platform. Therefore, Mintos will gradually limit the issuance of loans and pass over to offering notes. Twino is registered as investment service providing company and also holds the licence from the Financial and Capital Market Commission of the Republic of

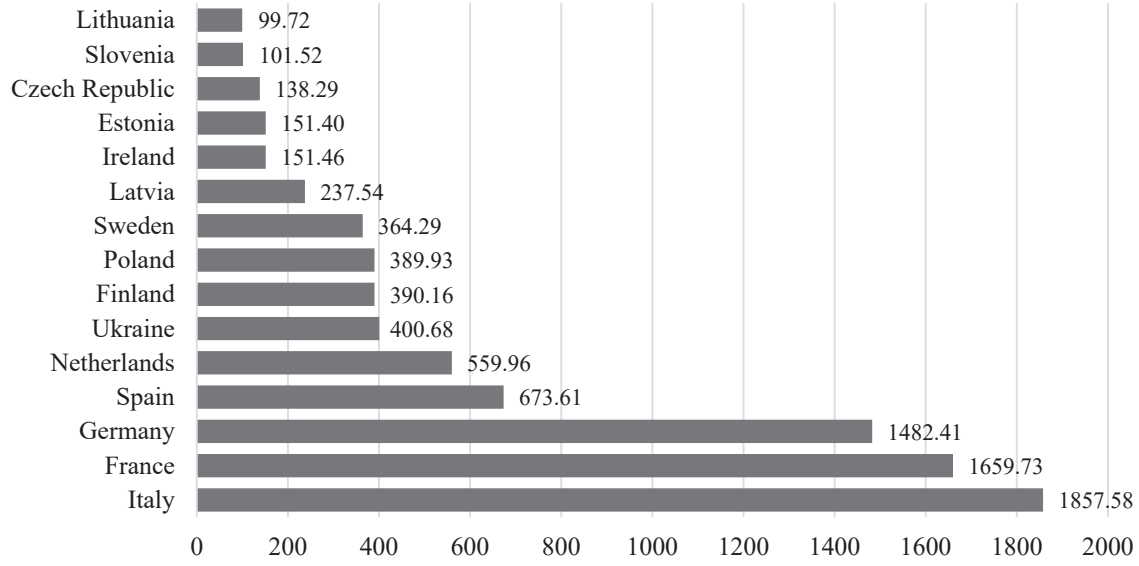

Figure 2. Total value of alternative finance market transactions in Europe excl. the UK in 2020 by country, USD million.

Source: author's construction based on Statista, 2021.

Latvia; hence becoming a regulated market place from August 2021.

PeerBerry is a company run by Aventus Group with the headquarters in Latvia; though, its legal address is registered in Croatia, while the office address is in Lithuania. The platform has not been licenced by a relevant supervisory authority. Credimi (Italy), Fellow Finance (Finland), October (France) and Opyn (Italy) operate the traditional peer-to-peer model. All of them are licenced: Credimi has a credit licence issued by the Bank of Italy, Fellow Finance has a payment licence issued by Finland's Supervisory Authority, October has a crowdfunding licence issued by France's Organisation for the Single Register of Intermediaries in Insurance, Banking and Finance, while Opyn has an investment licence and a payment licence issued by the Bank of Italy. Robocash was launched in Russia and has headquarters in Croatia. It is not regulated and it does not disclose statistics; though, it shares its funding volumes with P2P market data. It has simple interface and it is appropriate for beginners.

Bondora and EstateGuru are Estonian based platforms. Bondora is a licenced P2P platform and it has a credit licence issued by Estonia's Financial Supervisory Authority. EstateGuru is platform offering investments in real estate loans. Interesting that it is an Estonian company having received a licence as crowdfunding platform operator from the Bank of Lithuania. It is the leading European marketplace providing short-term property-backed loans.

Analysis of alternative market volumes and types

The activities of European countries in alternative finance market are different due to the number of available platforms, regulation as well as consumer and business interests (Figure 2). The data exclude the United Kingdom as the market share of the UK is 59.35% (USD 12.6 billion) in 2020 and market volume 6.8 times exceeds the volumes of Italy which is the next country in the range.

In 2020, Italy's value of alternative finance market is USD 1.86 billion which corresponds to 8.72% of total market. The next countries with the largest volumes of transactions are France (7.79% of total market) and Germany (6.96% of total market). Further both volumes and market shares represented by other countries are considerable smaller. Hence, the market volumes of all Baltic States (USD 488.66 million) stand between the volumes of the Netherlands and Ukraine. The market share of the Baltic States equals to 2.29% where Latvia is the largest representative (USD 237.54 million or 1.12% of total market). It is interesting that the figures of alternative finance volumes per capita show completely different breakdown. Here, in 2020, Latvia took the 4th position in the world context and the 2nd position in Europe followed directly by Estonia and Lithuania. If the market volume was USD 222.42 million per capita in the USA and USD 186.23 million per capita in the UK, then in Latvia the respective figure was USD 125.93 million per capita, USD 114.13 million per capita in Estonia and USD 90.78 million per capita in Lithuania (Cambridge Centre for …, 2021). Certainly such high ranking of the Baltic States is due to small number of population compared with the USA and the UK. However, the comparison with Luxembourg which has 2.8 times less population than Latvia shows very

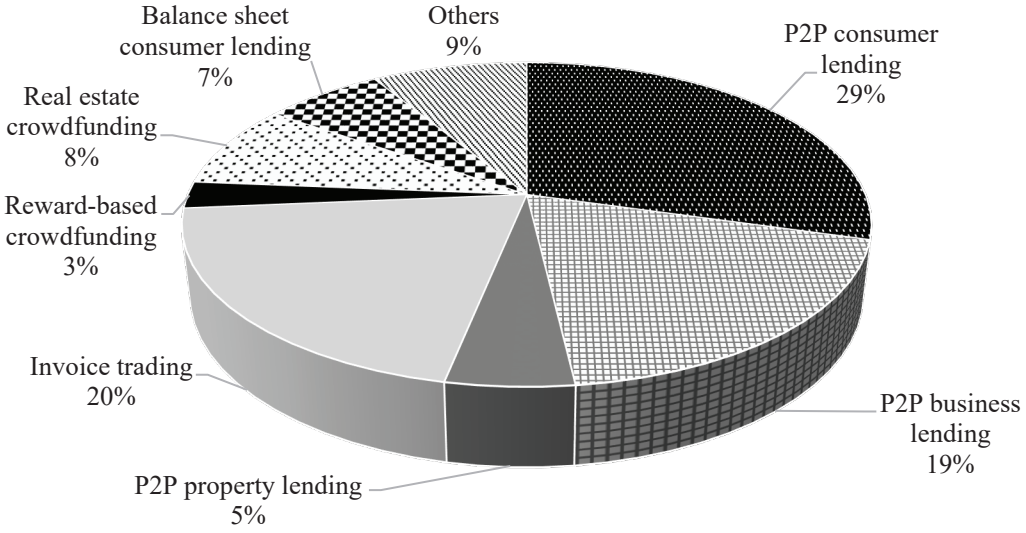

Figure 3. Alternative finance market in Europe excl. the UK in 2020 by type, %.
Source: author's construction based on Statista, 2021.

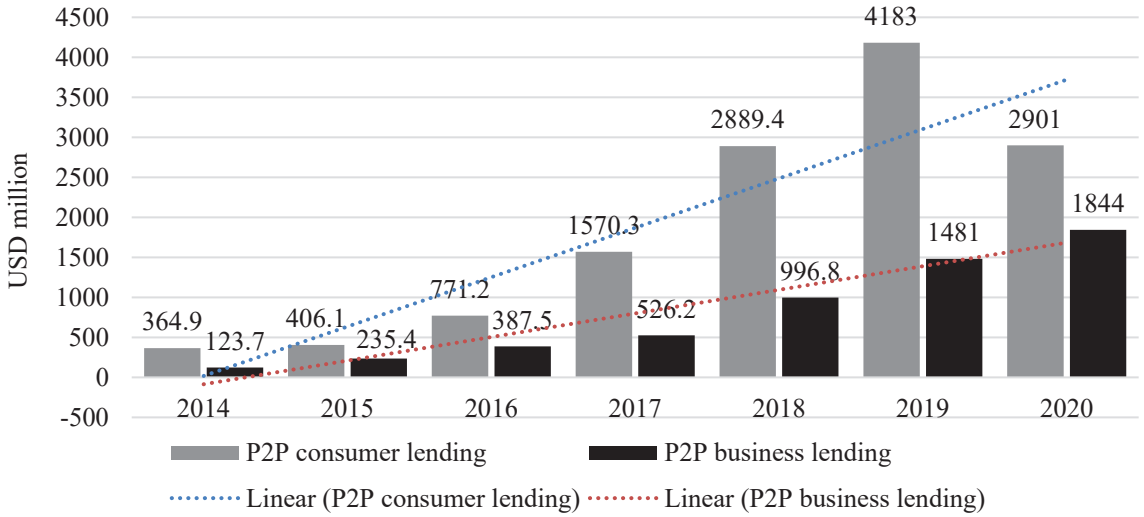

Figure 4. P2P consumer and business lending volumes in Europe between 2014 and 2020, USD million.
Source: author's construction based on Statista, 2021.

high level of finance technologies in the Baltic States. Cambridge Centre of Alternative Finance in its report has named Latvia, Estonia and Lithuania as 'the Baltic tigers' that strive to become 'leading international hubs' in alternative finance market and financial technologies (Cambridge Centre for …, 2021).

The results of the breakdown of alternative finance market by type are reflected in Figure 3 where the UK is excluded from the analysis for better representation of the data.

In 2020, as it seen in Figure 3, peer-to-peer lending (both consumer and business) and invoice trading are three the most widespread types of alternative finance in Europe covering 68% of the entire market size. The rest types of alternative finance occupy considerably lower market shares, i.e. 3-7% each. The type 'others' includes donation-based crowdfunding, equity-based crowdfunding and debt-based securities with 3% market share each and balance sheet business trading and consumer purchase finance with 1% market share each.

Peer-to-peer consumer lending is the most common lending type also in all Baltic States, followed by business lending in Latvia and Lithuania, while property lending is the 2nd favourite P2P financing in Estonia.

Peer-to-peer consumer and peer-to-peer business lending are the two most favourite types of P2P lending market requiring a particular analysis of their market volumes (Figure 4).

On average, both P2P consumer and business lending volumes have grown by 50.49% annually between 2014 and 2020. Though, the periodical fluctuations of these lending types differ by years. In absolute figures, peer-to-peer consumer lending experienced the highest increase in 2018 when the lending volume grew by USD 1319 million. Relatively this is only 84% increase compared with the previous year, where the growth was 103.62% compared with 2016. In 2019, the lending volumes slightly increased (by USD 1.29 billion or 44.77%), while a similar scope decrease was observed in 2020, when the consumer lending volumes declined by USD 1.28 billion or 30.65%. This decrease might be directly related with the Covid pandemic and change in consumer priorities. The dynamics of P2P business lending shows a constant moderate increase in the lending volumes. Nevertheless the growth speed has slowed down, it is positive, for example, in 2020 the business lending volumes grew by USD 363 million or only 24.51% compared with the previous year. It is worth mentioning that business lending volumes are smaller than consumer lending volumes in absolute figures (the difference is 2.4 times on average); hence, showing that consumers are more active in peer-to-peer transactions.

Conclusions

1. Peer-to-peer platforms mainly ensuring a high return rate have recently become very popular allowing to invest resources in various projects including real estate, loans, invoice trading and businesses. The main significant drawback of these platforms is that they are risky. One of the major risks is that the service provider may no longer ensure the platform operation, so an investor is under the risk to lose its investment.
2. The alternative finance market volumes continue to increase steadily year by year reaching USD 22.60 billion in 2020 and the United Kingdom has the largest market share of 59.35% (USD 12.6 billion) in 2020. The UK market volume 6.8 times exceeds the volumes of Italy which is the next country in the range.
3. At the beginning of 2022, there are 315 alternative finance platforms in Europe, the largest number of alternative finance platforms operate in the UK (50) followed by Spain (36) and France (32), while the Baltic States together operate 50 platforms. Mintos (Latvia) is the leading alternative finance platform worldwide offering various types of services.
4. Peer-to-peer lending (both consumer and business) and invoice trading are three the most widespread types of alternative finance in Europe covering 68% of the entire market size. The rest types of alternative finance occupy considerably lower market shares, i.e. 3-7% each. The decrease in P2P lending volumes in 2020 might be directly related with the Covid pandemic and change in consumer priorities; though, the dynamics of P2P business lending shows a constant moderate increase in the lending volumes.
5. The present research allows proposing that alternative finance models need to be more popularised among consumers explaining model operation principles and advantages and disadvantages in more details.

References

Bachman, A., Becker, A., Buerckner, D., & Hilker, M. (2011). Online peer-to-peer lending – a literature review [Electronic version]. *Journal of Internet Banking and Commerce*. 16 (2), 18 p.

Battisti, E., Creta, F., & Miglietta, N. (2020). Equity crowdfunding and regulation: implications for the real estate sector in Italy. *Journal of Financial Regulations and Compliance*. 28 (3), 353–368. DOI: 10.1108/JFRC-08-2018-0109.

Bilan, Yu., Rubanov, P., Vasylieva, T., & Lyeonov, S. (2019). The influence of industry 4.0 on financial services: Determinants of alternative finance development. *Polish Journal of Management Studies*. 19 (1), 70–93. DOI: 10.17512/pjms.2019.19.1.06.

Cambridge Centre for Alternative Finance. (2019). *Shifting paradigms the 4th European alternative finance market benchmarking report*. Cambridge: University of Cambridge, Judge Business School.

Cambridge Centre for Alternative Finance. (2021). *The 2nd global alternative finance market benchmarking report*. Cambridge: University of Cambridge, Judge Business School.

Financial and Capital Market Commission (s.a.). *FCMC issues licences to 'Mintos Marketplace' and 'Mintos Payments'*. Retrieved January 15, 2022, from https://www.fktk.lv/en/news/fcmc-issues-licences-to-mintos-marketplace-and-mintos-payments/.

Galland, D. (2017). *The 4 best P2P lending platforms for investors in 2017 - detailed analysis.* Retrieved January 7, 2022, from https:// www.forbes.com/sites/oliviergarret/2017/01/29/the-4-best-p2p-lending-platforms-for-investors-in-2017-detailed-analysis/?sh=282f85a452ab.

Lenz, R. (2016). Peer-to-peer lending: Opportunities and risks. *European Journal of Risk Regulation*. 7 (4), 688-700. DOI: 10.1017/S1867299X00010126.

Mazure, G. (2017). Perspectives of crowdfunding as innovative and alternative finance platform in Latvia. In Economic Science for Rural Development' 2017: Proceedings of the International Scientific Conference, No 46: New Dimensions in the Development of Society. Home Economics. Finance and Taxes, 27-28 April 2017 (pp. 279–286). Jelgava: Latvia University of Agriculture.

Montgomery, N., Squire, G., & Syed, I. (2018). Disruptive potential of real estate crowdfunding in the real estate project finance industry: A literature review. *Property Management* 36 (1), 597–619. DOI: 10.1108/PM-04-2018-0032.

Nevo, D., & Kotlarsky, J. (2020). Crowdsourcing as strategic IS sourcing phenomenon: Critical review and insights for future research. *The Journal of Strategic Information Systems*. 29 (4). DOI: 10.1016/j.jsis.2020.101593.

P2P market data (2022, January). Top 70 crowd financing platforms by funding volumes. Retrieved March 1, 2022, from https://p2pmarketdata.com/?utm_term=p2p%20lending&utm_campaign=Frontpage%20Sales-Search%20Europe&utm_source=adwords&utm_medium=ppc&hsa_acc=3984162988&hsa_cam=14821630027&hsa_grp=128667841423&hsa_ad=563443868819&hsa_src=g&hsa_tgt=kwd-2102696194&hsa_kw=p2p%20lending&hsa_mt=p&hsa_net=adwords&hsa_ver=3&gclid=EAIaIQobChMI0YuXw4yt9gIVwQIGAB2RjwJkEAAYAiAAEgJDQvD_BwE.

Schwienbacher, A. (2019). Equity crowdfunding: anything to celebrate? *Venture Capital*. 21 (1), 65–74. DOI: 10.1080/13691066.2018.1559010.

Siaulyte, R., & Lakstutiene, A. (2021). P2P lending platform evaluation of operating peculiarities. *Science and Studies of Accounting and Finance: Problems and Perspectives*. 15(1), 15–22. DOI: 10.15544/ssaf.2021.02.

Statista. (s.a.). P2P consumer and business lending volumes in Europe. Retrieved February 22, 2022, from https://www.statista.com/statistics/412400/europe-alternative-finance-transaction-value-p2p-lending/.

Statista. (s.a.). Peer-to-peer consumer and business lending transaction value in Europe. Retrieved February 28, 2022, from https://www.statista.com/statistics/412400/europe-alternative-finance-transaction-value-p2p-lending/.

Statista. (s.a.). Total value of alternative finance market in Europe. Retrieved February 22, 2022, from https://www.statista.com/statistics/412394/europe-alternative-finance-transaction-value-market-segment/.

Statista. (s.a.). Total value of alternative finance market transactions in Europe. Retrieved February 22, 2022, from https://www.statista.com/statistics/1081271/europe-market-volume-alternative-finance-by-country/.

Tetreault, T. (2019, February). Revenue-based financing: how a revenue-based loan works. Retrieved: February 22, 2022, from https://fitsmallbusiness.com/revenue-based-financing/.

 DOI: 10.22616/rrd.28.2022.030

EMPLOYER REPUTATION MANAGEMENT: CREATING EMPLOYER ATTRACTIVENESS IN IT SECTOR

***Miglė Šontaitė-Petkevičienė**
Vytautas Magnus University, Lithuania
*Corresponding author's email: migle.sontaite-petkeviciene@vdu.lt

Abstract
This paper focuses on employer reputation management as an approach for the creation of employer attractiveness. Specifically, this paper analyses employer reputation management in IT sector. The aim of this paper is to answer the question how employer reputation is built and managed in IT sector for the creation of employer attractiveness. In pursuance to reach the aim, this paper employs scientific literature analysis and synthesis in the field of employer reputation management, as well as field analysis and expert interviews. Results of this research prove that employer reputation management is a very important tool for creating employer attractiveness and is commonly used by organizations in IT sector to attract talents. Thus, the most important advantage of building and managing good employer reputation for IT organizations is a possibility to reach a better competitive position over other IT organizations in nowadays global marketplace while attracting greatly demanded talented IT specialists.
Key words: employer reputation, reputation management, corporate reputation, reputation, employer attractiveness, IT sector.

Introduction

The construct of employer reputation is gaining an increasingly growing interest from the theoretical as well as practical point of view. Due to the fact that in today's global marketplace employees daily face new and appealing possibilities for employment, organizations aiming to build its attractiveness as an employer are forced to look for new ways to attract talented employees. Nowadays, in the field of marketing and business management, more and more attention is being given to employer reputation management.

In contemporary business environment we notice a growing demand for talents. Having good corporate reputation as an employer is particularly important for nowadays organizations to successfully operate in the market, grow business and stay competitive. With good employer reputation organizations from various countries and industries strive to attract potential and maintain existing talented employees.

In today's global marketplace, it is becoming increasingly difficult for organizations to build and maintain competitiveness and leadership in the market. It is becoming difficult for organizations to compete not only in the exchange of goods and services, but also in the rapidly growing competition for talented employees, who are considered as the main source for successful performance of organizations. Although employers fight to attract and retain talented employees in most industries, IT sector is particularly sensitive in today's business market.

Organizations from IT sector that are able to build and maintain good corporate reputation have more possibilities to operate successfully. Good corporate reputation helps organizations to secure a strong, long-term competitive advantage in the eyes of its stakeholder groups and is also a vital tool while competing for talented employees who are greatly important for organization's success. It is therefore very important to have a good corporate reputation towards its main stakeholder groups, especially towards the most important. Since employees are one of the most important stakeholder groups of organizations from the IT sector, it is necessary to focus all available resources on the growing need to build and manage good employer reputation as it helps to increase the attractiveness of the organization to potential and existing employees.

However, changing needs and expectations of employees, intensifying competition for talents and the growing flow of employer marketing communication, stipulate organizations to look for effective solutions to build employer attractiveness. Organizations face the need to build good corporate reputation as employers not only convey a message about them as good employers, but also build good employer reputation that could help to compete successfully in the market for talents. For all the above-mentioned reasons, organizations face the need to build its attractiveness through building and managing its employer reputation.

Problem of the research. Since nowadays in Lithuania, other EU countries and even global marketplace the struggle of organizations for the attraction and retainment of talented employees is evident in many industries, a particularly sensitive sector is IT. This is attributed to the rapidly growing need for digitalisation of the economy, which is correspondingly increasing the need for employees in the IT sector. The shortage of talented IT employees in the labour market creates the conditions for employees from this sector to be very selective and carefully examine the employer while employing or leave the employer without any second thoughts if the

employer does not meet expectations. For employers from IT sector this situation creates reasonable demands to invest in building the attractiveness of the organization through building and managing its employer reputation.

Although Lithuania is not the only country in Europe that faces a huge shortage of IT specialists, Lithuania lacks them most compared to other Baltic countries. Lithuania is increasingly focusing its efforts on the digitalization of economy, in which the implementation of digital technologies in the business processes of various industries plays a key role. Digitalization affects all areas of businesses and society. In order to take advantage of the opportunities provided by digital technologies, it is very important to have sufficient level of competencies that are necessary for managing digital processes. But, for example, Lithuania lacks about 14,000 IT specialists (Infobalt, 2020; lrytas.lt, 2021; 15min.lt, 2021), And it is predicted that this need for IT specialists in Lithuania will grow 10 percent each year (LRT.lt, 2020). At the global level the lack of IT specialists is a much bigger problem. According to LRT.lt (2020) until 2023 the lack of IT specialists in the world will reach 4.3 million. Large mismatch between supply and demand in the labour market creates possibilities for IT specialists to choose employers very selectively and, requires from employers of IT sector to increase its attractiveness and improve employer reputation. According to a study conducted by Infobalt, Invest in Lithuania (lt. Investuok Lietuvoje) and MOSTA, over the past decade the need for IT specialists in Lithuania has grown ten times faster compared to the need of total workforce. From the Lithuanian organizations surveyed, as many as 78 percent reported they are looking for additional employees (15min.lt, 2018).

Thus, there is a high risk that large investors will relocate their investments to other countries in the face of a shortage of IT specialists. This is especially a big risk because in Lithuania most of the investments are attracted from the information technology sector. Due to such a situation, this paper is dedicated to analysing employer reputation building and management in the IT sector, as this business area faces the greatest difficulties in finding and retaining talented employees and faces the greatest need to build its corporate reputation as a good employer.

Yet, employer reputation building and management as a tool for the creation of employer attractiveness is quite an underexplored topic in the scientific literature. Scholars argue that this field needs deeper knowledge and tools on how to build and manage employer reputation while creating employer attractiveness. Because of this scarcity in the theory, the question is not if employer reputation should be built and managed but how it should be done in order to create employer attractiveness. The absence of comprehensive theoretical and practical information on how employer reputation should be built and managed for the creation of employer attractiveness raises many issues for the owners and managers of various organizations, particularly in the IT sector.

Object and aim of the research. The object of the research is employer reputation building and management in IT sector for the creation of employer attractiveness. The aim of the research is to ascertain how employer reputation is built and managed in IT sector for the creation of employer attractiveness.

Objectives of the research. Objectives of this research are set in the following logic: (1) to analyse theoretical construct of employer reputation; (2) to conduct field analysis of employer reputation building and management in IT sector; (3) to conduct expert interviews in order to identify how employer reputation is built and managed in practice by IT companies for the creation of employer attractiveness.

Materials and Methods

The paper is organized using both theoretical and empirical research approach. In this paper employer reputation construct, specifics of employer reputation building and management, the use of employer reputation building and management for the creation of employer attractiveness, analysis of employer reputation building and management in IT sector and, application of employer reputation in practice by Lithuanian IT companies were examined.

At first, theoretical scientific literature analysis was performed in the field of employer reputation Theoretical analysis was followed by the field analysis of the market data from secondary sources. Findings from theoretical scientific literature analysis and field analysis were further discussed during the final step of research – conducting interviews with representatives of IT sector. Insights collected during expert interviews amended collected data with the point of view from within. Methods used for this paper are further explained in more detail.

Theoretical analysis. Pursuing to reach the aim of the paper, theoretical research methods that are used in this paper embrace scientific literature logical analysis and synthesis. The author of this paper used analysis and synthesis of scientific literature to execute research and assess the construct of employer reputation. For the theoretical analysis keyword search in Business Source Complete (EBSCO), Emerald Management eJournals Collection, SAGE Journals Online, ScienceDirect, Taylor & Francis and Web of Science databases was done in order to collect international scientific publications necessary for the research.

Field analysis. Secondary data from various Lithuanian trustworthy sources was used to perform qualitative field analysis, which focused on IT sector overview in Lithuania. While analysing secondary sources, problematic aspects of building and managing employer reputation of IT sector organizations in Lithuanian labour market were identified. When performing qualitative field analysis of the IT sector organizations in Lithuanian labour market the following sources of information were examined: reports of the IT sector employer reputation rankings; latest publications and reports of recruitment companies that provide staffing services to the IT organizations; media articles and reports published by employers from the IT sector.

Expert interviews. In order to collect primary data and gather opinion of experts from IT sector about the importance of employer reputation for IT organizations, dimensions shaping corporate reputation of IT organizations as employers, expert interviews were conducted. The interviews were conducted in the form of online meetings and discussions using MS Teams online meetings platform. An individually prepared questionnaire was used as the basis for the interviews and interviewed experts were provided with guidance when answering questions and, asked for clarification or elaboration when it was necessary. To obtain opinion of several different experts from the IT sector, two different experts from Lithuania were interviewed: (1) human resource manager that works with IT organizations and provides staffing services to them; (2) general manager of one large international IT company.

A single questionnaire was prepared for conducting interviews. The questionnaire for expert interviews consisted of 10 open questions. Experts were asked to share their opinion about employer reputation and its importance to employees in IT sector as well as to organizations itself, by what means IT organizations build and manage their employer reputation, how they attract IT talents, what are the most important dimensions for building IT employer reputation, what is the role of salary vs. employer reputation, etc. Before starting interviews, experts were introduced with the aim of the interview, its logic and expected result were highlighted. Expert interviews were organized in February, 2022. The duration of each interview was approximately 20–40 minutes.

Results and Discussion

This section provides results from three stages of research: theoretical scientific literature analysis, field analysis and expert interviews.

Many researchers agree that nowadays employer reputation is extremely valuable to organizations of any industry as it helps to build employer attractiveness. According to Kot *et al.* (2021) the literature has given attention to employer reputation and described that it is not only related to attracting or hiring the potential workforce, but it also impacts the retention level of qualified human capital. Dögl & Holtbrügge (2014) agree that employer reputation is relevant not only to attract but also to retain qualified employees. Thus, according to Xie, Bagozzi, & Meland (2015) employer reputation plays a really important role in the recruitment process.

Theoretical conceptualizations on employer reputation

Employer reputation can be defined as the general public's evaluation of the company as an employer (Cable & Turban, 2001). Organizations with a good employer reputation tend to be associated with higher levels of organizational identification. Attraction of employer reputation may apply to companies' current and potential employees, when perceived or anticipated reputation is evaluated. Therefore, positive and strong reputation of an employer is likely to attract identification from job applicants (Xie, Bagozzi, & Meland, 2015).

Dudharejia (2019) believes that the perception that job candidates have towards business could determine whether or not they pursue an opportunity to work for. Nugroho & Liswandi (2018) agree that employer attractiveness and corporate reputation has significant influence towards intention to apply for a job. Dudharejia (2019) adds that everyone wants to work for a company that they love and admire. Therefore, improving employer reputation can help to not only attract highly talented candidates, but also keep them more engaged with business operations in the long run. This can directly lead to a more productive workplace, greater employee satisfaction, and higher retention rates.

Research results of Xie, Bagozzi, & Meland (2015) show that both instrumental attributes (i.e. evaluation of job attributes) and symbolic attributes (i.e. company reputation and identity congruence between self-identity and perceived organizational identity) of an employer brand significantly affect its attractiveness (i.e. applicants' intention to search for information and to apply for a job). Nugroho & Liswandi (2018) agree that as employer reputation progresses, employer attractiveness increases in the eyes of job seekers, and this improves the quality of a company's recruitment. Dudharejia (2019) lists ways to build and maintain good employer reputation. According to him, active response to all employee reviews, share of real employee stories, showcase what makes an organization unique, not better, and usage of employees as recruiters are great ways to build and maintain good employer reputation.

Results from field analysis on employer reputation building and management in IT sector

Human resources are considered as the most important factor of an organization's competitive advantage. Thus, organizations should care about its employees, listen to their feedback, suggestions, show how important everyone is for an organization and invest in employer reputation building. Although in recent years almost all organizations in Lithuania are facing difficulties in finding qualified employees, there is a particularly large shortage of qualified IT specialists. Currently, IT sector in Lithuania is facing really problematic situation with human resources, as large international organizations come to Lithuania, which offer better working conditions and salaries, and create difficulties for Lithuanian capital organizations in competing for employees. However, we should keep in mind that IT specialists are not only needed by IT organizations, but also by organizations from any industry.

Since organizations have diminishing possibilities to attract and retain IT talents by offering high salaries, it is very important for organizations to start looking for non-financial means of motivation. Human resource managers agree that there is a great need for the development of a long-term strategy for attracting and retaining experienced IT specialists. It is very important nowadays for organizations to invest in building and managing good employer reputation. However, organizations should be aware that corporate reputation is built over many years but can be destroyed in one day. This is also applicable in the case of employer reputation. Good corporate reputation is a very important strategic and long-term asset of an organization. Due to this, it is much easier for organizations having good corporate reputation to achieve their strategic goals. Thus, organizations put big efforts in building their corporate reputation with their stakeholders, especially with most important ones. And in the case of IT organizations or organizations that need IT specialists the most important stakeholder group is employees.

Results from annually organized elections in Lithuania "The Most Desired Employer" show that IT organizations care about their employer reputation as organizations from IT sector have been receiving excellent evaluations from employees for the last several years. When analysing results of 'The Most Desired Employer' elections in Lithuania from the last two years, it is noticeable that in 2021 there were 3 organizations from information and telecommunications sector that were listed between winning organizations as best employers in Lithuania: Tele2 (3rd position), Telia Lietuva (8th position) and All Media Lithuania (14th position) (Verslo žinios, 2021). When analysing the results of the year before, it is noticeable that in 2020 there were 5 organizations from information and telecommunications sector that were listed as best employers in Lithuania: Tele2 (4th position), All Media Lithuania (8th position), DevBridge LT (10th position), Telia Lietuva (14th position) and TIA Technology (17th position) (Verslo žinios, 2020).

In 2020, CVbankas.lt which is a leading job listings portal in Lithuania announced its rankings 'Leader in labour market' for the first time. In a list of the top 30 most sought after employers in 2020 published by CVbankas.lt (2020) there were 4 organizations from information and telecommunications sector that were listed between most sought after employers in Lithuania: Telia (3rd position), Bitė (13th position), Tele2 (19th position) and Tesonet (26th position). In a list of the top 30 most sought after employers in 2021 published by CVbankas.lt (2021) there were 4 organizations from information and telecommunications sector that were most sought after employers in Lithuania: Telia (4th position), Bitė (17th position), Transcom (29th position) and Tele2 (30th position).

First research of corporate reputation of Lithuanian IT sector was conducted by TNS LT together with Infobalt in 2015. Research results showed that reputation index of the Lithuanian IT sector is one of the best in Europe. Reputation index of the Lithuanian IT sector reached 67 points, while the average reputation index of the European IT sector was 56 points (Kantar, 2015). During the research of the following year it was identified that Lithuanian IT sector reached 69 points, while the average reputation index of the European IT sector was the same – 56 points (Tnews.lt, 2019). Research of corporate reputation of Lithuanian IT sector in 2016 showed that companies in the IT sector are trusted by 47 percent of all interest groups, also known as reputation ambassadors, and their evaluation is critical to maintaining good corporate reputation (Kantar, 2016). Head of insights and research, J.Račkytė-Vilimė, pointed out that Lithuanian IT sector is perceived by different groups of society as one of the most promising and extremely reputable. High level of corporate reputation reflects the potential for further successful development of this sector. A good corporate reputation for the players in the sector is not only an achievement but also an obligation to maintain high standards of performance and an incentive to further strengthen the trust of their audiences (Kantar, 2016). The top three companies in the IT sector that stood out in Lithuania in 2019 were Barclays, NFQ Technologies and Microsoft Lithuania (Tnews.lt, 2019). From this we can see that the first three companies with the best corporate reputation are large international companies.

While commenting research results on Lithuanian IT sector's corporate reputation, J.Račkytė-Vilimė

stated that good corporate reputation in the IT sector is determined by several key factors. From the point of view of stakeholder groups most important things for maintaining good corporate reputation are honesty and responsibility of business principles, focus on the needs of customers and financial stability. The responsible activity of the organization and the culture of customer service outweigh the importance of the impeccable reputation of the CEO, the company's leadership in its field or concern for the protection of intellectual property (Kantar, 2016).

Recruitment company Amston made a research in 2020 on what motivates employees most during the pandemic. Žvaginytė & Sirgedaitė (2021) pointed out that in the IT sector, competitive salary with additional financial benefits remained a key factor for both junior and experienced professionals. They also noticed that IT specialists expect from employers to invest in their skills and competencies improvement. Experienced specialists additionally expect health insurance and a package of other options offered by the organization. Žvaginytė & Sirgedaitė (2021) highlight the importance of non-monetary incentives during the pandemic as it became an important tool for increasing employee motivation and involvement in the IT sector. Expectations of younger and more experienced IT specialists coincide. IT specialists attach the greatest importance to the opportunity to contribute to the development of interesting projects. Also, specialists desire to get a sense of security from the organization which can be ensured by the stability of the organization's operations and a professional and periodically growing team. To younger IT professionals a clear career plan put together with managers and identified growth opportunities are also important. For experienced IT professionals, freedom of decision-making plays an important role in the list of motivating non-financial factors. IT representatives also expect flexibility from the employer regarding scheduling and teleworking.

Research done in Lithuania by the recruitment company Peoplelink in 2019 distinguished the key factors that influence the willingness of IT specialists to work for an organization (Figure 1). Results of the research published by Peoplelink (2019) revealed that employer reputation and organization's ability to generate added value to employees are becoming increasingly important to IT specialists. Salary remains very important, but it is not the only factor for recruiting IT talent. Candidates in the IT sector tend to evaluate managers in the organization from a personality, leadership style and professionalism in the field point of view when making a decision. Research highlights that candidates will never agree to come to work in the organization if they have experienced negative feelings during a meeting with an employer. Peoplelink offers to the employers to reward IT specialists in the same way that salespeople reward customers. Another factor shaping employer's reputation, according to Peoplelink research, is flexible working conditions and this aspect is increasingly emphasized by candidates from the IT sector (Peoplelink, 2019). Head of Peoplelink, J.Lemešiūtė, adds that properly managed employment, introduction of newcomer, training and release process protects against negative feedback about the employer and contributes to maintaining good employer reputation (Delfi, 2020). All most important dimensions influencing IT specialists from Lithuania willingness to work for organizations are seen in Figure 1.

Results from expert interviews on employer reputation building and management in IT sector for the creation of employer attractiveness

Second stage of empirical research – expert interviews – were done to gather insights from IT sector about the importance of employer reputation for IT organizations and IT specialists, dimensions

Figure 1. Most important dimensions influencing IT specialists from Lithuania willingness to work for organizations (n=120) (Source: Peoplelink, 2019).

on which IT organizations build and manage their employer reputation and how IT talents are attracted to employ. Online informal expert interviews have been performed with two different experts from Lithuanian IT sector: (1) human resource manager providing staffing services to IT organizations and (2) general manager of one large international IT company.

When experts were asked about the main reasons for the lack of IT specialists in Lithuania, experts indicated several reasons. One of the reasons for the shortage of IT specialists in Lithuania could be the entry of large foreign capital IT organizations into the Lithuanian market. This causes problems to local organizations because it is difficult for them to compete for IT talents as they cannot offer salaries of the same level, nor same working environment. Another reason for the shortage of IT specialists in Lithuania, according to experts, is that IT specialists can work remotely in organizations from all over the world. In addition, international IT organizations rely heavily on IT talents, so they are willing to pay high salaries and offer various motivational packages, which often makes it impossible to attract such employees to work for local organizations.

When experts were asked if publicly available information about organizations is important to IT specialists when choosing where to go for a job interview, experts mutually agreed that potential employees from IT sector tend to evaluate employers based on the information found in media, social networks, various groups, and blogs. IT specialists are aware that there is a shortage of IT specialists, so they are very selective when choosing an organization to work for. Experts also highlighted that candidates not only analyse feedback about the employer itself, but also how profitable organization is as well as other publicly available information. Due to this, experts believe that good corporate reputation of the employer is important for potential IT employees when deciding on applying to work. Corporate reputation of employer is even more important when aiming to attract talented, highly experienced IT professionals, as IT talents receive much more job offers and are very selective. According to experts even smaller organizations must take care of their employer reputation because it is a long-term strategy to compete in the job market. Meanwhile, organizations from IT sector are simply forced to invest in their employer reputation if they want to stay competitive. Talented IT specialists are highly important for the success of organizations in the IT sector, so even a loss of one highly experienced IT employee is a big loss for an organization in this sector.

Experts distinguished the main means by which employers compete to attract talented IT employees. The most common means on top of competitive salary used by Lithuanian employers to attract IT talents are: flexible work schedule, opportunity to work from home, bonuses for timely completed projects, paid health insurance, paid life insurance, additional days off, workplace equipped to the highest standards, stylish resting zones in the office, free food, free snacks, free drinks, various free leisure activities, free trainings.

When asked about how IT organizations build good employer reputation, experts pointed out that first of all IT organizations invest in creation of work environment that creates positive emotions to employees, where it is good to work and even relax. Employer's ability to be flexible in various situations, the creation of a comfortable work and leisure environment, and maintenance of friendly relations are also very important aspects shaping employer reputation. Another aspect that helps to build good employer reputation is the fulfilment of promises given to employees, because unfulfilled promise might destroy good employer reputation very quickly. On the other hand, happy and loyal employee is very valuable when it comes to having brand ambassadors for the organization and, this is also important for building good employer reputation. Such IT organizations don't have difficulties in finding IT specialists, because brand ambassadors tend to invite their friends or relatives to come to work for the organization. It is very important to be close to all employees and listen to their complaints or suggestions. Experts pointed out that IT organizations often look for new ways to encourage, reward, maximize development, advance career possibilities, and make sure that employees feel good in the organization.

Experts distinguished the most important dimensions of corporate reputation that they believe for the most part help to build good employer reputation and attractiveness of the employer in IT sector. They believe that the most important dimensions for a potential employee in the IT sector are: working conditions, salary and good atmosphere in the organization. On the other hand, experts pointed out the importance of corporate communication in the media while broadcasting success stories and promoting corporate brand.

When experts were asked whether a competitive salary can compensate poorer employer reputation of an IT organization, both experts agreed that this depends on how experienced potential employee is. Experts believe that competitive salary can only compensate poorer employer reputation of an IT organization for less experienced IT specialists. They emphasized that IT specialists with big knowledge and experience will not come to work for IT organization with poorer employer reputation. To conclude, experts from IT sector stressed out that good employer

reputation is very important for IT organizations as it greatly helps to build its attractiveness to potential and existing IT employees.

Conclusions

Analysis of scientific literature allows to conclude that attraction of employer reputation applies to potential and existing employees. Employer attractiveness and employer reputation have significant influence towards intention to apply for a job. As employer reputation progresses, employer attractiveness increases in the eyes of employees, and this improves organization's recruitment possibilities. Theory also distinguishes ways to build and maintain good employer reputation, which are: active response to all employee reviews, sharing of real employee stories, showcasing what makes an organization unique, and usage of employees as recruiters.

Results from field analysis showed that the importance of employer reputation building and management are taken into account by many Lithuanian organizations from the IT sector. IT organizations in Lithuania make great efforts to shape their employer reputation. IT organizations, especially international ones, invest in creating an attractive value proposition for candidates, offering both financial and non-financial benefits, and actively communicate about it in the media. Overall, IT sector in Lithuania is a sector with a very good corporate reputation compared to other sectors. However, this is more applicable to large international organizations, while local organizations still have room for improvement when building and managing their employer reputation.

Results from expert interviews confirmed that good employer reputation is very important for potential IT employees when deciding on applying to work. Employer reputation is even more important when aiming at attracting talented, highly experienced IT professionals. According to experts, even smaller organizations must take care of their employer reputation because it is a long-term strategy to compete in the job market. The most important dimensions of corporate reputation that for the most part help to build good employer reputation and attractiveness of the employer in IT sector are working conditions, salary, and good atmosphere in the organization.

References

15min.lt (2018). *Lietuvai trūksta 13 tūkstančių* IT *specialistų: rizikuoja pralošti investicijas (Lithuania lacks 13 thousand of IT specialists: risks to loose investment).* Retrieved March 8, 2022, from https://www.15min.lt/verslas/naujiena/finansai/lietuvai-truksta-13-tukstanciu-it-specialistu-rizikuoja-pralosti-investicijas-662-955312?copied/verslas/naujiena/finansai/lietuvai-truksta-13-tukstanciu-it-specialistu-rizikuoja-pralosti-investicijas-662-955312. (in Lithuanian).

15min.lt (2021). *Praraja auga: trūksta 14 tūkst.IT darbuotojų, po dešimtmečio triskart tiek (Gorge grows: lacks 14 thousand IT employees, after a decade three times more).* Retrieved March 8, 2022, from https://www.15min.lt/verslas/naujiena/bendroves/it-darbuotoju-stoka-siandien-truksta-14-tukst-po-desimtmecio-reikes-triskart-tiek-663-1528552. (in Lithuanian).

Cable, D.M., & Turban, D.B. (2001). Establishing the dimensions, sources, and value of job seekers' employer knowledge during recruitment. *Research in Personnel and Human Resources Management.* 20, 115–163.

CVbankas.lt (2020). *Paskelbti "Darbo rinkos lyderiai 2020" – kurie darbdaviai pernai sulaukė didžiausio Lietuvos žmonių susidomėjimo? (‹Labour market leaders 2020' have been announced – which employers received biggest attention of Lithuanian employees?).* Retrieved March 9, 2022, from https://www.cvbankas.lt/karjeros-patarimas/darbo-rinkos-lyderiai-2020.html. (in Lithuanian).

CVbankas.lt (2021). *CVbankas.lt konferencijoje paskelbti 'Darbo rinkos lyderiai 2021' – kurie darbdaviai pernai sulaukė didžiausio Lietuvos žmonių susidomėjimo? ("Labour market leaders 2021" have been announced in CVbaknas.lt conference – which employers received biggest attention of Lithuanian employees?).* Retrieved March 9, 2022, from https://www.cvbankas.lt/karjeros-patarimas/paskelbti-darbo-rinkos-lyderiai-2021.html?save_locale=1. (in Lithuanian).

Delfi.lt (2020). *Kriterijai, pagal kuriuos įmonės renkasi darbuotojus, o darbuotojai – įmones: tyrimo rezultatai nustebino (Criteria based on which organizations select employees and employees select organizations: The results of the research were surprising).* Retrieved March 9, 2022, from https://www.delfi.lt/darbas/darbo-rinka/kriterijai- pagal-kuriuos-imones-renkasi-darbuotojus-o-darbuotojai-imones-tyrimo-rezultatai-nustebino.d?id=84060041. (in Lithuanian).

Dögl, C., & Holtbrügge, D. (2014). Corporate environmental responsibility, employer reputation and employee commitment: an empirical study in developed and emerging economies. *The International Journal of Human Resource Management*. 25(12), 1739–1762. DOI: 10.1080/09585192.2013.859164.

Dudharejia, M. (2019). Smart employer branding can cost you nothing. *HR Future.* June. 14-16.

Infobalt.lt (2020). *Lietuvos skaitmeninės ekonomikos apžvalga 2020 (Overview of Lithuanian digital economy*

2020). Retrieved March 8, 2022, from https://drive.google.com/file/d/1twNBxe9E-2DO4j7gmW9DZbvE4J-QWC5t/view. (in Lithuanian).

LRT.lt (2020). *IT specialistų bumas išliks dar ilgai – iki 2030 m. jų trūkumas pasieks net 4,3 mln. visame pasaulyje (Boom of IT specialist will remain for a long time – until 2030 shortage will reach 4,3 million in the whole world).* Retrieved March 9, 2022, from https://www.lrt.lt/naujienos/verslas/4/1249678/it-specialistu-bumas-isliks-dar-ilgai-iki-2030-m-ju-trukumas-pasieks-net-4-3-mln-visame-pasaulyje. (in Lithuanian).

Kantar.lt (2015). *TNS LT: Lietuvos IT sektoriaus reputacija – viena geriausių Europoje (TNS LT: Reputation of Lithuanian IT sector is one of the best in Europe)*. Retrieved March 9, 2022, from http://www.kantar.lt/lt/news/tns-lt-lietuvos-it-sektoriaus-reputacija-viena-geriausiu-europoje-/. (in Lithuanian).

Kantar.lt (2016). *Kantar TNS: Lietuvos IT sektoriaus reputacija lenkia Europos vidurkį* (Kantar TNS: Reputation of Lithuanian IT sector outstrip European average). Retrieved March 9, 2022, from http://www.kantar.lt/lt/news/kantar-tns-lietuvos-it-sektoriaus-reputacija-lenkia-europos-vidurki/. (in Lithuanian).

Kot, S., Hussain, H.I., Bilan, S., Haseeb, M., & Mihardjo, L.W.W. (2021). The role of artificial intelligence recruitment and quality to explain the phenomenon of employer reputation. *Journal of Business Economics & Management.* 22(4), 867–883. DOI: 10.3846/jbem.2021.14606.

lrytas.lt (2021). *Vien Lietuvoje* šių *specialistų reikia 14 tūkst. – paklausa kasmet išsipučia 3 tūkstančiais (Lithuania alone needs 14 thousands of such specialists – each year demand grows by 3 thousand).* Retrieved March 9, 2022, from https://www.lrytas.lt/verslas/rinkos-pulsas/2021/12/31/news/vien-lietuvoje-siu-specialistu-reikia-14-tukst-paklausa-kasmet-issipucia-3-tukstanciais-21750352. (in Lithuanian).

Nugroho, A.H., & Liswandi (2018). The influence of employer attractiveness, corporate reputation and the use of social media towards intention to apply for a job. *International Journal of Management, Accounting and Economics.* 5(7), 553–565.

Peoplelink (2019). *Ko nori darbuotojai? (What employees want?).* Retrieved March 9, 2022, from https://peoplelink.lt/wp-content/uploads/2019/10/Ko-nori-darbuotojai-tyrimas-2019.pdf. (in Lithuanian).

Tnews.lt (2019). *Geriausios IT* įmonės *Lietuvoje (Best IT organizations in Lithuania).* Retrieved March 9, 2022, http://tnews.lt/2019/12/23/geriausios-it-imones-lietuvoje/. (in Lithuanian).

Verslo žinios (2020). *Paskelbti reitingo "Geidžiamiausias darbdavys" nugalėtojai (Winners of rankings "Most desirable employer" have been announced).* Retrieved March 9, 2022, from https://www.vz.lt/verslo-valdymas/2020/08/05/paskelbti-reitingo-geidziamiausias-darbdavys-2020-nugaletojai. (in Lithuanian).

Verslo žinios (2021). *Išrinkti geidžiamiausi Lietuvos darbdaviai (Most desirable Lithuanian employers are elected).* Retrieved March 9, 2022, from https://www.vz.lt/verslo-valdymas/2021/06/10/isrinktigeidziamiausi-lietuvos-darbdaviai. (in Lithuanian).

Xie, C., Bagozzi, R.P., & Meland, K.V. (2015). The impact of reputation and identity congruence on employer brand attractiveness. *Marketing Inteligence & Planning.* 33(2), 124–146. DOI: 10.1108/MIP-03-2014-0051.

Žvaginytė, E., & Sirgedaitė, B. (2021, March). *Tyrimas: karantino metu darbuotojams svarbiausia darbdavio stabilumas ir asmeninis augimas (Research*: *during the pandemics most important to employees is employer's stability and personal growth)*. Retrieved March 9, 2022, https://www.amston.lt/blog/darbuotoju-motyvacijos-tyrimas/. (in Lithuanian).

 DOI: 10.22616/rrd.28.2022.031

DEVELOPING TRANSPARENT ORGANIZATIONAL CULTURE IN A CASE OF LITHUANIAN COMPANIES

***Sonata Staniulienė**
Vytautas Magnus University, Lithuania
*Corresponding author's email: sonata.staniuliene@vdu.lt

Abstract
The study was conducted to find out whether the organizational culture of Lithuanian companies is sufficiently transparent and how to develop transparent organizational culture. The literature was examined on levels and components of transparent organizational cultures. Quantitative research was conducted to determine whether the instruments used by organizations to disclose transparency, clarity and accuracy was sufficient to develop a transparent organizational culture. According to the results of the study, most Lithuanian companies disclose their conduct through values and beliefs, although disclosure through artifacts was rated lower. Not enough of clarity was acknowledged, and it was better achieved through values and less through artifacts, but there was no basis for this at the level of assumptions. Finally, the highest means were found in the accuracy component of organizational transparency, although it could be better expressed at the level of artifacts, where the score was lower.
Key words: transparent organisational culture, organizational transparency, disclosure, clarity, accuracy.

Introduction

According to Wallis (2020), society expectations for transparency should not be diminished as the organizational environment becomes increasingly complex and people care about what they do not understand and, therefore, do not trust. It is also discussed explicitly how to reduce scepticism in organizations (Parris *et al*., 2014). In addition, stakeholders are gaining even more power as advances in communication technology make transparency a common expectation (Bennis *et al*., 2008). Worldwide, it is considered normal to have open access to the communication flow in organizations. Organizations may complain about too much of regulation and reporting requirements, although, as Götz & Marklund (2014) argued, over the past few decades, transparency, along with related terms such as openness and accountability, has become essential feature of modern organisation. This request for transparency is a global phenomenon. As Wallis (2020) states, in the past, transparency was mainly focused on financial accounting. As society evolves, we start to understand the profits of protecting employees, society and the nature. This has led to additional regulation, as well as related regulations requiring additional transparency.

Recently a number of studies examines the factors of organizational transparency (Pirson & Malhotra, 2011; Awad & Krishnan, 2006; Kaptein, 2008; Walumbwa *et al*., 2008). Many researchers analyse the content of organizational cultures as well (Schein, 2004; Bennis *et al.*, 2008), etc.), but there is still the lack of researchers' attention to the research of transparent organisational culture based on it's levels, components, or it's relevance. Due to the mentioned reasons, further research in Lithuanian organizations is needed to solve research problem how to develop transparent organizational culture in case of Lithuanian organizations.

Consequently, the object of the research is transparent organizational culture in case of Lithuanian companies. The aim of the research is to provide solutions how to develop organizational culture after examining the case of Lithuanian companies.

Research methods used in this paper are scientific literature review and quantitative method of survey.

Materials and Methods

Overview of common definitions of transparency are proposed in the setting of B2C relations (Granados, Gupta & Kauffman, 2010; Zhu, 2004), financial and accounting (Bushman *et al*., 2004; Winkler, 2000); product management (Howlett *et al.*, 2009), negotiation (Garcia, 2002), the relationship between the organization and stakeholders: internal (Kaptein, 2008) and external (Bushman *et al.*, 2004), as well as organizational culture development (Fombrun & Rindova, 2000; Kaptein, 2008; Pirson & Malhotra, 2011). Schnackenberg & Tomlinson (2016) offered definition of transparency, fitting wide area of analysis, as the perceived quality of intentionally shared information from a sender. There is a consensus that transparency can exist in a variety of research contexts and areas.

Bernstein (2012) points out that there are no negative effects of transparency and that it cannot be too much of transparency. Transparency works as a mechanism of control and is a factor of equality in society (Schnackenberg & Tomlinson, 2016). Imbedded in the organisational culture, it prevents bribery, corruption, and crime (Paik, Warner-Søderholm, & Huse, 2018). Transparency reduces stakeholder distrust (Misangyi *et al*., 2008), helps to manage reputation and saves from public scandals (Klara, 2010), performs decision making in more responsible (Awaysheh & Klasse+n, 2010) and more ethical way (Halter & de Arruda, 2009), employees are

less opportunistic (Bessire, 2005), more collaborative, committed (Jahansoozi, 2006), cooperative (Piske, 2002), and engaged (Vogelgesang & Lester, 2009).

According to Kordnaeij, Fani & Masoudi (2014) organizational transparency is the positive factor on the performance results, where organization's culture is an intermediate variable in this relation. Paik, Chow & Vance (2011) argues that cultural values and norms are the basis of transparency and anticorruption and are better performing than government regulations. It's agreed widely that performance results are positively affected by organizational transparency (Berggren & Bernshteyn, 2007; Bernstein, 2012). Stronger competitive advantages relate to organizational transparency in companies (Halter & de Arruda, 2009), as well as the ability to differentiate products to the consumers (Carter & Curry, 2010), to offer safer products to the market (Beulens *et al*., 2005), to develop a favourable brand image (Halter *et al*., 2009), to be more persuasive in marketing (Miao & Mattila, 2007), and to increase sales and profit margins (Parris *et al*., 2014). According to Bennis *et al.* (2008), devastating results are often got when an organizational culture is not transparent. Lack of transparency directly affects the organizational effectiveness (Smith *et al*., 2021).

The components of organisational transparency are examined by Bushman *et al*. (2004), Eijffinger & Geraats (2006), Zhu (2004), Walumbwa *et al.* (2011), Kaptein (2008), and many other scholars. Schnackenberg & Tomlinson (2016) framework seems to be based most of the assumptions conceptualizing transparency in three ways:

- Disclosure, which is understood as the open and timely sharing of information of interest to stakeholders (Williams, 2008). Perotti & von Thadden (2005) view is that stakeholders do not have the opportunity to know the details of a company's situation when information is not openly shared. Transparency can only be achieved by openly sharing information with stakeholders (Schnackenberg & Tomlinson, 2016).
- Clarity is understood as the level of comprehensibility of the information provided. Organizations must present information clear (Winkler, 2000) and understandable (Street & Meister, 2004) in order to consider it transparent. According Daft & Lengel (1986), a problem is not a sufficiency of information, but rather the clarity of it, especially when a huge amount of information is provided.
- Accuracy is defined as the level of correctness of the information. The information is not considered transparent if it is purposefully unfair or unfoundedly false (Walumbwa *et al*., 2011). Akhigbe & Martin (2006) also argue that accuracy is one of the elements of transparency.

Thus, if an organization considers transparency to be one of its most important organizational values, it can respond to the interests of its stakeholders, improve its relationship with the public, and at the same time improve its performance.

Schein (2004) identifies organizational culture as a key model of beliefs developed or discovered by a group of individuals who work together to survive in an environment, and integration problems in the organization.

Transparency from organizational culture perspective is defined as increasing the visibility of all elements of culture in the organization, when its employees can clearly observe their expression, results and adjust their behaviour accordingly (Kaptein, 2008). Then transparent organisational culture could be described as an institution where employees communicate to exchange ideas and thoughts, involving everyone in the business in making decisions and accepting responsibility for outcomes, building trust and pride. Kaplan (2018) highlights a culture of internal transparency, which is essential to create an environment in the company that is conducive to learning from examples and mistakes. According to Kaplan (2018), a culture of transparency must be shaped first and foremost by leaders who demand accountability, as well as encourage improvement, and leaders must set an example for all. Respect, transparency, and trust from leadership promote a healthy culture (Howard & Ulferts, 2017). The organizational culture that encourages humility as a foundation of competitive advantage institutionalizes values and norms of transparency (Maldonado, Vera, & Ramos, 2018).

Schein (2004) discloses levels in the organizational of culture, revealing the essence of organizational culture, which can be specified for development of transparent organizational culture after examining the components of organizational transparency:

1) Artifacts are perceived as contractual visible objects to outsiders: physical premises, organizational symbols, language, stories (myths, legends), actions (rites, rituals, ceremonies), heroes, body language. The evidence of organizational transparency can get form of artifacts as a code of conduct, the reports of social responsibility, the rituals of discussing interests of stakeholders or whistleblowing, etc.

2) Values are common for group members that indicate how things work must take place. From the analysis of the features of transparent organizational culture, we can see that it strongly follows values of openness, visibility, accountability, attention, justice, agreement, etc.

3) The basic assumptions are the beliefs and assumptions inherent in the subconscious of individuals, which go unnoticed, and which become an

integral part of their lives, difficult to explore because it is abstract. The basic assumptions of transparent organizational culture should be based on disclosure of what is moral in organizational-wide discussions, clarity of communication and actions, as well as accurate matching the facts with communication and following legal and ethical conduct, as it was disclosed as important for development of organizational transparency previously.

Propositions

After analysis of the instruments for development of organizational transparency and levels of organizational culture, raised on the discussion above, the subsequent research hypotheses were developed:

H1: Transparent organisational culture in companies in Lithuania is developed through disclosure.

It is based on the premise that disclosure of artifacts, values, and basic assumptions can lead to development of transparent organisational culture.

H2: Transparent organisational culture in companies in Lithuania is developed through clarity.

It is grounded by the premise that clarity of artifacts, values and basic assumptions can lead to development of transparent organisational culture.

H3: Transparent organisational culture in companies in Lithuania is developed through accuracy.

It is assumed that accuracy of artifacts, values and basic assumptions can lead to development of transparent organisational culture.

In order to find out whether a transparency in organisational culture of Lithuanian companies is developed through the instruments of disclosure, clarity and accuracy, quantitative research is carried out.

Methods

Quantitative research method was selected for data collection, which aims to acquire quantitative information about many research objects (in this case, employees of Lithuanian companies).

Instrument and Measure

The research questionnaire contains an introductory part, which defines who and for what purpose the research is carried out, emphasis on anonymity and nine main questionnaire question blocks: the first three are on disclosure of artifacts, values, and assumptions, following are intended to reveal clarity component of transparency, and the last are related to accuracy. This set of questions is based on the three-component model of transparency of Schnackenberg & Tomlinson (2016). Each component was analysed by the three-level model of organisational culture by Schein (2004). The set of questions from Cameron & Quinn (2006) proposed organizational Competing values framework was used as well in order to reveal specificity of different types of organisational culture when developing organizational transparency. Respondents were asked to rate the accuracy of the presented feature by choosing an answer on a Likert scale from 1 to 5, where '1' means 'strongly disagree' and '5' means 'strongly agree'), demographic questions are placed at the end of the questionnaire. Participants were sent an invitation e-mail with a link to fill the online questionnaire.

Participants

The research sample was calculated on the basis of Paniotto formula (Kardelis, 2002). The Department of Statistics of Lithuania provided data that there were 1,423.000 persons who were working in 2022. The selected sample error size is 7%. Calculations show that 196 respondents need to be questioned to ensure the representativeness and reliability of the survey. The survey involved 214 respondents working in various Lithuanian companies; therefore, it can be stated that the results of the survey are reliable.

50.2% of participants were up to 25 years of age, 22.2% – from 26 to 35, 6.7% – from 36 to 45, 11.1 % – from 46 to 55, and 4.4% – older than 56, respectively; 37.3% have university degree, 16.9% – college, 27.1% – secondary, 11.6% – vocational, and basic education; 40% worked in the same organization from 3 months to 1 year, 23.6% – from 1 to 3 years, 18.2% – from 3 to 10, 12.4% – more than 10 years, respectively; 32.8% worked as specialists, 19.7%, – workers, 17.2% – service staff, 12.2% – managers, 9.4% – executives, and 7% as sellers; 68.9% work in private company, 19.1% – in state-owned, and 6.2% – in NGO; 40.9% of companies were big, 17.3% – medium, 20.9% – small, and 15.1% – in micro companies; 46.2% were service companies, 19.6% – selling, 14.2% – production, and 20% – mixed.

Data Analysis

The obtained data were examined by the SPSS 21 software. Descriptive statistics, crosstabulation were used for data analysis.

According to the Kolmogorov-Smirnov test, the data is not normally distributed, as well, measured on a rank scale: therefore, Spearman correlation coefficient (when $p < 0.05$) was used for data analysis. The reliability of the questionnaire was screened using Cronbach's alpha coefficient, which 'relies on the correlation between the individual questions that make up the questionnaire and evaluates whether all scale questions adequately reflect the research size, enables to specify the number of questions required on the scale' (Pukėnas, 2009, p. 24). The Cronbach's alpha coefficient average is 0.845, which indicates a high level of internal consistency for the scale with the sample.

Results and Discussion

Depending on analysis of different elements of disclosure in organizational transparency, it can be

stated that for Lithuanian organisations it is important to act fairly, honestly, not to lie (mean – 4.03 from 5), the organization seeks the opinion of customers, buyers, consumers about its goods and services (4.04), employees clearly know moral norms in the organization (4.02), they discuss with colleagues what is right, moral in the activities of the organization, and what is not more often (3.93) than with managers (3.52). However, colleagues are still often silent when they see or hear about the unethical actions of others (2.94). The organizations could include various stakeholders more in a round table discussion (2.92).

Quite many employers conclude non-compete agreements with employees (3.86) and employees must sign a confidentiality agreement upon employment (3.78), that diminishes disclosure element in organizational transparency.

In favour of clarity in organizational transparency, in the organizational cultures lie principles to match words with actions (3.76), institutionalized rules at work that employees know (3.73), but there is still a lot of ignorance and doubt at work about how to deal with specific situations (2.83), and high risk is justified in the organizations (3.91).

The element of accuracy in organizational transparency is mostly assured via organizational ethical and moral leaders who lead by example (4.03). Managers show that unethical activities are not tolerated in the organization (4.00). Salaries are paid in an 'envelope' quite rearly (1.53), as well as bribes given to other institutions for advantage or benefit (1.62) and customers bribe employees for better services (1.69), bribes for promotion or recruitment are more common (2.25). Advertising of unethical, false products or services is quite a rear norm (1.69), a bit more distorted picture is provided for buyers, customers and consumers giving incorrect information about goods and services on labels, instructions, advice (1.81). While forged documents (e.g., financial statements) are quite rear practise (1.71), abuse of office by managers should be still on concern (1.99).

There is statistically significant correlation (Table 1) between words and actions in the organization and employee exploitation (0.594), there employees are required to maintain the secrets of the organization (-0.531), bribes are taken for promotion or hiring (0.506), and to maintain the organization's secrecy about illegal activities, and counterfeit documents (e.g., financial statements) (0.547). Falsification of documents correlates to compensation for work partly in an 'envelope' (0.568), bribes given to representatives of other institutions for the benefit or advantage (0.610), and unethical, false advertising of products or services (0.509). Links were found between abuse of office and bribes for promotion or hiring (0.542), to bribes to other institutions for convenience or benefit (0.524), or to employees for better services (0.507), forgery of documents (0.528), unfair dismissal (0.601), unethical, false advertising (0.552), tolerance of lack of quality in goods and services (0.504), exploitation of employees in the organization (0.643), and mismatches words with actions (0.531). Bribes to other institutions for advantage or benefit relate to bribes to employees for better services (0.697), as

Table 1

The statistically significant correlation among statements on organizational transparency and organizational culture in Lithuanian companies

Statements		Falsification of documents	Bribes to employees for better services	Bribes for promotion, recruitment	Moral leading by example	Required to maintain org. secrets	Abuse of office
Mismatches words with actions	Corr.Coeff.	0.531**	0.329**	0.506**	-0.594**	0.531**	0.531**
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Compensation partly in an 'envelope'	Corr.Coeff.	0.568**	0.333**	0.398**	-0.222**	0.474**	0.419**
	Sig.(2-tailed)	0.000	0.000	0.000	0.001	0.000	0.000
Bribes to other institutions for the benefit or advantage	Corr.Coeff.	0.610**	0.697**	0.504**	-0.160*	0.409**	0.524**
	Sig.(2-tailed)	0.000	0.000	0.000	0.019	0.000	0.000
Unethical, false advertising	Corr.Coeff.	0.552**	0.528**	0.440**	-0.277	0.408**	0.552**
	Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Tolerance of lack of quality in goods and services	Corr.Coeff.	0.504**	0.342**	0.429**	-0.386	0.418**	0.504**
	Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Exploitation of employees	Corr.Coeff.	0.643**	0.397**	0.353**	-0.496**	0.407**	0.634**
	Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000

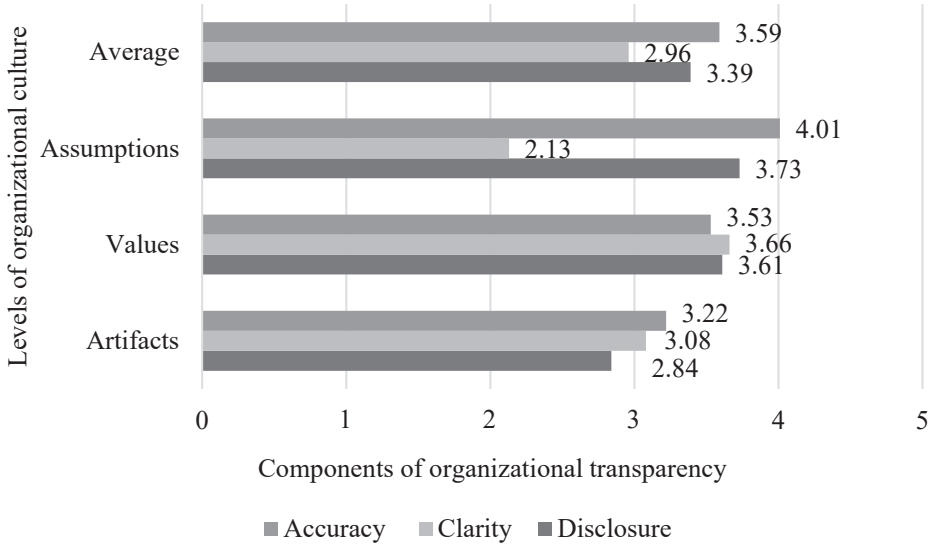

Figure 1. The expression of components of organizational transparency in different levels of organizational culture in Lithuanian companies.

well as to bribes for promotion or recruitment (0.504). Also, unethical, false advertisements of products and services correlate to the tolerance of lack of quality in goods and services (0.596), the harm of organization's performance to the local community (0.543), buyers, customers and consumers are given then incorrect information about goods and services on labels, instructions, advice (0.545) and services (0.528).

Otherwise, there is a strong positive statistical correlation between the presence of the leaders of the organization as ethical leaders and moral example and the importance of acting fairly, honestly and not lying in the organization (0.582), coincidence of words in the organization (0.637), and more respect for the principle of equality (0.608), as well as, if there is an opportunity in the organization to discuss with managers in the team what is right, moral, and what is not (0.590). Having an organization's code of ethics can be associated with having an ethics council or committee or specialist responsible for ethics (0.528), the organization's efforts to protect personal data by investing in IT (0.603) and announcing social responsibility reports (0.537). Reporting of social responsibility of organizations can be related to the social activities organization for the society (0.531), communication of social responsibility to the society (0.563), being actually socially responsible, what is confirmed by actions (0.599), and having an ethics council, committee or at least specialist in the organization (0.557). If organization invites the social partners to discuss performance improvement, such an organization is more likely to respect the interests of all stakeholders and seek to satisfy them (0.512).

According to the study, different types of organizational cultures are prone to different transparency issues. Although the correlation is quite weak, most links are observed with the market type of organizational culture, where employees are more likely to be required to maintain the organization's secrecy about illegal activities (0.348), false documents (0.318), abuse of official position (0.356), to recruit employees incorrectly (0.369) and unfairly dismiss employees (0.347), where unethical or false advertisements for the organization's products / services are allowed (0.322), it is not important to act fairly and honestly (-0.432), the organization doesn't observes the principle of equality (-0.332), it is normal for an organization to behave in a way that is useful in the case of frequent changes of positions (0.364), words doesn't coincide with actions (-0.456), and the leaders of an organization are not ethical leaders and moral role models (-0.447).

Having in mind that market type is the most spread in Lithuanian organizations (Staniuliene & Gavenaite, 2021), it only strengthens the understanding of necessity to form transparent and ethical cultures in the country.

Hierarchy culture correlates only with publishing social responsibility reports (0.351). While adhocracy culture can be linked to observation the principle of equality (0.331), words coincidence with actions 0.389, ethical and moral leadership (0.310), but also to high risk taken in this type organizations (0.302).

Clan type organizational culture refers to importance to act fairly and honestly in an organization, not to lie (0.360) and ability to discuss with managers what is right, moral, and what is not (0.590), in line with the principle of equality (0.406), because here the leaders of an organization are ethical and moral examples (0.477), there words more coincide with

actions (0.358), and employees clearly know moral norms that are observed in the organization (0.397).

Based on the study results, H1: 'Transparent organisational culture in companies in Lithuania is developed through disclosure' is partly confirmed. Most of the companies in Lithuania disclose their conduct through values and beliefs, although the institutionalisation of disclose through artifacts is assessed in lower scores.

H2: 'Transparent organisational culture in companies in Lithuania is developed through clarity' is rejected because not enough of clarity was acknowledged, and clarity is achieved better through values, less – through artifacts, but there is no background in the level of assumptions available for that. It can be a signal that there are more believers in uncertainty of environment than in clarity, nevertheless clarity is valued in organizations and expressed through artifacts as it's possible.

Finally, H3: 'Transparent organisational culture in companies in Lithuania is developed through accuracy' is also confirmed. The highest means were found in accuracy component of organisational transparency, although it can be better expressed in artifacts level, where the score is lower.

Conclusions

After the analysis of the scientific literature, it was determined that the interdisciplinary and multidimensional theoretical construct of transparency can be applied to the analysis and development of transparency in the organizational culture in companies. Various dimensions of transparency are used in research, and they mostly can be attributed to components of disclosure, clarity, and accuracy, which can be institutionalized at different levels of organizational culture: artifacts, values, and basic assumptions.

Quantitative research revealed that the organizational culture in Lithuanian companies is sufficiently transparent in most of the cases. According to the results of the study, most Lithuanian companies disclose their transparency through values and beliefs although disclosure through artifacts was rated worse. The sufficiently noticeable dimension of clarity was not found and was better achieved through values and less through artifacts, but there is a lack of basis for this at the level of assumptions. Finally, the accuracy component of organizational culture transparency is best developed in Lithuanian companies although it may be better expressed at the level of artifacts, where the expression is found to be lower.

For further studies in other companies, the components of transparency, clarity and accuracy can be applied to evaluate transparency dimensions and develop a transparent organizational culture, embedded at different levels of organizational cultures. The analysis of the links between the research questions lead to the understanding that the leadership plays a very important role in creating a transparent organizational culture, more transparent in more adaptive clan and adhocracy types of culture, with high level of respect to the interests of external and internal company's stakeholders.

References

Akhigbe, A., & Martin, A.D. (2006). Valuation impacts of Sarbanes-Oxley: Evidence from disclosure and governance within the financial services industry. *Journal of Banking & Finance*, 30, 989–1006.

Awaysheh, A., & Klassen, R.D. (2010). The impact of supply chain structure on the use of supplier socially responsible practices. *International Journal of Operations and Production Management*, Vol. 30, No. 12, 1246–1268.

Bennis, W., Goleman, D., & O'Toole, J. (2008). *Transparency: How leaders create a culture of candor*. San Francisco, CA: Jossey-Bass.

Berggren, E., & Bernshteyn, R. (2007). Organizational transparency drives company performance. *Journal of Management Development*, 26, 411–417.

Bernstein, E.S. (2012). The transparency paradox: A role for privacy in organizational learning and operational control. *Administrative Science Quarterly*, 57, 181–216.

Bessire, D. (2005). Transparency: a two-way mirror? *International Journal of Social Economics*, 32 (5), 424–438.

Beulens, A.J., Broens, D.F., Folstar, P., & Hofstede, G.J. (2005). Food safety and transparency in food chains and networks: relationships and challenges. *Food Control*, 16 (6), 481–486.

Bushman, R., Chen, Q., Engel, E., & Smith, A. (2004). Financial Accounting Information, Organizational Complexity and Corporate Governance Systems. *Journal of Accounting and Economics*, 37, 167–201. DOI: 10.1016/j.jacceco.2003.09.005.

Cameron, K.S., & Quinn, R.E. (2006). *Diagnosing and Changing Organisational Culture Based on Competing Values Framework*. San Francisco: Josey Bass.

Carter, R.E., & Curry, D.J. (2010). Transparent pricing: theory, tests, and implications for marketing practice. *Journal of the Academy of Marketing Science*, 38 (6), 759–774.

Daft, R.L., & Lengel, R.H. (1986). A proposed integration among organizational information requirements, media richness, and structural design. *Management Science*, 32, 191–233.

Eijffinger, S., & Geraats, P. (2006). How transparent are central banks? *European Journal of Political Economy*, 1, 1–21.

Fombrun, C., & Rindova, V. (2000). The road to transparency: Reputation management at Royal Dutch/Shell. In M. Schultz, M.J. Hatch, & M.H. Larsen (Eds.), *The expressive organization: Linking identity, reputation and the corporate brand,* 77–97. Oxford, UK: Oxford University Press.

Garcia, S.M. (2002). Power and the illusion of transparency in negotiations. *Journal of Business and Psychology*, 17, 133–144.

Granados, N., Gupta, A., & Kauffman, R.J. (2010). Information transparency in business-to-consumer markets: Concepts, framework, and research agenda. *Information Systems Research*, 21, 207–226.

Halter, M.V., & de Arruda, M.C.C. (2009). Inverting the pyramid of values? Trends in less developed countries. *Journal of Business Ethics*, 90 (3), 267–275.

Halter, M.V., de Arruda, M.C.C., & Halter, R.B. (2009). Transparency to reduce corruption? *Journal of Business Ethics*, 84 (3), 373–385.

Howlett, E.A., Burton, S., Bates, K., & Huggins, K. (2009). Coming to a restaurant near you? Potential consumer responses to nutrition information disclosure on menus. *Journal of Consumer Research*, 36, 494–503.

Kaplan, G.S. (2018). Building a Culture of Transparency in Health Care. *Harvard Business Review Digital Articles*, 11 (9), 1–5.

Kaptein, M. (2008). Developing and testing a measure for the ethical culture of organizations: The corporate ethical virtues model. *Journal of Organizational Behavior*, 29, 923–947.

Kardelis, K. (2002). *Mokslinių tyrimų metodologija ir* metodai *(Methodology and methods of scientific research)*. Kaunas: Judex. (in Lithuanian).

Klara, R. (2010). When the oil spill is this big, it pays not to be crude. *Brandweek*,. 51, 1.

Kordnaeij, A., Fani, A.A., & Masoudi, Z. (2014). Organizational Culture of the Missing Link between Organizational Transparency and Organizational Performance. *Organizational Culture Management Summer,* 12(2),173–89.

Maldonado, T., Dusya, V., & Ramos, N. (2018). How humble is your company culture? And, why does it matter? *Business Horizons*, 61 (5), 745–753. DOI: 10.1016/j.bushor.2018.05.005.

Miao, L., & Mattila, A.S. (2007). How and how much to reveal? The effects of price transparency on consumers' price perceptions. *Journal of Hospitality and Tourism Research*, 31 (4), 530–545.

Misangyi, V.F., Weaver, G.R., & Elms, H. (2008). Ending corruption: the interplay among institutional logics, resources, and institutional entrepreneur. *Academy of Management Review*, 33 (3), 750–770.

Norbert Götz, & Carl Marklund. (2014). The Paradox of Openness: Transparency and Participation in Nordic Cultures of Consensus. APA 7th Edition (American Psychological Assoc.).

Paik, Y., Warner-Søderholm, G., & Huse, M. (2018). In search of an institutional framework for anticorruption: Lessons from Scandinavia Thunderbird. *International Business Review*, 61(4). DOI: 10.1002/tie.22028.

Paik, Y., Chow, I., & Vance, C. (2011). Interaction effects of globalization and institutional forces on international HRM practice: Illuminating the convergence–divergence debate. Thunderbird International Business Review, 53(5), 647–659. DOI: 10.1002/tie.20440.

Parris, D.L., Dapko, J.L., Arnold, R.W., & Arnold, D. (2016). Exploring transparency: a new framework for responsible business management. *Management Decision, 5*4 (1), 222–247. DOI: 10.1108/MD-07-2015-0279.

Perotti, E.C., & von Thadden, E. (2005). Dominant investors and strategic transparency. *Journal of Law, Economics, & Organization*, 21, 76–102.

Pirson, M., & Malhotra, D. (2011). Foundations of organizational trust: What matters to different stakeholders*? Organization Science,* 22, 1087–1104.

Piske, R. (2002). German acquisitions in Poland: an empirical study on integration management and integration success. *Human Resource Development International*, 5(3), 295–312.

Schein, E.H. (2004). *Organizational culture and leadership*, 3rd ed. San Francisco: JosseyBass.

Schnackenberg, A.K., & Tomlinson, E.C. (2016). Organizational transparency: A new perspective on managing trust in organization-stakeholder relationships. Journal of Management, 42(7), 1784–1810. DOI: 10.1177/0149206314525202.

Smith, A.B., Dwyer, B., Gellock, J., & Graham, J.A. (2021). NCAA Coaches and Academic Professionals Perceptions of Importance, Commitment, and Effectiveness of Organizational Culture and Student-Athlete Experience. *Journal of Issues in Intercollegiate Athletics*, 14, 740–770 740 © 2021.

Staniulienė, S., & Gavėnaitė, E. (2021). Employee Commitment in Relationship to Organizational Culture: The Case of Lithuanian Companies. In: Bilgin M.H., Danis H., Demir E., García-Gómez C.D. (eds), *Eurasian Business and Economics Perspectives. Eurasian Studies in Business and Economics*, 19. Springer, Cham. DOI: 10.1007/978-3-030-77438-7_3.

Street, C.T., & Meister, D.B. (2004). Small business growth and internal transparency: The role of information systems. *MIS Quarterly*, 28, 473–506.

Vogelgesang, G.R., & Lester, P.B. (2009). Transparency: how leaders can get results by laying it on the line. *Organizational Dynamics*, 38(4), 252–260.

Wallis, S.E. (2020). Exceeding the limits: Commentary on 'The limits of transparency'. *Systems Research & Behavioral Science*, 37(1), 170–173. DOI: 10.1002/sres.2653.

Walumbwa, F.O., Luthans, F., Avey, J.B., & Oke, A. (2011). Authentically leading groups: The mediating role of collective psychological capital and trust. *Journal of Organization Behavior*, 32, 4–24.

Williams, C.C. (2008). Toward a taxonomy of corporate reporting strategies. *Journal of Business Communication,* 45(3), 232–264.

Winkler, B. (2000). Which kind of transparency? On the need for clarity in monetary policy-making. *Working paper,* 26. European Central Bank, Frankfurt, Germany.

Zhu, K. (2004). Information transparency of business-to-business electronic markets: A game-theoretic analysis. *Management Science*, 50, 670–685.

 DOI: 10.22616/rrd.28.2022.032

IMPORTANCE OF INNOVATIONS FOR ENTREPRENEURSHIP DEVELOPMENT – VIEWS OF ENTREPRENEURS IN KURZEME REGION

***Dace Stefenberga[1], Biruta Sloka[2], Baiba Rivza[3]**
[1]Ventspils University of Applied Sciences, Latvia
[2]University of Latvia, Latvia
[3]Latvia University of Life Sciences and Technology, Latvia
*Corresponding author's email: Dace.Stefenberga@venta.lv

Abstract
Innovation is one of the most influential aspects for entrepreneurship development. Therefore, also academic researchers pay a lot of attention on different aspects related to innovations. Current research paper is devoted to evaluation of the views of entrepreneurs related to innovation practical applications and problems of introduction of innovations. Aim: evaluate the views of entrepreneurs related to innovation practical applications and problems of introduction of innovations. Research methods applied: previous conducted scientific research results analysis, analysis of statistical data, survey of entrepreneurs. Survey data are analysed by most used characteristics of descriptive statistics: indicators of central tendency or location (arithmetic mean, mode, median) and by indicators of variability or dispersion using standard deviation, standard error of mean and range. Most important results by views of entrepreneurs are: innovations support increase of expert and increase of share in realisation of products or services.
Key words: innovations, entrepreneurship, region, survey.

Introduction

Innovation is one of the most influential aspects for entrepreneurship development. Therefore, also academic researchers pay a lot of attention on different aspects related to innovations. Current research paper is devoted to evaluation of the views of entrepreneurs related to innovation practical applications and problems of introduction of innovations. Aim: evaluate the views of entrepreneurs related to innovation practical applications and problems of introduction of innovations. Tasks: 1) analyse previously conducted scientific research results; 2) analysis of statistical data on innovations development in Latvia; 3) analysis of good experience of Estonia and Lithuania for increase of innovations; 3) analysis of views of entrepreneurs on innovation for their entrepreneurship. Research methods applied: previously conducted scientific research results analysis, analysis of statistical data, survey of entrepreneurs. Survey data are analysed by indicators of descriptive statistics: indicators of central tendency or location (arithmetic mean, mode, median), by most often used indicators of variability or dispersion (range, standard deviation, standard error of mean).

Theoretical Findings

Academic researchers have investigated in detail many important aspects of role of innovations in entrepreneurship, on innovation affecting growth of starting entrepreneurs where the researchers have indicated that culture and economic freedom has influence (Saeedikiya, Ashourizadeh, & Temiz, 2022) where many innovative aspects are evaluated. Researchers have pointed out on aspects on linking non-financial motivators of women entrepreneurs with entrepreneurial satisfaction with use of multivariate analysis including cluster analysis (Yadav & Kumar, 2022) where practical usable conclusions are suggested. Researchers have analyzed entrepreneurs' dreams that entrepreneurial ecosystems can promote sustainability (Raposo, Fernandes, & Veiga, 2022). Inspiring the entrepreneurial university in realisation of two experiments and with the development of proposal for aspects of innovation in higher education (Etzkowitz, Dzisah, & Clouser, 2022). Aanalysis of critique of innovation districts are covered for analysis of entrepreneurial living and the burden of shouldering urban development (Kayanan, 2022) where researcher has devoted special and deep attention on innovations for entrepreneurship development. Researchers have innovative approaches – like orchestrating entrepreneurial ecosystems in circular economy: the new paradigm of sustainable competitiveness (Castro Oliveira *et al*., 2022). Researchers have performed detailed analysis on emerging needs of social innovators and social innovation ecosystems (Audretsch, Eichler, & Schwarz, 2022) with conclusions that social innovations are becoming more and more important in different fields of entrepreneurship. Researchers have performed modelling (social) for intra entrepreneurship (Carvalho, 2022) for more detailed analysis of innovation for entrepreneurship. Aspects on relying on the engagement of others with detailed review of the governance choices facing social media platform start-ups (Reuber & Fischer, 2022; Fayolle & Gailly, 2008). Data management efficiency is on deep attention with major opportunities for shared value innovation (Lichtenthaler, 2022). Cooperation and innovation are considered as key success factors for development in regions (Štefenberga, 2019). Researchers have analysed the impact of bankruptcy regimes on entrepreneurship and innovation and were

looking is there any relationship (Prusak *et al*., 2022) analysed product and service innovation in Portugal where are indicating several patterns and specificities (Costa, Rocha, & Madeira, 2022) and have paid attention on listening to the buzz and exploring the link between firm creation and regional innovative atmosphere as reflected by social media (Corradini, Folmer, & Rebmann, 2022). Endogenous development of green finance and cultivation mechanism of green bankers are investigated in big detalisation degree (Zhang *et al*., 2022). Factors of the effectiveness of innovative development of Baltic states in the context of digitalization are on special attention by academic researchers (Vasilevska & Rivza, 2020). The role of innovation in sustainable regional development is analysed (Štefenberga & Sloka, 2019). Researchers are analyzing how the creative mindset affects entrepreneurial success in the tourism sector considering the mediating role of innovation capability (Yodchai, Ly, & Tran, 2022). Regional development issues and consequences of Covid 19 pandemic as experience and recently developed ability and innovative approaches for remote work (Štefenberga, Rivža, & Sloka, 2021) which could be used also after pandemia. Digitalization in the Baltic States is of special attention for politicians and researchers (Rivza & Rivza, 2020) as the reasonable political decisions could be developed based on research result conclusions and suggestions. For successful work organization, it is important to respect also ergonomic aspects (Kalkis, Andza, & Roja, 2020; Kalkis, Graveris, & Roja, 2021). Marketing aspects in innovations in entrepreneurship are becoming more and more important (Batraga *et al*., 2019) as well as financing aspects (Romanova *et al*., 2018). Municipalities have special role for innovations in entrepreneurship (Savrina & Seimuskane, 2018; Seimuskane, Vilka, & Brekis, 2017). Development of products and services in small enterprises with found proposition of an artifact to discuss creative logics is on research agenda (De Sordi *et al*., 2022). Researchers have considered that there is the impact of information technology culture and personal innovativeness in information technology on digital entrepreneurship success (Abubakre, Zhou, & Zhou, 2022; Hatt, 2018). Different countries have different approaches and findings for small and medium enterprises in Mexico and the craft beer sector in Baja California where among the most important factors are dynamic capabilities, culture and innovation (Alvarado, 2022; Gabrielsson *et al.*, 2020), importance of education for innovations (Flynn, 2018). and other important aspects for innovations in entrepreneurship, like national innovations systems (Alnafrah & Mouselli, 2020), role of creative economy for sustainable economic development (Štreimikienė & Kačerauskas, 2020) where more and more importance has e – commerce development (Vasiļevska & Sproģe, 2020) in all those aspects innovations are considered of great importance for entrepreneurship.

Materials and Methods

For empirical research methods applied in this paper based on analysis of research results which were based on previously conducted scientific research, analysis of different official statistical data, conducted survey of entrepreneurs was performed. For many aspects related to innovations in entrepreneurship in the empirical research in survey by entrepreneurs, several questions to be evaluated in scale 1-10 were asked. Obtained survey of entrepreneurs data are analysed with indicators of descriptive statistics – among them statistical indicators of central tendency or location (arithmetic mean of the evaluations by entrepreneurs, mode as most often chosen evaluation by entrepreneurs, median as indication distribution of evaluations by entrepreneurs) were used most often, as well as with indicators of variability or dispersion of the evaluations by entrepreneurs (range – indicating difference between higher and lower evaluations by entrepreneurs, indicators of variability – standard deviation and standard error of mean) were used most often.

In Latvia, more and more attention is paid to research and development and innovations statistics as it was also analysed and stressed in the meeting of Statistics Board of Latvia on March 17, 2022 (Central Statistics Bureau, 2022) where some suggestions how to improve those aspects taking into account experience of other countries were analysed and developed. In Estonia, Ministry of Economics Communication of Estonia sends a letter to entrepreneurs inviting to allocate at least 2% from turnout of the company while in Lithuania, there are tax reductions in case of innovations (Central Statistics Bureau, 2022) to increase innovations in companies as well as to reflect more precise information on those aspects. Innovations for entrepreneurship are among very important aspects which are analyzed in Europe with the help of the same methodology where the data source used by statistical authorities to acquire the data is a survey on innovations in enterprises which is based on Community Innovation Survey questionnaire reflecting two innovations (Official Statistics portal, 2022). To design a sample frame, all statistical units which are precise in correspondence with the description of the target population are included. To prepare a sample frame, the information of Statistical Business Register of Republic of Latvia was used. The sample size was set by the Central Statistical Bureau specialists by using Neyman's optimal allocation. It is very important to mention that the sample was

Table 1

Number of respondents in the Community Innovation Survey in Latvia in 2006-2018

Year	Sample size
2016-2018	3103
2014-2016	3103
2012-2014	1501
2010-2012	1573
2008-2010	1358

Source: Official Statistics database.

built based on the method of stratified simple random sampling (Official Statistics portal, 2022), sample sizes in analyzed years (2006-2018) are included in Table 1.

Community Innovation Survey in Latvia is realised based fully on Eurostat methodology and data are collected strictly respecting random sampling requirements to get representative data. Information on respondents included in the business sector sample is extrapolated by using weight for each sample unit by specialists of Central statistical Bureau. Estimation calculations of data are based on the Horvitz-Thompson estimator (Official Statistics portal, 2022). That makes confidence that data are representative and could be used for research and for decision making.

Results and Discussion

In recent years data on number of innovative enterprises and share of innovative enterprises in Republic of Latvia are growing and data are included in Table 2.

Data indicate that innovation-active enterprises share in Republic of Latvia during the last decade is increasing in all fields (total, industry, manufacturing and services) with bigger increase of innovation-active enterprises share in manufacturing. To investigate views of entrepreneurs about several aspects of innovations, the survey of entrepreneurs was conducted, and several questions related to importance of innovations in their production on development of products and services were asked. The data were obtained by personal interviews of entrepreneurs, each of them was approached personally and agreed on time to be interviewed. To obtain data in the survey, main indicators of descriptive statistics were used; results of analysis are reflected in Table 3 and 4.

Survey results of entrepreneurs indicate that entrepreneurs have shown that the most important aspect among the analysed was that innovations have supported increased offer of products or services with the high evaluations – there was the biggest average of evaluations (7.07) with evaluations 7 and 9 (indicated by mode) given most often, half of entrepreneurs in Kurzeme region evaluated this aspect with evaluation 7 or less, and half of entrepreneurs in Kurzeme region have evaluated with 7 or more (characterised by median), there was the lowest variability of entrepreneurs evaluations which is indicated by indicators of dispersion: standard deviation and standard error of mean.

Views of entrepreneurs are very different as almost for all evaluated aspects cover full evaluation scale which is used by entrepreneurs for evaluations except for the statement that productivity has increased – the lowest evaluation was 2 there. The most important aspect was indicated that productivity has increased – arithmetic mean of the evaluations was 6.9 with mode 8 and median 7. Less important aspects by entrepreneurs there were considered the organization of production

Table 2

Innovation-active enterprises in Latvia in 2008-2018

Kind of activity	Number of innovation-active enterprises						Share of innovation-active enterprises (in %)					
	2008	2010	2012	2014	2016	2018	2008	2010	2012	2014	2016	2018
TOTAL	1408	1234		1276	1453	1558	24,3	29,9	30,4	25,5	30,3	32,9
Industry	707	364	619	622	678	761	26.9	19.2	29.3	28.2	32.6	37.7
Manufacturing	658	323	549	559	609	690	28.1	19.6	29.6	28.9	33.7	39.4
Services	460	328	822	654	775	797	14.5	14.6	31.4	23.4	28.5	29.3

Source: Authors construction based on Official Statistics database.

Table 3

Main characteristics of most used descriptive statistics on Kurzeme region entrepreneurs' assessments of the impact of innovations on the aspects of the company's operations

Statistical indicators		Opened new market or increased market share	Increased offer of products or services	The quality of products / services has improved	Productivity increased
N	Valid	30	30	31	31
	Missing	7	7	6	6
Arithmetic mean		6.10	7.07	6.97	6.90
Standard error of arithmetic mean		0.435	0.389	0.419	0.392
Median		6.5	7	7	7
Mode		9	7 and 9	9	8
Standard deviation		2.383	2.132	2.331	2.181
Range		8	8	9	8
Minimum		1	2	1	2
Maximum		9	10	10	10

Source: Authors calculation based on Dace Štefenberga conducted survey of entrepreneurs, evaluation scale 1-10, where 1 – no influence; 10 – significant influence.

work improved where full scale of evaluations was used by entrepreneurs – in the evaluations for this aspect there was the biggest variability of views by entrepreneurs – standard deviation and standard error of mean were the biggest, the most often chosen evaluation was 9 (mode), half of entrepreneurs gave evaluation 7 or less and half of entrepreneurs gave evaluation 7 or more (characterized by median). The lowest evaluations were given to the aspect that Consumption of materials and / or energy per unit of output decreased where the arithmetic mean of the evaluations was only 4.7 although all evaluation scale was used by the respondents but the most often chosen evaluation was 2 (mode) and half of respondents gave evaluations 4 or less and half of respondents gave 5 or more (median was 4.5). Entrepreneurs have indicated that all analyzed aspects related to innovations were important to them even if the views of several entrepreneurs were quite different. Survey data analysis has confirmed many aspects of innovations having importance for development of products and services also in Kurzeme region in Latvia.

Table 4

Main characteristics of most used descriptive statistics on Kurzeme region entrepreneurs' assessments of the impact of innovations on the aspects of the company's operations

Statistical indicators		Productivity increased	The organization of production work improved	Consumption of materials and / or energy per unit of output decreased
N	Valid	31	31	30
	Missing	6	6	7
Arithmetic mean		6.90	6.26	4.70
Standard error of arithmetic mean		0.392	0.499	0.477
Median		7	7	4.5
Mode		8	9	2
Standard deviation		2.181	2.781	2.615
Range		8	9	9
Minimum		2	1	1
Maximum		10	10	10

Source: Authors calculation based on Dace Štefenberga conducted survey of entrepreneurs, evaluation scale 1-10, where 1 – no influence; 10 – significant influence.

Conclusions

1. Latvia can take into account good experience in motivation of companies for innovations from other countries and especially from neighboring countries – Estonia and Lithuania.
2. Innovation-active enterprises share in Republic of Latvia during the last decade was increasing in all fields (total, industry, manufacturing and services) with bigger increase in manufacturing.
3. Entrepreneurs in Latvia consider that innovations have increased the offer of products or services, the quality of products / services has improved, productivity has increased and the organization of production work has improved; influence of innovations on aspects of new market opening or increase of market share in respective markets as well as aspect on consumption of materials and / or energy per unit of output has decreased and were considered less important.
4. Entrepreneurs in Latvia can take more in their consideration findings and suggestions by entrepreneurs of other countries especially in other Baltic countries in increase of role of innovations in their companies operation in creation of products or services.

Acknowledgement

This research is supported by the National Research Programme 'LATVIAN HERITAGE AND FUTURE CHALLENGES FOR THE SUSTAINABILITY OF THE STATE' project 'CHALLENGES FOR THE LATVIAN STATE AND SOCIETY AND THE SOLUTIONS IN INTERNATIONAL CONTEXT' INTERFRAME-LV', No. VPP-IZM-2018/1-0005.

References

Abubakre, M., Zhou, Y., & Zhou, Z. (2022). The impact of information technology culture and personal innovativeness in information technology on digital entrepreneurship success. *Information Technology and People,* 35(1), 204–231. DOI: 10.1108/ITP-01-2020-0002.

Alnafrah, I., & Mouselli, S. (2020). The Role of National Innovation Systems in Entrepreneurship Activities at Baltic State Countries. *Journal of the Knowledge Economy*, 11(1), 84–102. DOI: 10.1007/s13132-018-0537-x.

Alvarado, A.A. (2022). Small and Medium Enterprises in Mexico and the Craft Beer Sector in Baja California: Dynamic Capabilities, Culture, and Innovation. *Journal of Evolutionary Studies in Business*, 7(1), 166–203. DOI: 10.1344/jesb2022.1.j102.

Audretsch, D.B., Eichler, G.M., & Schwarz, E.J. (2022). Emerging needs of social innovators and social innovation ecosystems. *International Entrepreneurship and Management Journal*, 18(1), 217–254. DOI: 10.1007/s11365-021-00789-9.

Batraga, A., Salkovska, J., Braslina, L., Legzdina, A., & Kalkis, H. (2019). New innovation identification approach development matrix. *Advances in Intelligent Systems and Computing*, 783, 261–273. DOI: 10.1007/978-3-319-94709-9_26.

Carvalho, J.M.S. (2022). Modelling (Social) Intra/Entrepreneurship Process. *Emerging Science Journal*, 6(1), 14–36. DOI: 10.28991/ESJ-2022-06-01-02.

Castro Oliveira, J., Lopes, J.M., Farinha, L., Silva, S., & Luízio, M. (2022). Orchestrating entrepreneurial ecosystems in circular economy: the new paradigm of sustainable competitiveness. *Management of Environmental Quality: An International Journal*, 33(1), 103–123. DOI: 10.1108/MEQ-11-2020-0271.

Central Statistics Bureau of Republic of Latvia. (2022). Research & Development and Innovations Statistics in Latvia (in Latvian), presentation in meeting of Statistics Board of Latvia on March 17, 2022. Retrieved March 30, 2022, from https://www.csp.gov.lv/lv/media/4170/.

Corradini, C., Folmer, E., & Rebmann, A. (2022). Listening to the buzz: Exploring the link between firm creation and regional innovative atmosphere as reflected by social media. *Environment and Planning A*, 54(2), 347–369. DOI: 10.1177/0308518X211056653.

Costa, V.O., Rocha, R.R., & Madeira, M.J. (2022). Product and service innovation in Portugal: patterns and specificities. *International Journal of Innovation Science*. 14(1), 21–39. DOI: 10.1108/IJIS-09-2020-0140.

De Sordi, J.O., Nelson, R.E., Meireles, M., & Hashimoto, M. (2022). Development of products and services in small enterprises: proposition of an artifact to discuss creative logics. *Journal of Small Business and Enterprise Development*, 29(1), 18–46. DOI: 10.1108/JSBED-09-2020-0327.

Etzkowitz, H., Dzisah, J., & Clouser, M. (2022). Shaping the entrepreneurial university: Two experiments and a proposal for innovation in higher education. *Industry and Higher Education*, 36(1), 3–12. DOI: 10.1177/0950422221993421.

Fayolle, A., & Gailly, B. (2008). From craft to science: Teaching models and learning processes in entrepreneurship education. *Journal of European Industrial Training*, 32(7), 569–593. DOI: 10.1108/03090590810899838.

Flynn, P. (2018). DIVE-IN: Problem first team formation in entrepreneurship education. Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE 2018-September, pp. 253–259.

Gabrielsson, J., Hägg, G., Landström, H., & Politis, D. (2020). Connecting the past with the present: the development of research on pedagogy in entrepreneurial education. *Education + Training*, 62(9), 1061–1086. DOI: 10.1108/ET-11-2019-0265.

Hatt, L. (2018). Threshold concepts in entrepreneurship – the entrepreneurs' perspective. *Education + Training*, 60(2), 155–167. DOI: 10.1108/ET-08-2017-0119.

Kalkis, H., Andza, K., & Roja, Z. (2020). Physical Load and Preventive Measures in Metal Manufacturing Industry. *Advances in Intelligent Systems and Computing*, 1215, 48–55. DOI: 10.1007/978-3-030-51549-2_7.

Kalkis, H., Graveris, I., & Roja, Z. (2021). Ergonomic Indicators and Physical Workload Risks in Food Production and Possibilities for Risk Prevention. *Lecture Notes in Networks and Systems*, 273, 47–53. DOI: 10.1007/978-3-030-80713-9_7.

Kayanan, C.M. (2022). A critique of innovation districts: Entrepreneurial living and the burden of shouldering urban development. *Environment and Planning A*, 54(1), 50–66. DOI: 10.1177/0308518X211049445.

Lichtenthaler, U. (2022). Data management efficiency: major opportunities for shared value innovation. *Management Research Review*, 45(2), 156–172. DOI: 10.1108/MRR-10-2020-0639.

Official Statistics database of Republic of Latvia. (2022). Retrieved March 6, 2022, from https://stat.gov.lv/en/metadata/2875-innovations-enterprises#stat_process.

Prusak, B., Morawska, S., Łukowski, M., & Banasik, P. (2022). The impact of bankruptcy regimes on entrepreneurship and innovation. Is there any relationship? International Entrepreneurship and Management Journal, 18(1), 473–498. DOI: 10.1007/s11365-021-00773-3.

Raposo, M., Fernandes, C.I., & Veiga, P.M. (2022). We dreamed a dream that entrepreneurial ecosystems can promote sustainability. *Management of Environmental Quality: An International Journal*, 33(1), 86–102. DOI: 10.1108/MEQ-01-2021-0010.

Reuber, A.R., & Fischer, E. (2022). Relying on the engagement of others: A review of the governance choices facing social media platform start-ups. *International Small Business Journal: Researching Entrepreneurship*, 40(1), 3–22. DOI: 10.1177/02662426211050509.

Rivza, B., & Rivza, P. (2020). Digitalization in the Baltic States. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2020, 2020-August (2.1), pp. 135–144. DOI: 10.5593/sgem2020/2.1/s07.018.

Romanova, I., Grima, S., Spiteri, J., & Kudinska, M. (2018). The payment services Directive II and competitiveness: The perspective of European fintech companies. *European Research Studies Journal*, 21(2), 3–22. DOI: 10.35808/ersj/981.

Saeedikiya, M., Li, J., Ashourizadeh, S., & Temiz, S. (2022). Innovation affecting growth aspirations of early stage entrepreneurs: culture and economic freedom matter. *Journal of Entrepreneurship in Emerging Economies*, 14(1), 45–64. DOI: 10.1108/JEEE-05-2020-0145.

Savrina, B., & Seimuskane, L. (2018). Income and Quality of Life Influence on Citizens' Participations in Activities of Local Governments in Latvia. CBU International Conference Proceedings 2018: Innovations in Science and Education, 6, 424–432. DOI: 10.12955/cbup.v6.1193.

Seimuskane, L, Vilka, I., & Brekis, E. (2017). Assessment of Socio-Economic Status Relevance for Latvian Electoral Participation, Local Government and Urban Governance in Europe, 209–232. DOI: 10.1007/978-3-319-43979-2_11.

Štefenberga, D., Rivža, B., & Sloka, B. (2021). Regional Development Issues and Consequences of Covid 19 pandemic- Experience and Ability for remote work. *Regional Formation and Development Studies*, 33(1), 137–144. DOI: 10.15181/rfds.v33i1.2205.

Štefenberga, D., & Sloka, B. (2019). The Role of Innovation in Sustainable Regional Development, proceedings of 9th International Scientific Conference 'Rural Development 2019' Proceedings 'Research and Innovation for Bioeconomy' 2019, pp 486–491, Vytautas Magnus University, Kaunas, DOI: 10.15544/RD.2019.071. https://ejournals.vdu.lt/index.php/rd/article/view/599.

Štefenberga, D. (2019). Cooperation and Innovation as a Key Success Factors for Development in Regions, *Regional Formation and Development Studies*, 28(2), 116–123. DOI: 10.15181/rfds.v28i2.1948.

Štreimikienė, D., & Kačerauskas, T. (2020). The creative economy and sustainable development: The Baltic States. *Sustainable Development*, 28(6), 1632–1641. DOI: 10.1002/sd.2111.

Vasilevska, D., & Rivza, B. (2020). Factors of the effectiveness of innovative development of Baltic states in the context of digitalization. International Multidisciplinary Scientific GeoConference Surveying Geology

and Mining Ecology Management, SGEM, 2020, 2020-August (2.1), pp. 153–160. DOI: 10.5593/sgem2020/2.1/s07.020.

Vasiļevska, D., & Sproģe, I. (2020). E-commerce Market in the Baltic Countries: State-of-the-Art and Trends of Development. *Lecture Notes in Networks and Systems*, 117, 620–629. DOI: 10.1007/978-3-030-44610-9_60.

Yadav, R., & Kumar, D. (2022). Linking non-financial motivators of women entrepreneurs with entrepreneurial satisfaction: A cluster analysis. *World Review of Entrepreneurship, Management and Sustainable Development*, 18(1-2), 40–64. DOI: 10.1504/WREMSD.2022.120768.

Yodchai, N., Ly, P.T.M., & Tran, L.T.T. (2022). How the creative mindset affects entrepreneurial success in the tourism sector: the mediating role of innovation capability. *International Journal of Contemporary Hospitality Management*, 34(1), 279–298. DOI: 10.1108/IJCHM-06-2021-0695.

Zhang, W., Liu, X., Liu, J., & Zhou, Y. (2022). Endogenous development of green finance and cultivation mechanism of green bankers. *Environmental Science and Pollution Research*, 29(11), 15816–15826. DOI: 10.1007/s11356-021-16933-5.

 DOI: 10.22616/rrd.28.2022.033

EUROPEAN UNION FUNDING SUPPORT TO LATVIAN MUNICIPALITIES FOR DEGRADED AREAS REVITALIZATION

***Mairita Stepina**, **Modrite Pelse**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: mairita.stepina@llu.lv

Abstract
The formation and existence of degraded areas is one of the consequences of civilization, which has a negative impact on both the environment and economic development in the municipality. The problem of degraded areas has been faced by all countries worldwide, including Latvia, when as a result of the change of the state political system in the 1990s after the collapse of the Soviet system, a large number of inactive production companies appeared, resulting in a significant number of polluted / degraded areas. To solve the existing problem, local governments in Latvia use European Regional Development Fund (ERDF) funding under the Operational Program 'Growth and Employment' 5.6.2, specific support objective 'Revitalization of territories by regenerating degraded areas in accordance with local government integrated development programs' (SSO 5.6.2) to ensure the sustainable development of the territory by revitalizing degraded areas. In the implementation of projects, local governments must ensure the fulfilment of the indicators planned in the projects in the following groups of indicators: the area of degraded areas has been renewed, adapted for the location of new businesses or expansion of existing businesses in order to promote employment and economic activity in local governments; new jobs created in supported areas; non-financial investments made by businesses located in the supported territory in their own intangible investments and fixed assets. Therefore, it is necessary to evaluate the indicators of the implemented projects in order to be able to draw conclusions about the financial aspects of the project implementation and the progress of the project implementation.
Key words: degraded area, revitalization, municipality, EU fund.

Introduction

Across Europe, including Latvia, the existence of degraded areas is a challenge for municipalities in developing spatial improvement plans and planning funding for their return to the economy. In order to find solutions, the municipality must include these areas in its development planning documents and draw up a plan for their renewal or revitalization. The term "revitalization" has been studied in the theoretical literature in connection with the restoration and redevelopment of degraded areas, the return of derelict land to green areas and the elimination of soil pollution. The analysis of theoretical aspects of the revitalization of urban degraded areas shows that the concept of 'revitalization' has become particularly relevant in recent years and is often used for changes in urban planning and the environment defined as operations, including rehabilitation, reconstruction and modernization aimed at transforming, for economic and social purposes, a building, site or city that has been destroyed or abandoned, creating new, usable values (Wilkosz-Mamcarczyk & Wilczkeiwicz, 2015).

Urban planning is focused on the principles of sustainable development, in the implementation of which the municipality has to face various challenges: to be able to meet the needs of all stakeholders in the field of land use, address environmental issues, address real estate availability, and promote business development (Cappai, Forgues, & Glus, 2019). Development planning in local governments is aimed at solving current problems in the territory of a particular local government with the funds at its disposal, as well as using Europe Union (EU) structural funds. By including degraded areas in their development programs, the municipality commits to investing in the revitalization of these areas.

Latvian municipalities can apply for support from EU funds by implementing the SSO 5.6.2 project program, which aims at revitalization of territories, regeneration of degraded areas in accordance with municipal development programs, ensuring environmentally friendly and environmentally sustainable territorial growth and job creation (Ministry Cabinet Regulation No.645, 2015). In accordance with the EU Council Decision on the EU Multiannual Framework for 2014-2020, Latvia has received 4.4 billion Euros (EUR 4,418.233) for the implementation of Cohesion Policy objectives through EU funds (ERDF, ESF and CF) (Ministry of Finance of the Republic of Latvia, 2022), including revitalization of degraded areas. In order to be able to provide recommendations to local governments in the future work in the process of revitalization of degraded areas, it is necessary to evaluate the project indicators achieved during the EU funds planning period 2014-2020.

The aim of the article is to study the available EU support for the revitalization of degraded areas for Latvian municipalities and to analyse the indicators of municipal projects.

Materials and Methods

The following research methods were used in the research: first, analysis of theoretical literature sources. The authors chose this method because it

provides an opportunity to analyse theoretical aspects of the revitalization of degraded areas, as well as the role of the municipal planning process in the revitalization of degraded areas, using the sources of scientific literature. An analytical approach was used in the study of theoretical literature sources, resulting in collection of the obtained data. The analysis of theoretical literature sources is based on scientific publications, conference proceedings, and project management books. Second, the authors used the method of statistical data analysis in the research to analyse the results of the projects by determining their arithmetic mean by groups of indicators, the standard deviation for each group of indicators and checking the data with the Mann Whitney Test. This method makes it possible to determine the dispersion rate of projects submitted by municipalities, providing a statement on the level of homogeneity of projects. The statistical data used were the results of SSO 5.6.2 projects compiled by the Ministry of Environment Protection and Regional Development (MEPRD), as well as publicly available statistical information on the total acquisition of ERDF funding by municipality (Ministry of Finance of the Republic of Latvia, 2020). To determine how ERDF funding correlated with project indicators, the authors used the correlation method to calculate the Pearson Correlation Coefficient project performance indicators in terms of absorbed ERDF funding and total project funding. As a result, it is possible to determine which of the project performance indicators correlates more significantly with the project finances. The study analysed all Latvian municipalities that implement projects within the framework of SSO 5.6.2 (one municipality could submit several project applications in the period from 2016-2020, as project selection takes place in 3 rounds). The authors have set a long-term goal in future research to study the existing situation in the management of degraded areas in three Latvian cities – Daugavpils, Liepaja and Jelgava - therefore, in this study, the authors decided to launch part of a comprehensive study identifying the three cities as a sample in order to gain clarity on the performance and progress of the projects in these three cities. Consequently, the indicators of the sample are compared with the indicators of other municipal projects in order to find out whether there are significant statistical differences. Third, visualization of research data in a bar chart to show the relationship of the variables and comparison with other variables. Within the framework of this method, project indicators have been selected that reveal the progress of project implementation: what are the planned indicators in numerical form when submitting the project, and what is the progress of their achievement as of 08.02.2022.

Results and Discussion

After the collapse of the Soviet Union in the early 1990s, the Baltic States underwent structural changes not only in their policies but also in their economies. As a result of the changes, more and more abandoned, unused territories were created, where no economic activity took place, and their existence caused not only damage to the aesthetic image of the city, but also pollution and threats to population (Kotval, Tohvri, & Tintera, 2014). Such spots are called degraded areas, and their existence is a problem not only faced by post-Soviet countries, but also in Europe, the United States and on a worldwide scale. In the Czech Republic, for example, the existence of degraded areas became relevant with the privatization and economic restructuring processes, which mostly affected industrialized zones in cities. It can therefore be concluded that degraded areas have become one of the main constraints on the development of the area, and their existence tends to have a negative impact on the whole city, not only because of direct impact but also because of other aspects, such as rising unemployment, economic and environmental problems (Kuda, Techmann, & Szeligova, 2021).

In order to solve the problem of degraded areas, the attention and activities of urban planners should be focused on their reorientation towards the reintegration of degraded areas into economic circulation or the return of economic activity to them. Economic theorists define the term “land” as a resource that serves as an object of economic activity, infrastructure, housing, as a soil for agricultural production, and an area for social recreation (Bergh & Hubacek, 2005). To ensure its sustainability, it must be ensured that the land is used in the most efficient way (Science of Environmental Policy, 2013). The return of degraded areas for re-use is possible if a revitalization process is implemented, which in the theoretical literature means ‘the initiative of economic regeneration of degraded areas, ensuring its development potential’ (Nathanail & Pahlen, 2006). The term ‘revitalization’ is used not only to describe changes in urban planning and the landscape, but also to describe the various processes of transformation, both in architecture and in the social sciences and economics. The need for revitalization can be justified by its long-term benefits: an increase in the urban development index, a reduction in public health threats, an improved environment, and added value for business development (Dry, 2002). For the functioning of the spatial development system that ensures the revitalization of degraded areas, Adams, De Sousa and Tiesdell (2010) identified the following sequence of actions:

1) identification of degraded areas (their definition – typology, definition of perception criteria, database as records or register);

2) identification of potential and risks of degraded areas (analysis of conditions), environmental rehabilitation, vision of comprehensive recovery;

3) planning of the revitalization of degraded areas, development of an implementation plan, implementation of the plan, its monitoring and achievement of the objective.

Consecutive observance of the above-mentioned activities will ensure more efficient implementation of development principles for local governments. Urban development issues in municipalities are addressed in relation to the basic principles of sustainable development, which include the integration of environmental, social and economic aspects into development programs, ensuring a balanced approach to the sustainable development of urban areas (Grodac, 2011).

In this process, the municipality must find a compromise between various goals of sustainable development: the creation of the city structure, the use of land, combining it with environmental and social factors. In accordance with Section 15, Paragraph 13 of the Law on Local Governments of 9 June 1994, local governments are obliged to ensure the improvement of their administrative territory and sanitary cleanliness. According to the data of the official statistical database of Latvia, the highest concentration of population is observed in Latvian cities, which indicates that there is more economic activity than in the periphery; therefore, when planning urban development, special attention should be paid not only to economic factors but also environmental quality aspect.

By introducing a wide range of financial, fiscal, legal, regulatory and policy incentives, a municipality can ensure a successful, competitive position in degraded areas. Such incentives are particularly needed for degraded areas redevelopment to attract the attention of potential investors, as investors are largely reluctant to invest in degraded areas redevelopment based on lack of confidence about the benefits and potential risks (location, unavailability of infrastructure, reduced real estate value), uncertain investment volume (Mert, 2019). In view of the above, it can be concluded that the primary task of the municipality is to ensure favourable conditions for attracting the widest possible attention of stakeholders to the regeneration of degraded areas in order to invest their resources in the development of the area. Municipal budgets are limited and must primarily provide funding for operational needs, but successful strategic planning can provide a way to raise the interest of potential investors about investment opportunities. Thus, it can be concluded that the limited financial resources within the existing budget are one of the biggest obstacles to the revitalization of degraded areas. It should be noted that the possibilities of loans to local governments tend to be limited, as the risk of liability associated with the repayment of the loan increases. As a result, it can be concluded that without state intervention, degraded areas are not economically competitive in the field of business development with 'green' areas (Kotval & Meitl, 2017).

Studying the international experience in countries such as the USA, the Czech Republic and Germany, which deal with the issues of the revitalization of degraded areas, the authors conclude that each of the above countries has a different approach to the use of various financial instruments. For example, the United States has established an Environmental Protection Agency (EPA), which deals with environmental issues, including the development of regulations and revitalization programs for degraded areas, environmental research, and funding for the restoration of degraded areas. According to the information published on the official website of the EPA www.epa.gov, the EPA, based on the developed rehabilitation program of degraded areas, provides financial support for:

- the assessment of degraded areas to determine the condition of the degraded area (up to USD 500,000.00 per applicant), to carry out the inventory of the site, to assess it, as well as to develop site-specific restoration plans and promote public involvement in the restoration of degraded areas;
- working capital grants to provide funding to the beneficiary in the form of loans and grants for decontamination activities in degraded areas. These grants help to strengthen the market and encourage stakeholders to attract resources for clean-up and rehabilitation of degraded areas. When the loans are repaid, the loan amount is returned to the fund and re-lent to other borrowers, providing a permanent source of capital for the society;
- degraded areas decontamination grants for privately owned areas;
- multifunctional grants to provide funding for assessment and clean-up activities in degraded areas through multi-city cooperation;
- employment grants to enable non-profit organizations, local authorities and other organizations to recruit, train workers and integrate them into the labour market in areas affected by the presence of degraded areas;
- comprehensive compensation for public bodies to enable the prevention, assessment, restoration and re-use of degraded areas in the context of sustainable development.

The above suggests that the US provides comprehensive funding opportunities not only for local governments but also for public organizations

and private owners. Such an approach creates opportunities not only for the return of degraded areas to economic circulation, but also for the public to participate in the elimination of degraded areas.

The situation in Germany is characterized by the fact that the management of degraded areas is regulated by the Federal Environment Agency. As in Latvia, the public sector is facing the challenges of today's economy, and urban budgets are becoming increasingly limited, so Germany is using public-private partnerships to revitalize degraded areas (Stadt Dortmund, 2004). Funding is provided by a variety of funding sources: EU funds (ERDF funding), the German Federal Finance Programs, the Land and Property Fund, and local funding programs such as the Social City Action Plan. Beneficiaries are municipalities, state and public organizations (Kwon & Zabel, 2020). The issues of the revitalization of degraded areas in the Czech Republic are handled by the Ministry of Regional Development, the Ministry of the Environment and the Ministry of Industry and Trade. In order to implement the revitalization projects for degraded areas, project promoters can use various loan programs with reduced interest rates, EU structural funds and various state programs for the renovation of abandoned buildings. In the Czech Republic, CZK 2 billion has been allocated from the state budget for the rehabilitation of degraded areas for 2017-2023 (Skrabal, 2018).

In Latvia, the revitalization of degraded areas is based on development planning documents developed by local governments, which take place in accordance with the Development Planning System Law (Development Planning System Law, 2009). Under the influence of this law, the local government, which implements the functions assigned to it, subordinates its development plans hierarchically to regional and national level planning documents. In Latvia, revitalization of degraded areas, based on development planning documents developed by local governments, takes place in accordance with the Development Planning System Law (Development Planning System Law, 2009). In the light of this law, the local government, which implements the functions assigned to it, subordinates its development plans hierarchically to regional and national level planning documents. For the development of the territory, local governments implement a policy aimed at growth and economic development, in the implementation of which local governments use the support of EU funds. Since Latvia became a member of the European Union, it has received EU subsidies for projects in various areas: regional and urban development, employment and social inclusion, agriculture and rural development, maritime and fisheries policy, research and innovation, and more. Thus, it can be concluded that the main instrument for the sustainable development of the municipal territory is the projects of the EU funds, as well as the projects financed by other financial instruments, which ensure the implementation of the objectives defined in the municipal development strategies and programs. The implementation of projects is directly related to the development of the municipality in order to ensure not only the well-being of the inhabitants of its territory and the improvement of living conditions, but also to increase the attractiveness of the business environment and achieve competitive territory ratings. In order to avoid a situation when the resources available to the municipality are used for purposes other than its development and growth, it must be ensured that the municipality is able to assess the potential of the areas at its disposal, taking into account not only the physical condition and location of the land, but also by assessing the benefits that the resource can provide if it is included in the economic cycle (Stepina & Pelse, 2021). Therefore, it is necessary to set priorities in the use of resources and include solutions to the identified situations in development and investment plans.

By including degraded areas in its development plans, the municipality undertakes to take all necessary actions to return them to economic circulation. Carrying out such activities is possible by attracting the support of EU funds intended for local governments as recipients of funding. The implementation of projects takes place within the framework of the SSO 5.6.2 Operational Program, and the aim of this measure is the revitalization of territories by regenerating degraded areas in accordance with municipal development programs, ensuring environmentally friendly and environmentally sustainable territorial growth and job creation (Ministry Cabinet Regulation No. 645, 2015). As a result, municipalities will be able to invest in the rehabilitation of degraded areas and prevent pollution risks or eliminate existing pollution. In this way, the accessibility of the territory for business will be promoted and the number of newly created jobs in companies will be increased. The announcement of projects envisages 4 rounds, and the implementation of the project must achieve three outcome indicators: 1. the area of degraded areas has been renovated, adapted to accommodate new businesses or expand existing businesses in order to promote employment and economic activity in municipalities; 2. new jobs have been created in the assisted areas; 3. businesses located in the assisted area have made non-financial investments in their own intangible assets and fixed assets. The values of the output indicators are applicable if they are related to businesses that have benefited from the infrastructure investments made within the project (Ministry Cabinet Regulations No. 645, 2015). Revitalization projects for degraded areas

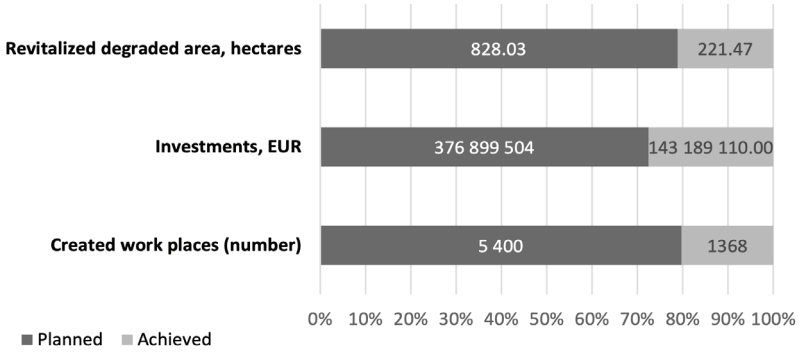

Figure 1. Execution of project indicators.

Source: author's created by MEPRD information until 08.02.2022.

are implemented in the policy area 'Environmental Protection', which is one of the areas of activity of the Operational Program "Growth and Employment".

The values of the project indicators are analysed taking into account the project results that are relevant as of 08.02.2022, according to the information provided by the MEPRD. As some of the projects are still in the implementation stage, adjustments are possible in the indicators and as a result of the projects, because in accordance with the Cabinet Regulation No. 645, the project result indicators will be achieved by 1 December 2023. According to the SSO of the EU fund Managing Authority's (Ministry of Finance) division into areas of operational support, SSO 5.6.2 is included in the field of environmental protection, but its purpose and results are of an economic nature – creation of new jobs and attraction of non-financial investments (Figure 1).

The information in Figure 1 confirms that results of the projects planned for the moment have not been achieved to the extent that the municipalities had originally proposed. In total, 221.47 ha of degraded areas have been revitalized out of the planned 828.03 ha, 1388 job places have been created out of the planned 5400, and the amount of non-financial investments made by businesses is 1 431 879 EUR of the planned 376 899 504 EUR.

When analysing the project statistical data, the authors summarized the results of the analysis in Table1. As mentioned above, using the method of statistical analysis, the authors investigated whether the results of three Latvian national cities' projects

Table 1

Analysis of statistical data of revitalization project indicators in the period from 2016 to 2022

Project outcome indicator	Municipality	Statistical indicators			
		n	Mean	Std. Deviation	Mann Whitney test, sig (2-tailed)*
Area of revitalized degraded areas adapted for the location of new businesses or expansion of existing businesses to promote employment and economic activity in municipalities (ha)	Jelgava, Liepaja, Daugavpils	18	10,04	9,89	0,29
	Other municipalities	95	6,36	6,42	
Number of new jobs created in supported areas (number)	Jelgava, Liepaja, Daugavpils	18	73,83	82,95	0,21
	Other municipalities	95	38,27	35,58	
Non-financial investment in intangible assets and fixed assets by merchants located in the assisted area (EUR)	Jelgava, Liepaja, Daugavpils	18	4541138,56	5976495,40	0,36
	Other municipalities	95	2448430,09	2379854,36	

*According to the results of the Kolmogorov-Smirnov test, the data do not correspond to the normal distribution.
Source: created by the authors based on Ministry of Environment and Regional Development information until 08.02.02022.

Table 2

Correlation of project indicators in the period from 2016 to 2022

Project outcome indicator	Pearson Correlation coefficient R	
	ERDF funding (EUR)	Total funding (EUR)
Area of revitalized degraded areas adapted for the location of new businesses or expansion of existing businesses to promote employment and economic activity in municipalities (ha)	0,615*	0,558*
Number of new jobs created in supported areas (number)	0,682*	0,806*
Non-financial investment in intangible assets and fixed assets by merchants located in the assisted area (EUR)	0,475*	0,561*

*Correlation is significant at the 0.01 level (2-tailed).
Source: created by the authors based on Ministry of Environment and Regional Development information until 08.02.02022.

differ significantly from the results of other municipal projects and what is the significance level of these differences (Table 1).

The indicator 'n' in the table is the sample size or number of projects. This indicates that the number of projects in the sample is 18 in the study period, while in other municipalities it is 95. The results of the analysis show that by determining their arithmetic mean value by indicator groups, it is possible to determine the standard deviation. The context of this data analysis shows that the variance of the data from the arithmetic mean is large, but the projects are heterogeneous: there are projects where the area to be regenerated is 1 ha and there are those where 15 ha are regenerated. All calculations were verified with the Mann Whitney Test. In the context of this study, the test does not show a statistically significant difference between the indicators.

In order to find out the relationship between the two project indicators, the authors performed a correlation analysis (Table 2).

With the performed correlation calculations, the authors found out how the ERDF and total funding correlate with project indicators: renewed degraded area, number of newly created jobs and non-financial investments made by businesses with their own intangible assets and fixed assets. Correlation values can range from -1 to 1; and the closer the indicator is to 0, the link between indicators tends to be nonexistent. According to the results of the study, it can be concluded that the link between the indicators is strong: the indicator "Newly created jobs" and "Restored degraded areas" are most strongly correlated. It shows that the investments made within the framework of all municipal projects are primarily based on the number of newly created jobs, and the area of restored degraded areas indicates the significance of these indicators in the context of the project.

Conclusions

1. Municipality activity of project program SSO 5.6.2. can be assessed as a high level, which shows that the long-term goals of local governments include the conditions for sustainable development and municipality are actively solving the problems caused by degraded area in their territory;
2. It is possible to attract EU funding for the revitalization of degraded area if the local government includes degraded area in municipality development planning documents, which comply with the definition of Ministry Cabinet Regulation No. 645;
3. Studying the international experience in the revitalization of degraded territories, the authors conclude that each country uses different financial support instruments to solve the revitalization of degraded territories – support from EU funds, state budget resources, comprehensive funding opportunities for public organizations and private owners;
4. MEPRD compiled data on the progress of project indicators, the project indicators planned by local governments were not fulfilled in total, as the municipality had put forward when submitting project applications for support from EU funds. Taking into account the fact that the term of project implementation in accordance with the Cabinet Regulation No. 645 has been set until December 1, 2023, the planned indicators in their numerical expression must be achieved within the set term. In order to carry out a detailed analysis at the end of the period, the reasons for the changes in the project that led to the risks of non-compliance should be examined;
5. The content of the submitted projects is not homogeneous, which is confirmed by the analysis of statistical data, which indicates that the project is implemented only by large municipalities in

terms of territory, but also by small municipalities. According to the Mann Whitney test, the heterogeneity of projects is a considerent as insignificant, which shows that the sample groups that include Jelgava, Liepaja and Daugavpils project indicators do not differ from the general group – all municipalities that have submitted project applications;

6. The calculations of the correlation analysis show that the link between the project indicators and the funding provided for the project is close – the indicator 'Newly created jobs' and 'Restored degraded area' are the most strongly correlated. The above shows that the investments made within the framework of all municipal projects are primarily based on the number of newly created jobs and the area of restored brownfields, which indicates the significance of these indicators in the context of the project;
7. The investments made in the revitalization of municipal degraded area not only ensure the development of entrepreneurship, but also create an aesthetic urban environment and address environmental issues, ensuring the sustainable development of the territory.

References

Andres, L. (2012). *Levels of Governance and Multi-stage Policy Process of Brownfield Regeneration: A Comparison of France and Switzerland.* International Planning Studies. DOI: 10.1080/13563475.2011.638184.

Bergh, J.C., & Hubacek, K. (2005). *Changing concepts of 'land' in economic theory: From single to multi-disciplinary approaches. Ecological Economics*. (2006) pp. 5–27. DOI: 10.1016/j.ecolecon.2005.03.033.

Cappai, F., Forgues, D., & Glaus, M. (2019). *A Methodological Approach for Evaluating Brownfield Redevelopment Projects.* Urban Science. DOI: 10.3390/urbansci3020045.

Danel, R., Neustupa, Z., & Stalmachova, B. (2012). *Best practices in design of database of brownfield revitalization projects.* 12th International Multidisciplinary Scientific GeoConference SGEM, 2012, Technical University of Ostrava, Czech Republic.

Kotval, Z., Tohvri, E., & Tintera, J. (2014). Urban brownfields in Estonia: scope, consequences, and redevelopment barriers as perceived by local governments. Moravian geographical reports. DOI: 10.1515/mgr-2014-0021.

Nathanail, P., Pahlen, G., Edward, G., Franz, M., & Thornton, G. (2006). The challenge of sustainability: incentives for brownfield regeneration in Europe, Environmental science & policy. 116–134. DOI: 10.1016/j.envsci.2006.08.008.

Kwon, Y., & Zabel, R. (2020). Evolution of urban development and regeneration funding programs in German cities. DOI: 10.1016/j.cities.

Republic of Latvia Law. (2009). *Development Planning System Law.* 2009, Riga, Latvia.

Regulations of the Cabinet of Ministers No. 645 (2015). *'Operational Program' Growth and Employment 5.6.2. Objective of the Objective Support Objective 'Revitalization of Territories by Regeneration of Brownfields in Accordance with Integrated Development Programs of Local Governments'* 2015, Riga, Latvia.

Science for Environment Policy. (2013). Brownfield Regeneration: Science Communication Unit. University of the West of England (UWE), Bristol, May 2013, Issue 39.

Skrabal, J. (2018). Utilization of European Funds for Brownfields Regeneration. International Conference on European Integration, 2018. Ostrava, Czech Republic. pp. 1484–1491.

Stepina, M., & Pelse, M. (2021). *Approbation of Project management methodology in degraded areas revitaliztaion projects.* In 27th Annual International Scientific Conference 'Research for Rural Development 2021'. 2021, 247–253. Latvia University of Life Sciences and Technologies, DOI: 10.22616/rrd.27.2021.035.

Tendero, M., & Plottu, B. (2019). A participatory decision support system for contaminated brownfield redevelopment: a case study from France. 2019. DOI: 10.1080/09640568.2018.1512476.

Turner, R.K., Clark, G.L., Feldmann, M.P., & Gertler, M.S. (2010). *Markets and Environmental Quality. The Oxford Handbook of Economic Geography*. Oxford, New York, pp. 585–606.

Wilkosz-Mamcarczyk, M., & Wilczkiewicz, M. (2015). *Reviztalization – definition, genesis, examples.* Geomatics, Landmanagement and Landscape No. 2. 71–79. Uniwersytet Rolniczy w Krakowie.

 DOI: 10.22616/rrd.28.2022.034

ANALYSIS OF START-UP DEVELOPMENT REGISTERED IN THE ASSOCIATIONS IN THE BALTIC STATES

***Aija Vonoga[1], Baiba Kļaviņa[2]**
[1]Rezekne Academy of Technologies, Latvia
[2]Vidzeme University of Applied Sciences, Latvia
*Corresponding author's email: aija.vonoga@rta.lv

Abstract
This research paper focuses on start-ups. The topicality of the research is based on economic development requirements and trends. Development of start-ups is an important chain link in the innovation system and promotes the change of the paradigm to modern and innovative economy. The aim of the research is to study start-up associations in Latvia, Lithuania and Estonia and analyze start-ups registered in databases of these associations. Tasks of the research are the following: to carry out a theoretical analysis of Latvian, Lithuanian and Estonian start-up associations and start-ups; to study the variables that characterize start-ups registered in start-up associations in Latvia, Lithuania and Estonia; to perform data analysis and visualize results; to present conclusions and proposals for further research. Research covers data about start-ups founded in the period from 2011 until 2021 and included in Baltic start-up association databases. General scientific research methods used in the research are the monographic or descriptive research, the comparative analysis and the descriptive statistics. Research authors conclude that Latvian association of start-ups is different from counterparts in Lithuania and Estonia. It might be assumed that it affects the divergence of the number of start-ups registered in databases. In Latvia, this number is almost 10 times lower than in other Baltic states.
Key words: Start-up, Estonia, Latvia, Lithuania, association, ecosystem.

Introduction

There are various definitions of the concept of start-up in the literature, but Steve Blank and Bob Dorf define a start-up as follows: 'A start-up is not a smaller version of a large company. A start-up is a temporary organization looking for a scalable, repeatable and profitable business model' (Blank & Dorf, 2020). Analyzing this definition, it can be concluded that the goal of start-up is to create a successful business model to grow and develop in the market. The study of start-ups is conducted in the context of the Baltic market although their markets are small compared to other countries.

Compared to other countries, Estonia, Latvia and Lithuania have small markets and limited economic power, which shows that they are not attractive to international suppliers and are not able to offer as high offers as other countries (Webb *et al*., 2021). Researching the literature in scientific databases on the topic, such as Sciencedirect, Ebsco, Scopus, MDPI, etc., studies of start-up companies in the Baltic States are not available, accordingly this confirms the usefulness for research of start-ups in the Baltic context.

Start-ups are drivers of change that bring innovation and find new solutions to old problems (Devadiga, 2017). They are inventing new business models that surprise existing markets. Their business is based mainly on new technologies and knowledge (Cockayne, 2019). Several studies indicate that start-ups have a positive impact on the economy and contribute to its development (Reisdorfer-Leite *et al*., 2020). Successful start-ups create new jobs and contribute to economic prosperity (Tripathi *et al*., 2019). The positive impact of the start-up on the economy is also observed in the Baltic States.

So far in 2021, Lithuania has seen 277 million EUR in investment (compared to just 17.9 million EUR in 2020 and 151 million EUR in 2019). In 2020, Estonian start-ups received 115 million EUR in capital (Sifted, 2022). Latvian startups have raised more than 247 million euros in 2021 (Magnetic Latvia, 2022). The Baltics have birthed Bolt, the Estonian ride-hailing app, and Vinted, Lithuania's increasingly popular secondhand clothes marketplace. Other, but exited unicorns include Skype and Wise (previously TransferWise). But with only two unicorns, the region has a lot of room for growth – and needs it if it's going to compete with more established markets. Fintechs like consumer lender Sun Finance, which recently placed 2nd in the FT1000 with a compound growth rate of 752%, are particularly promising. And thanks to start-up-friendly regulations, Lithuania is Europe's second-largest regulated fintech hub. While many Baltic start-ups have also moved out of the small and underpopulated regions to capitalise on more established markets, as usual, this list only includes start-ups headquartered in Estonia, Latvia and Lithuania (Sifted, 2022).

Start-up is a new activity that involves the development and validation of a business model (Trinh, 2019). Start-up performance can be affected by material capital, human capital, knowledge and entrepreneurial capital (Audretsch & Keilbach, 2010). Understanding the factors that affect a company's survival is a key issue for the proper management of business projects and start-up programs, given the high risk of business mortality in its first five years (Segura, 2019). Factors influencing start-ups at their initial stage continue to affect the company throughout its existence.

Start-up performance can also be affected by access to multiple networks, resources, and knowledge (Battistella, De Toni, & Pessot, 2018). In addition, open innovation practices promote networking, collaborative work and knowledge flow, partnerships and external links with other networks and companies (Pustovrh, Rangus, & Drnovšek, 2020). Networking between start-ups facilitates day-to-day work and knowledge transfer, so in the context of the Baltic States, it would be advisable to set up one Baltic start-up platform in order to promote joint cooperation and growth.

The aim of the research is to study and analyze start-up associations in Latvia, Lithuania and Estonia and analyze start-ups registered in databases of these associations. Tasks of the research are the following: to carry out a theoretical analysis of Latvian, Lithuanian and Estonian start-up associations and start-ups; to study the variables that characterize start-ups registered in start-up associations in Latvia, Lithuania and Estonia; to perform data analysis and visualize results; to present conclusions and proposals for further research.

Materials and Methods

Start-up ecosystems in Baltic states

Association – an official group of people who have joined together for a particular purpose (Oxford learners dictionaries, 2022). In the Baltic states Latvian start-up association, Start-up Lithuania and Start-up Estonia are working in order to develop start-up ecosystems.

Development of start-ups is an important chain link in the innovation system and promotes the change of the paradigm to modern and innovative economy. Over the last years the Ministry of Economics of Republic of Latvia and the bodies subordinated to it have been actively working on the creation of uniform supply for the start-up ecosystem. The Latvian start-up ecosystem has become more visible also in the international context. Every year several local events and festivals with international coverage bring together start-ups and their representatives (Ministry of Economics Republic of Latvia, 2020).

Latvian start-up association (NGO) Startin.LV was created in 2016 to unite Latvian start-up community around common values and provide joint opinion with the aim to develop a better start-up ecosystem in Latvia. Startin.LV is a platform that enables start-ups to initiate ideas, be heard and receive support in fulfilling their needs and solving problems. Objectives of Latvian start-up association are: to represent start-up interests; to gather up to date insights and represent start-ups joint interests; to unite 80+ start-up ecosystem members in Latvia; to create a united force for entrepreneurial growth in collaboration with ecosystem representatives, governmental institutions, universities, etc.; to support its members; to provide information, consultations and help in finding partners, investors and employees; to support start-ups interest and share up-to-date information about the start-up ecosystem (Startin.lv, 2022). Looking at the companies in the Latvian start-up database, it can be concluded that the largest companies (external funding exceeds EUR 4 million) are Printful, Lokalise, Printify, Lightspace Technologies, Sonarworks, Beetroot Lab, Juro, Giraffe360, Aerones, Nexpay and others. The largest start-up companies not only develop the Latvian economy, but also create Latvia's recognition in the world.

Start-up Lithuania is the national start-up ecosystem facilitator between fast-growing business, venture capital funds, accelerators, start-up friendly enterprises, and the government. Its supports start-up ecosystem by publishing start-up news, providing start-ups database and job marketplace, sending a weekly newsletter that covers the ecosystem, organizing start-up events (Seminars, BarCamp, Workshops, and Start-up Fair – main start-up event of the year), consulting, advising, introducing, networking (as they do know everyone in the ecosystem) and by educating the ecosystem and futurepreneurs. Start-up Lithuania is powered by Enterprise Lithuania, the governmental institution, which aims to support business establishment, entrepreneurship, and fosters export (Start-up Lithuania, 2022). Some of the largest registered companies in the Lithuanian start-up database are Vinted, Nium, Genius sports, City bee, Simplex and Transfergo.

Start-up Estonia is a governmental initiative aimed to supercharge the Estonian start-up ecosystem for it to be the birthplace of many more start-up success stories in the future. For that, Start-up Estonia is working on making Estonia one of the world's best places for start-ups by focusing on these building blocks: Strong ecosystem - uniting, building and representing the local start-up community. Supporting regional development and science-based decision making; Smart people - promoting diversity and co-organizing impactful start-up events with the community Smart money – educating and attracting investors, helping resources and know-how reach start-ups (Start-up Estonia, 2022). In 2018, there were 330 million euros invested into Estonian start-ups (Grant Thornthon, 2019). The largest companies registered in the Estonian start-up database (by turnover and taxes) are Bolt, Veriff, Swappie, Adcash, 3commas, Starship Technologies, Viseven and other companies that make a significant contribution to the overall Estonian economy.

Methodology of the research

Data used in research is taken from publicly available databases of start-up associations in

Latvia, Lithuania and Estonia. Data variables used in analyses - launch year (year founded), sector, market, type, business model, funding (investment), turnover 2021 Q4. Probabilistic data sampling was performed according to the stratified or typological random sampling method. Companies were selected first by year (from 2011-2021), and then individual units were selected by proportional sampling within the selected groups. There were 100 samples selected; however in the process of data cleaning, some samples were eliminated, so in the final data set for analysis, there are 96 samples of Lithuanian start-ups, 93 samples of Latvian start-ups and 97 samples of Estonian start-ups.

Results and Discussion

After the research of start-up associations databases, authors can conclude the common and different features in Latvia, Lithuania and Estonia. The Lithuanian start-up association has been operating for the longest time – since 2012. The Estonian Start-up Association has been operating since 2015 and the Latvian one since 2016. Looking at the form of activity – in Lithuania and Estonia start-up associations are state-owned companies, but in Latvia it is a non-governmental organization, hence the funding models are different – in Lithuania and Estonia the associations are funded by the state, but in Latvia by the member fees. Common factors are visibility and some special offers for members of databases in all three Baltic countries.

Number of start-ups

Data from publicly available start-up associations databases of the Baltic States were used for analysis Latvian start-up association Startin.lv, Start-up Lithuania and Start-up Estonia. To analyze the trend of the number of start-ups of Baltics, the number of start-ups and the year of establishment were used. At the moment of desk research, there were 1527 start-ups registered in the Lithuanian database, 1301 companies in the Estonian database and 166 enterprises in the Latvian association's database.

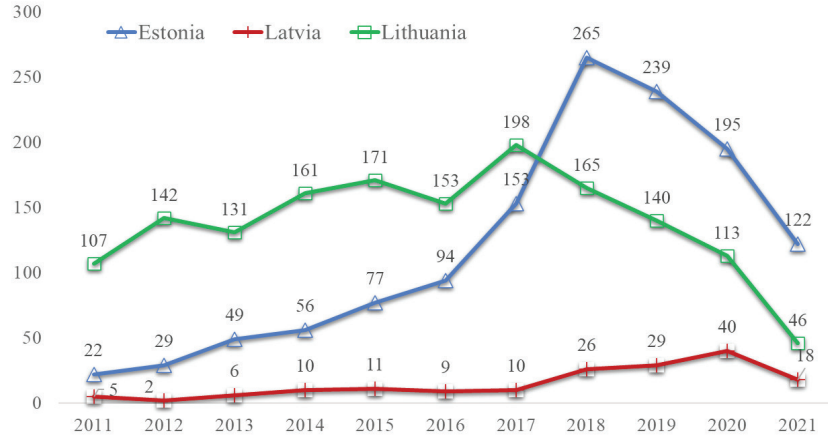

Figure 1. Number of start-ups in Baltic associations*, divided in groups by foundation year.

* Estonia – Start-up Estonia, Latvia – Latvian Start-up Association Startin.lv, Lithuania – Start-up Lithuania

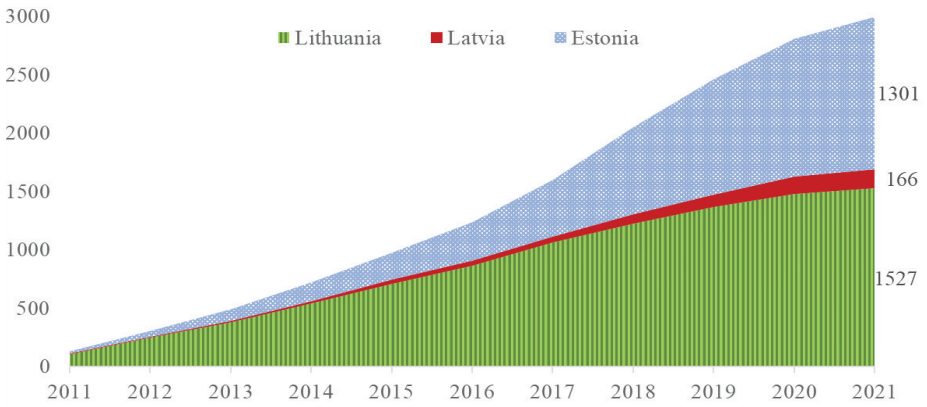

Figure 2. Number of start-ups in Baltic associations* (accumulative numbers).

* Estonia – Start-up Estonia, Latvia – Latvian Start-up Association Startin.lv, Lithuania – Start-up Lithuania

Table 1

Descriptive statistics

	LT_Funding	LV_Funding	EE_Turnover
Mean	3572031,25	3275693,849	7804442,268
Standard Error	1102195,99	1344363,076	3879061,733
Median	720000	300000	460000
Mode	1100000	50000	1100000
Standard Deviation	10799271,09	12964568	38204327,41
Sample Variance	1,16624E+14	1,6808E+14	1,45957E+15
Kurtosis	62,6615507	47,32072967	38,26443179
Skewness	7,380981907	6,526014577	6,16870192
Range	97890000	106896000	265991900
Minimum	10000	4000	8100
Maximum	97900000	106900000	266000000
Sum	342915000	304639528	757030900
Count	96	93	97
Confidence Level(95,0%)	2188135,696	2670021,11	7699876,683

In Figure 1, it can be seen that the number of start-up companies registered in all three Baltic States has increased between 2011 and 2017. Starting with 2018 in Lithuania and with 2019 in Estonia it can be observed a significant decline in the number of registered start-ups in national associations. However, the number of start-ups registered in the Latvian association continued to grow until 2020. The continued decline in 2020 and 2021 could be related to the spread of the Covid-19 pandemic in Europe and Latvia starting with 2020 and epidemiological constraints that slowed down the economy and prevented the emergence of new companies.

Figure 2 shows the number of start-ups in Baltic associations, divided in groups by foundation year from 2011 until 2021. The cumulative numbers in Figure 2 reflect the positive start-up growth. The number of companies in each country increased every year, but it can be clearly seen that the number of Lithuanian and Estonian start-up companies has a significant ascendancy over the total number of start-up companies registered in the Latvian association. It could be useful to study further the contributing factors that hinder the growth of the number of start-ups in the association in Latvia.

Financial indicators

Data regarding received funding was used from the Latvian and the Lithuanian associations. Due to lack of available data of investments in start-ups registered in the Estonian association, data on turnover for the year 2021 Q4 was used as a financial indicator. Although it cannot be argued that funding can be compared to turnover, to a certain extent these figures in the sample considered followed a similar trend.

Kurtosis and skewness are above 0 for all three variable groups, so it means that data curves are stretched and the data grouping in the center of the curve is enhanced, and the curve is shifted to the left. That can be observed in Figures 3.1., 4.1. and 5.1. Median indicates that the number of received funding in Lithuania (which is situated in the middle of the data set) is 720 thousand EUR; however, according to mode the most common sum of funding received in observed Lithuanian start-ups is 1,1million EUR. In the sampling of Latvian start-ups mentioned indicators are lower – median is 300 thousand EUR and mode is only 50 thousand EUR. That shows that there are relatively more small start-ups in Latvian association than in Lithuania. Start-ups with the smallest funding included in this research sampling of Latvian data is 4 thousand EUR while for Lithuania it is 10 thousand EUR. Then again the maximum received funding in Latvian start-up is 106,9 million EUR, which is a bit more than in Lithuanian sample data (97,9 million EUR). Meanwhile, indicators regarding turnover in 2021 in Estonian start-ups – median of 460 thousand EUR and mode of 1,1million EUR – are more similar to median and mode regarding funding of Lithuanian start-ups.

As can be concluded from figures 3.1. and 4.1., most Latvian and Lithuanian start-ups have received less than 20 million EUR for funding. When analyzed closer, ~80% in Lithuania and 90% in Latvia have received less than 5 million EUR in funding (Figures 3.2. and 4.2.). Almost half of start-ups in both countries have received from 100 thousand EUR to 1 million EUR of funding. But in Latvia, there are a bit more start-ups with funding less than 100 thousand EUR than in Lithuania, and vice versa, Lithuania has a bit more start-ups with funding from 1 to 10 millions than in Latvia.

It cannot be possible to compare funding of start-up with turnover of start-up; however, data regarding

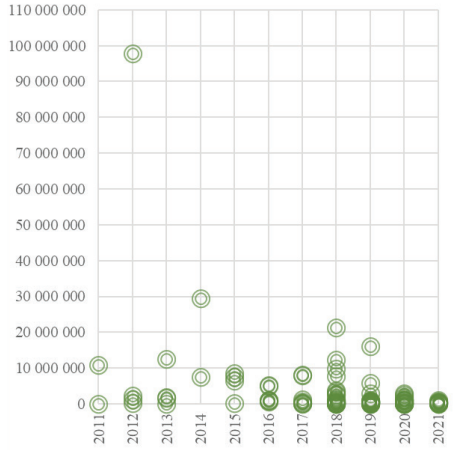

Figure 3.1. Sample of start-ups in the Lithuanian association database by received funding and their launch year.

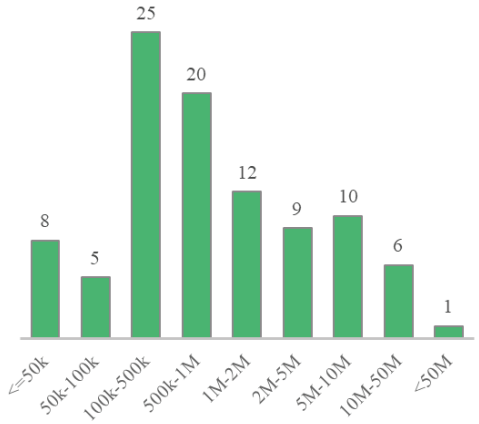

Figure 3.2. Sample of start-ups in the Lithuanian association database in clusters by received funding.

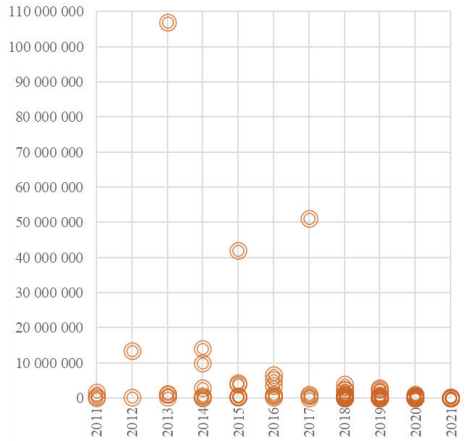

Figure 4.1. Sample of start-ups in the Latvian association database by received funding and their launch year.

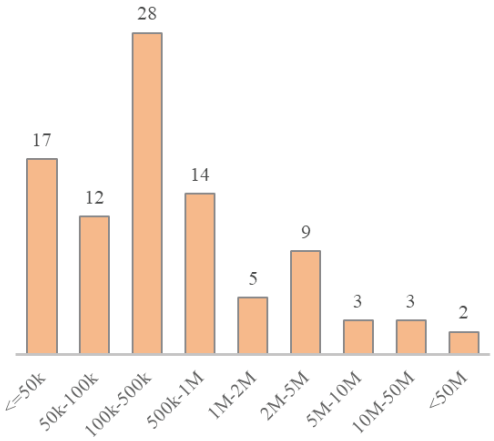

Figure 4.2. Sample of start-ups in the Latvian association database in clusters by received funding.

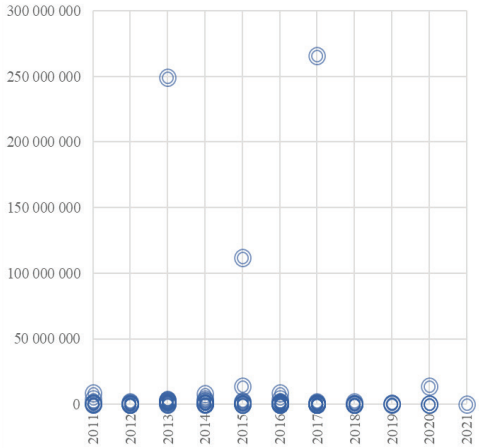

Figure 5.1. Sample of start-ups in the Estonian association database by turnover in 2021 and their launch year.

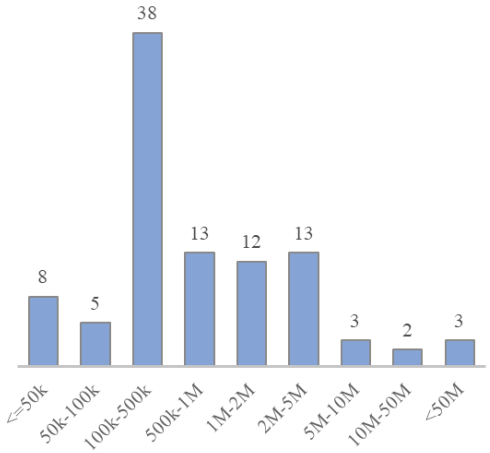

Figure 5.2. Sample of start-ups in the Estonian association database in clusters by turnover in 2021.

Estonian start-up turnover in 2021 Q4 shows similar trends as funding in Latvia and Lithuania. Not counting a couple of exceptions, most of the start-ups of the Estonian association in 2021 had turnover under 5 million EUR (Figures 5.1. and 5.2.). The biggest cluster (39%) consists of start-ups with turnover of 100 to 500 thousand EUR, followed by start-ups with turnover of 500 thousand to 5 million EUR in 2021 (what takes together another 39% of all analyzed start-ups).

Conclusions

Analyzing the available literature and the start-up databases, the authors conclude that start-ups are an important factor in economic growth; therefore, the development of start-up ecosystems will be rapidly growing in the future, as in recent years there has been a positive growth tendency in all Baltic countries.

It can be concluded that Latvian association of start-ups is different from its counterparts in Lithuania and Estonia. It might be assumed that it affects the divergence of the number of start-ups registered in databases. In Latvia, this number is almost 10 times lower than in other Baltic states.

Differences in the data included in the database and the methodology of their display hinder the possibility to fully compare the start-ups included in all three associations' databases.

The Lithuanian start-up association has been operating for the longest time – since 2012. The Estonian Start-up Association has been operating since 2015 and the Latvian one since 2016. Looking at the form of activity – in Lithuania and Estonia start-up associations are state-owned companies, but in Latvia it is a non-governmental organization, hence the funding model is different – in Lithuania and Estonia the associations are funded by the state, but in Latvia by the member fee. Common factors are visibility and some special offers for members of databases in all three Baltic countries.

It is difficult to evaluate and compare start-ups due to the different methodologies of the companies represented in the Baltic associations, because the variants (sectors, market, type) indicated in each country are different, only a small part overlaps. Also, some companies have indicated a number of sectors of activity, but some have not indicated them at all. Similar conclusions can be drawn regarding start-ups division by business models. Some companies have indicated more than one business model used; however, some companies have not indicated any model used.

The authors suggest that it is necessary to review the form and sources of funding for the Latvian start-up association at the national level, as this is an obstacle to the development of the Latvian start-up ecosystem compared to the rest of the Baltic States. In further research, it is planned to investigate the factors that influence start-ups and how to increase and promote start-ups in Baltic states.

References

Audretsch, D., & Keilbach, M. (2004). Entrepreneurship capital and economic performance. *Reg. Stud.*, 38, 949–959. DOI: 10.1080/0034340042000280956.

Battistella, C., De Toni, A.F., & Pessot, E. (2018). Framing open innovation in start-ups' incubators: A complexity theory perspective. *J. Open Innov. Technol. Mark. Complex.*, *4*, 33. DOI: 10.3390/joitmc4030033.

Blank, S., & Dorf, B. (2020). *The Startup Owner's Manual: The Step-By-Step Guide for Building a Great Company.* Retrieved January 29, 2022, from https://books.google.lv/books?hl=en&lr=&id=3p_ODwAAQBAJ&oi=fnd&pg=PR29&ots=ePqExs9WLr&sig=EdMFkPDjfPNry-qjalaLA7Nqrzo&redir_esc=y#v=onepage&q&f=false.

Cockayne, D. (2019). What is a start-up firm? A methodological and epistemological investigation into research objects in economic geography. *Geoforum* 2019, 107, 77–87. DOI: 10.1016/j.geoforum.2019.10.009.

Dackevičiene, A., Võrk, A., & Karanikolos, M. (2021). Lessons learned from the Baltic countries' response to the first wave of COVID-19. Health Policy. DOI: 10.1016/j.healthpol.2021.12.003.

Devadiga, N.M. (2017). Software engineering education: Converging with the startup industry. In Proceedings of the 2017 IEEE 30th Conference on Software Engineering Education and Training (CSEE&T), Savannah, GA, USA, 7–9. DOI: 10.1109/CSEET.2017.38.

Grant Thornthon (2019). Influence of start-ups on the Estonian economy just keeps increasing. Retrieved January 3, 2022, from https://www.grantthornton.ee/en/insights1/2019-influence-of-start-ups-on-the-estonian-economy-just-keeps-increasing/.

Magnetic Latvia (2022). 10 Biggest Latvian Startup Investmentsbin 2021. Retrieved January 2, 2022, from https://labsoflatvia.com/en/news/10-biggest-latvian-startup-investments-in-2021.

Oxford University press (2022). Definition of association noun from the Oxford Advanced American Dictionary. Retrieved January 24, 2022, from https://www.oxfordlearnersdictionaries.com/definition/american_english/association.

Pustovrh, A., Rangus, K., & Drnovšek, M. (2020). The role of open innovation in developing an entrepreneurial support ecosystem. Technol. Forecast. Soc. Chang., 152, 119892. DOI: 10.1016/j.techfore.2019.119892.

Reisdorfer-Leite, B., de Oliveira, M.M., Rudek, M., Szejka, A.L., & Junior, O.C. (2020). Start-up Definition Proposal Using Product Lifecycle Management. In Proceedings of the IFIP International Conference on Product Lifecycle Management, Rapperswil, Switzerland, 5-8 July 2020, pp. 426–436.

Segura, F.M. (2019). El perfil emprendedor y la intensidad competitiva del mercado como predictores de supervivencia en microempresas mexicanas. Contad. Adm. 65, 1–27.

Sifted (2022). The Baltic startups and scaleups to watch in 2021. Retrieved February 11, 2022, from https://sifted.eu/rankings/baltic-startups-top-rankings.

Startin.LV (2022). Latvian startup association (NGO)What is Startin.LV? Retrieved February 14, 2022, from https://startin.lv/learn-more/.

Startup Estonia (2022). What does Startup Estonia do? Retrieved February 14, 2022, from https://startupestonia.ee/.

Startup Lithuania (2022). One stop shop for current and future startups in Lithuania. Retrieved February 14, 2022, from https://www.startuplithuania.com/.

Trinh, T. (2019). Factors Affecting Startup Performance of Small and Medium-sized Enterprises in Danang City. Entrepreneurial Business and Economics Review, 7(3), 187–203. DOI: 10.15678/EBER.2019.070310.

Tripathi, N., Seppänen, P., Boominathan, G., Oivo, M., & Liukkunen, K. (2019). Insight into startup ecosystems through exploration of multi-vocal literature. Inf. Softw. Technol. 104, 56–77.

Webb, E., Winkelmann, J., Scarpetti, G., Behmane, D., Habicht, T., Kahur, K., Kasekamp, K., Köhler, K., Miščikiene, L., Misins, J., Reinap, M., Slapšinskaite-Dackevičienė, A., Võrk, A., & Karanikolos, M. (2021). Lessons learned from the Baltic countries' response to the first wave of COVID-19. Health Policy. 2021 Dec 13, S0168-8510(21)00293-1. DOI: 10.1016/j.healthpol.2021.12.003.

COMPARISON OF MODELS FOR SHEAR AT INTERFACE BETWEEN CONCRETE CAST AT DIFFERENT TIMES

***Atis Dandens**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: atis.dandens@llu.lv

Abstract
Dissimilar models for shear at interface between concrete cast at different times have been developed and included in European Standard EN 1992-1-1 (EN), next generation European Standard prEN 1992-1-1 (prEN) and American Concrete Institute Standard ACI 318-19 (ACI) based on previous research. It is necessary to compare models to identify dissimilarities and the need for further investigation. Two types of surfaces were chosen for comparison – very smooth and indented according to EN classification. Five concrete strength classes were selected for comparison – C20/25, C25/30, C30/37, C35/45 and C40/50 according to European Standard EN 206. Design shear resistance for each surface type and each concrete strength class corresponding to the assumed values of reinforcement ratio was calculated according to EN, prEN and ACI specifications. Models for shear at interface between concrete cast at different times included in standards EN, prEN and ACI provide dissimilar results. There is a negligible difference between design shear resistance at a lower reinforcement ratio for a very smooth surface. However, maximum design shear resistance varies significantly – up to 38%. There is a significant variation between design shear resistance for the indented surface at all values of reinforcement ratio. Maximum design shear resistance varies up to 27%.
Key words: adhesion, concrete, design shear resistance, friction, interface, shear connection.

Introduction

Shear at the interface between concrete cast at different times has been studied since the 1960s. The shear friction hypothesis has been formulated (Birkeland & Birkeland, 1966). Tests have been performed to investigate shear transfer in reinforced concrete, formulate a hypothesis for the behaviour of connections and present equations for the design (Mattock & Hawkins, 1972). A model for shear transfer of keyed connections has been developed (Tassios & Tsoukantas, 1978). Results of the research have been summarised in technical publications such as fib Bulletin 43. Dissimilar models have been included in European Standard EN 1992-1-1 (EN) and American Concrete Institute Standard ACI 318-19 (ACI). The main difference between the models – there is no coefficient for adhesion involved in the ACI model.

It has been found that finite element analysis gives a significantly better estimation of capacity for keyed shear joints than the use of equations presented in EN (Herfelt *et al*., 2016). This shows the need to analyse and improve the model included in the EN. New models for shear joints taking into account the dowel action of the reinforcement have been proposed (Sorensen *et al*., 2017). The results of recent studies have been included in the next generation of European Standard prEN 1992-1-1 (prEN).

The aim of the study is to compare models for shear at the interface between concrete cast at different times, given in standards EN, prEN and ACI and used by most European and American structural engineers, to identify dissimilarities and the need for further investigation.

Materials and Methods

Two types of surfaces were chosen for comparison – very smooth and indented according to EN classification. A very smooth surface is surface cast against steel, plastic or specially prepared wooden moulds. An indented surface is a surface with indentations (Figure 1). Surfaces, conditions of surfaces and corresponding factors for adhesion, c and friction, μ according to EN are shown (Table 1).

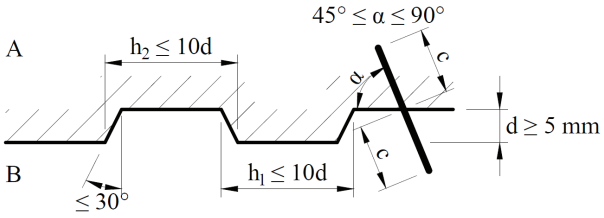

Figure 1. Indented surface according to EN.

A – new concrete, B – old concrete, c – anchorage of reinforcement, d – depth of indentations, h_1 and h_2 – the height of indentations, α – the angle between the reinforcement and surface plane. Figure prepared based on Figure 6.9 of EN.

Table 1

Surfaces, conditions and corresponding factors according to EN

Surface	Conditions of surface	Factor for adhesion[a], c	Factor for friction[b], μ
Very smooth	A surface cast against steel, plastic or specially prepared wooden moulds	0.025 to 0.10	0.5
Indented	A surface with indentations (Figure 1)	0.5	0.9

[a] Adhesion is the molecular force of attraction in the area of contact between bodies;
[b] Friction is the force resisting the sliding of one solid body against another.

The indented surface is named as 'keyed' in prEN. Minimum key height, h_1 and h_2, is given as 3d, where d is the depth of keys (Figure 2). Limits for ratio h_1 / h_2 are given as 0.5 to 2. The minimum α value for the interface reinforcement is reduced from 45° to 35°. It is stated that the key area must be calculated by multiplying key width, $b_{i,eff}$ by key length, $l_{i,eff}$ and factors for keyed interface shall be applied for the area of each key considering its concrete strength. Different symbols of factors for adhesion and friction are used, c_{v1} and μ_v, respectively. Next generation European Standard prEN 1992-1-1 (prEN) specifies lower factor values for adhesion to both very smooth and indented surfaces, 0.0095 and 0.37, respectively. However, factors for friction are the same – 0.5 and 0.9. Surfaces, conditions of surfaces and corresponding factors for adhesion, c_{v1} and friction, μ_v, according to prEN, are shown (Table 2).

ACI specifies contact surface conditions and corresponding coefficients of friction, μ. No coefficients for adhesion are involved. Contact surface condition when concrete is placed against hardened concrete that is clean, free of cement laitance, and not intentionally roughened was compared to a very smooth surface. Contact surface condition when concrete is placed against hardened concrete that is clean, free of cement laitance, and intentionally roughened to a full amplitude of approximately 1/4 in (6.35 mm) was compared to the indented surface. ACI specifies higher coefficient values for friction for normal weight concrete to both very smooth and indented surfaces, 0.6 and 1.0, respectively.

Five concrete strength classes were selected for comparison – C20/25, C25/30, C30/37, C35/45 and C40/50 according to European Standard EN 206. Corresponding characteristic cylinder compressive

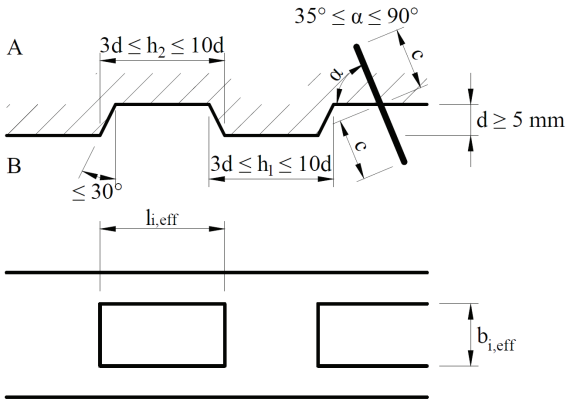

Figure 2. Keyed interface according to prEN.

A – new concrete, B – old concrete, $b_{i,eff}$ – width of key, c – anchorage of reinforcement, d – depth of keys, h_1 and h_2 – the height of keys, $l_{i,eff}$ – length of the key, α – the angle between interface plane and reinforcement. Figure prepared based on Figure 8.15 of prEN.

Table 2

Surfaces, conditions and corresponding factors according to prEN

Surface	Conditions of surface	Factor for adhesion, c_{v1}	Factor for friction, μ_v
Very smooth	A surface cast against steel, plastic or specially prepared wooden moulds	0.0095	0.5
Keyed	A surface with shear keys (Figure 2)	0.37	0.9

strength, f_{ck} values were used in calculations according to EN and prEN. Specified compressive strength of concrete, f_c' values used in calculations according to ACI were assumed to be the same as f_{ck} values.

EN specifies that the characteristic yield strength of reinforcement, f_{yk}, must be 400 to 600 N mm^{-2}. Next generation European Standard prEN 1992-1-1 (prEN) defines six reinforcing steel strength classes with corresponding characteristic values of yield strength of reinforcement, f_{yk} from 400 N mm^{-2} to 700 N mm^{-2}. ACI states that specified yield strength for non-prestressed deformed reinforcement, f_y for shear friction design must not exceed 60 000 psi (414 N mm^{-2}). Characteristic yield strength of reinforcement, f_{yk} for calculations according to EN and prEN was assumed to be 400 N mm^{-2}. Specified yield strength for non-prestressed reinforcement, f_y, used in calculations according to ACI, was assumed to be the same as f_{yk}, 58 015 psi, respectively.

Equation (6.25) of the EN was used for the calculation of design shear resistance at the interface, v_{Rdi}:

$$v_{Rdi} = cf_{ctd} + \mu\sigma_n + \\ + \rho f_{yd}(\mu \sin\alpha + \cos\alpha) \leq 0.5\nu f_{cd} \quad (1)$$

where:

c is a factor for adhesion that depends on the roughness of the interface (Table 1). For a very smooth surface value of c was taken equal to 0.025 in this study;

f_{ctd} is the design tensile strength of concrete, N mm^{-2}. The value of α_{ct} was taken equal to 1 and the value of γ_C was taken equal to 1.5 when calculating design tensile strength of concrete;

μ is a factor for friction that depend on the roughness of the interface (Table 1);

σ_n is stress per unit area caused by the minimum external force perpendicular to the interface plane that acts simultaneously with the shear force, N mm^{-2}. In this study the normal stress was disregarded;

ρ is the reinforcement ratio. Values of ρ were taken in the range from 0 to 0.4 with the step of 0.001 in this study;

f_{yd} is the design yield strength of reinforcement, N mm^{-2}. The value of γ_S was taken equal to 1.15 when calculating design yield strength of reinforcement. The value of f_{yd} equal to 347.8 N mm^{-2} was used in this study;

α is the angle between the reinforcement and surface plane and should be limited by 45° ≤ α ≤ 90° (Figure 1). Angle α was taken as 90° in this study;

ν is a strength reduction factor for concrete cracked in shear;

f_{cd} is the design compressive strength of concrete, N mm^{-2}. The value of α_{cc} was taken equal to 1 when calculating design compressive strength of concrete;

Equation (8.60) of the prEN was used for the calculation of design shear stress resistance at the interface, τ_{Rdi}:

$$\tau_{Rdi} = c_{v1}\sqrt{f_{ck}} / \gamma_C + \mu_v\sigma_n + \\ + \rho_i f_{yd}(\mu_v \sin\alpha + \cos\alpha) \leq 0.25 f_{cd} \quad (2)$$

where:

c_{v1} is a factor for adhesion that depends on the roughness of the interface (Table 2). The factor for the keyed interface was applied for the area of keys which was taken as half of the joint area in this study. The factor for very smooth interface was applied to the remaining area;

f_{ck} is the lowest compressive strength of the concretes at the interface, N mm^{-2};

γ_C is a partial factor for concrete. The value of γ_C was taken equal to 1.5 in this study;

μ_v is a factor for friction that depends on the roughness of the interface (Table 2). The factor for the keyed interface was applied for the area of keys which was taken as half of the joint area in this study. The factor for very smooth interface was applied to the remaining area;

σ_n is the compressive stress over the interface area A_i, caused by the minimum external axial force across the interface that acts simultaneously with the shear force, N mm^{-2}. The value of σ_n was taken equal to 0 N mm^{-2} in this study;

ρ_i is the reinforcement ratio. Values of ρ_i were taken in the range from 0 to 0.4 with the step of 0.001 in this study;

f_{yd} is the design yield strength of reinforcement, N mm^{-2}. The value of γ_S was taken equal to 1.15 when calculating design yield strength of reinforcement. The value of f_{yd} equal to 347.8 N mm^{-2} was used in this study;

α is the angle between interface plane and reinforcement and should be limited by 35° ≤ α ≤ 90° (Figure 2). Angle α was taken as 90° in this study;

f_{cd} is the design compressive strength of concrete, N mm^{-2}. The value of η_{cc} was taken equal to 1, the value of k_{tc} was taken equal to 1 and the value of γ_C was taken equal to 1.5 when calculating design compressive strength of concrete.

Equation (22.9.4.3) of the ACI was used for the calculation of nominal shear strength across the assumed shear plane, V_n:

$$V_n = A_{vf} f_y(\mu \sin\alpha + \cos\alpha) \quad (3)$$

where:

A_{vf} is the area of reinforcement crossing the assumed shear plane to resist shear, mm^2;

f_y is the specified yield strength of reinforcement, N mm^{-2}. The value of f_y was taken equal to 400 N mm^{-2} in this study;

Table 3

Maximum nominal shear strength according to ACI

Conditions of surface	Maximum nominal shear strength, V_n, N	
Concrete placed against hardened concrete that is clean, free of cement laitance, and not intentionally roughened	Lowest value of	$0.2f_c'A_c$; $5.52A_c$
Concrete placed against hardened concrete that is clean, free of cement laitance, and intentionally roughened to a full amplitude of approximately 1/4 in (6.35 mm)	Lowest value of	$0.2f_c'A_c$; $(3.31 + 0.08f_c')A_c$; $11.03A_c$

μ is the coefficient of friction;

α is the angle between shear-friction reinforcement and the assumed shear plane. Angle α was taken as 90° in this study.

ACI specifies that the nominal shear strength across the assumed shear plane, V_n, shall not exceed the limits (Table 3).

For comparison purposes, nominal shear strength, V_n and specified yield strength of reinforcement, f_y, were divided by A_c in Equation (3). Nominal shear strength, V_n, was multiplied by the strength reduction factor, ϕ, to obtain the design shear strength. The value ϕ was taken equal to 0.75 in this study.

Results and Discussion

The relationship between reinforcement ratio, ρ and design shear resistance, v_{Rdi}, for a very smooth surface for concrete strength classes selected for comparison are shown in Figure 3. There are negligible variations between values of design shear resistance determined using models of different standards at lower reinforcement ratio for all concrete strength classes considered. Maximum design shear resistance, $v_{Rdi,max}$ is different for a very smooth surface (Table 4).

The highest maximum design shear resistance, $v_{Rdi,max}$ for a very smooth surface for all concrete strength classes obtained by calculations according to EN – values are 1 to 38% higher depending on the concrete strength class and standard. The lowest design shear resistance for all concrete strength classes obtained when calculated according to ACI – values are 10 to 38% lower compared to those obtained according to prEN.

The relationship between reinforcement ratio, ρ and design shear resistance, v_{Rdi} for the indented

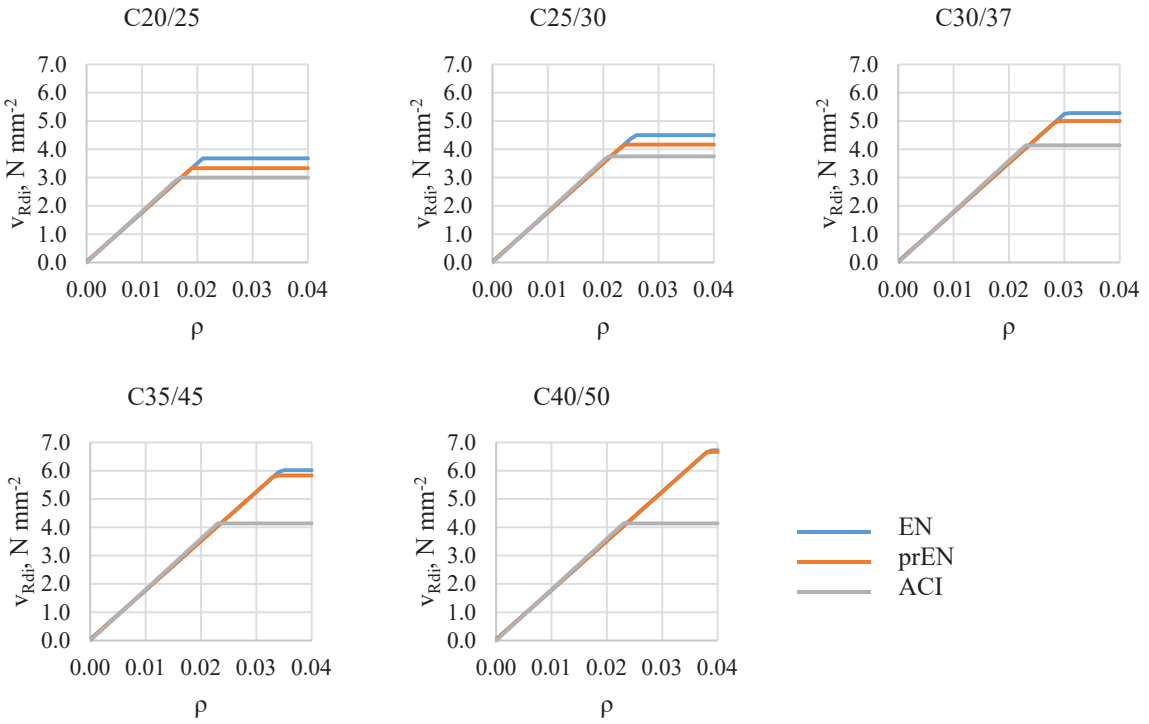

Figure 3. Relationship between reinforcement ratio, ρ and design shear resistance, v_{Rdi} for a very smooth surface.

Table 4

Comparison of maximum design shear resistance for a very smooth surface

Concrete strength class	Maximum design shear resistance, $v_{Rdi,max}$, N mm^{-2}, according to			Ratios	
	EN	prEN	ACI	prEN / EN	ACI / EN
C20/25	3.7	3.3	3.0	0.91	0.82
C25/30	4.5	4.2	3.8	0.93	0.83
C30/37	5.3	5.0	4.1	0.95	0.78
C35/45	6.0	5.8	4.1	0.97	0.69
C40/50	6.7	6.7	4.1	0.99	0.62

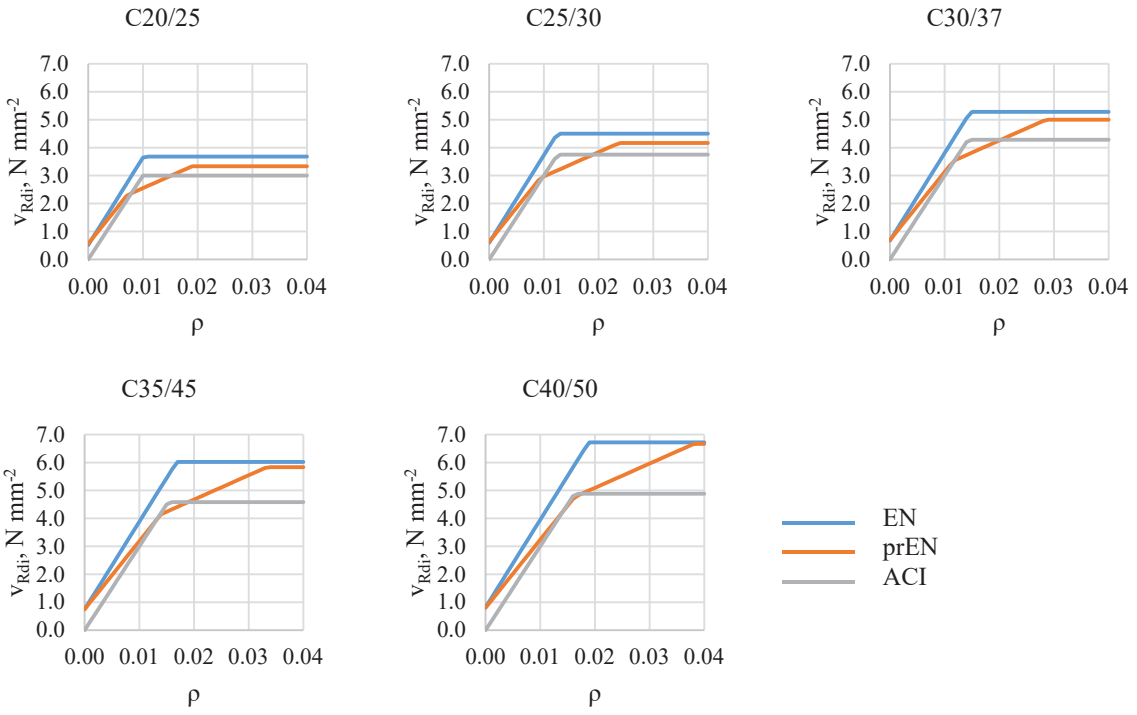

Figure 4. Relationship between reinforcement ratio, ρ and design shear resistance, v_{Rdi} for the indented surface.

surface for concrete strength classes selected for comparison are shown in Figure 4. There are variations between values of design shear resistance determined using models of different standards for all concrete strength classes considered. A comparison of design shear resistance, $v_{Rdi,0.001}$ for the indented surface at a reinforcement ratio value of 0.001 is shown in Table 5.

The highest design shear resistance, $v_{Rdi,0.001}$ for the indented surface at reinforcement ratio, ρ value of 0.001 for all concrete strength classes obtained by calculations according to EN – values are 2 to 73% higher depending on the concrete strength class and standard. The lowest design shear resistance for all concrete strength classes obtained when calculated according to ACI – values are 63 to 71% lower compared to those obtained according to prEN. A comparison of maximum design shear resistance, $v_{Rdi,max}$ for the indented surface is shown in Table 6.

The highest maximum design shear resistance, $v_{Rdi,max}$ for the indented surface for all concrete strength classes obtained by calculations according to EN – values are 1 to 27% higher depending on the concrete strength class and standard. The lowest design shear resistance for all concrete strength classes obtained when calculated according to ACI – values are 27 to 90% lower compared to those obtained according to prEN.

There is no coefficient for adhesion involved in the ACI model. Nevertheless, there is only negligible variation between design shear resistance determined using models of different standards for a

Table 5

Comparison of design shear resistance for the indented surface

Concrete strength class	Design shear resistance, $v_{Rdi,0.001}$ [a], N mm^{-2}, according to			Ratios	
	EN	prEN	ACI	prEN / EN	ACI / EN
C20/25	0.83	0.81	0.30	0.98	0.36
C25/30	0.91	0.88	0.30	0.96	0.33
C30/37	0.99	0.94	0.30	0.95	0.30
C35/45	1.06	0.99	0.30	0.93	0.28
C40/50	1.13	1.04	0.30	0.92	0.27

[a] Design shear resistance, $v_{Rdi,0.001}$, given at reinforcement ratio, ρ value of 0.001.

Table 6

Comparison of maximum design shear resistance for the indented surface

Concrete strength class	Maximum design shear resistance, $v_{Rdi,max}$, N mm^{-2}, according to			Ratios	
	EN	prEN	ACI	prEN / EN	ACI / EN
C20/25	3.7	3.3	3.0	0.91	0.82
C25/30	4.5	4.2	3.8	0.93	0.83
C30/37	5.3	5.0	4.3	0.95	0.81
C35/45	6.0	5.8	4.6	0.97	0.76
C40/50	6.7	6.7	4.9	0.99	0.73

very smooth surface at a lower reinforcement ratio. A higher value of the coefficient for friction defined in the ACI compensates for the lack of coefficient for adhesion.

There are factors for adhesion with relatively high values for the indented surface involved in the models of EN and prEN. Therefore, there is significant variation between the design shear resistance obtained using models of EN and prEN compared to that derived using a model of ACI at a lower reinforcement ratio. The variations between values determined according to EN and prEN increase as the reinforcement ratio increases. This is because factors for keyed interface were applied for the area of keys, according to requirements of prEN, which was taken half of the joint area in this study. To the remaining area, factors for a very smooth interface were applied.

Maximum design shear resistance determined using models of different standards for very smooth and indented surfaces is varied for all concrete classes considered. The variations between the values determined according to EN and prEN decrease as the strength class of the concrete increases, while the variations between the values determined according to EN and ACI increase. The upper limit of the shear strength defined in the standards is different.

Conclusions

Models for shear at interface between concrete cast at different times included in European Standard EN 1992-1-1, in the next generation European Standard prEN 1992-1-1 and American Concrete Institute Standard ACI 318-19 give dissimilar results. There is a negligible difference between design shear resistance at a lower reinforcement ratio for a very smooth surface. However, maximum design shear resistance varies significantly – up to 38%. There is a significant variation between design shear resistance for the indented surfaces at all values of reinforcement ratio. Maximum design shear resistance varies up to 27%.

In future research, results obtained using models included in standards need to be validated using the nonlinear finite element analysis and experimental load tests. It is necessary to develop a model for economical solutions with the required level of reliability.

Acknowledgements

This study was carried out within the project 'Modelling of Shear Behaviour of Connections Between Concrete Structures' funded by the Latvia University of Life Sciences and Technologies program 'Strengthening of Scientific Capacity at LLU'. Project number: Z54.

References

American Concrete Institute. (2019). Building Code Requirements for Structural Concrete. Commentary on Building Code Requirements for Structural Concrete. ACI 318-19. ACI 318R-19. Detroit.

Birkeland, W.P., & Birkeland, W.H. (1966). Connections in Precast Concrete Construction. *Journal of the American Concrete Institute*. 63(3), 345–368.

European Committee for Standardization. (2004). Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings. EN 1992-1-1. Brussels.

European Committee for Standardization. (2021). Concrete – Specification, performance, production and conformity. EN 206. Brussels.

European Committee for Standardization. (2021). Eurocode 2: Design of concrete structures – Part 1-1: General rules – Rules for buildings, bridges and civil engineering structures. DRAFT prEN 1992-1-1. Brussels.

Herfelt, A.M., Poulsen, N.P., Hoang, C.L., & Jensen, F.J. (2016). Numerical Limit Analysis of Keyed Shear Joints in Concrete Structures. *Structural Concrete*. 17 (3), 481–490. DOI: 10.1002/suco.201500161.

International Federation for Structural Concrete (fib). (2008). *fib Bulletin 43: Structural connections for precast concrete buildings*. Stuttgart: Sprint-Digital-Druck.

Mattock, H.A., & Hawkins, M.N. (1972). Shear Transfer in Reinforced Concrete – Recent Research. *PCI Journal*. 55–75. 17 (2), 55–75. DOI: 10.15554/pcij.03011972.55.75.

Sorensen, H.J., Hoang, C.L., Olesen, F.J., & Fischer, G. (2017). Testing and Modeling Dowel and Catenary Action in Rebars Crossing Shear Joints in RC. *Engineering Structures*. 145, 234–245. DOI: 10.1016/j.engstruct.2017.05.020.

Tassios, P.T., & Tsoukantas, G.S. (1978). Behaviour of Large-Panel Connections. *Batiment International, Building Research and Practice*. 11 (4), 226–232. DOI: 10.1080/09613218309442126.

TOWARDS 'BEYOND THE ZERO WASTE CONCEPT': INNOVATIVE SOLUTIONS FOR VALORIZATION OF FINE RESIDUAL WASTE FRACTION FROM LANDFILLS: RARE EARTH ELEMENTS POTENTIAL

***Juris Burlakovs[1], Ruta Ozola-Davidane[2], Zane Vincevica-Gaile[2], Magdalena Wdowin[1], Inga Grinfelde[3], Jovita Pilecka-Ulcugaceva[3], Ivar Zekker[4]**
[1]Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Poland
[2]University of Latvia, Latvia
[3]Latvia University of Life Sciences and Technologies, Latvia
[4]University of Tartu, Estonia
*Corresponding author's email: juris@geo-it.lv

Abstract
The growing population of the planet and the population's desire for ever-higher welfare standards have contributed to a linear economy-based consumer society model that is one of the main reasons for the increased volume of waste. Global sustainability, mitigation of climate change, and the reduction of pollution are strongly related to the waste management issue, and there is a need to switch from linear economy models to the circular economy. The maintaining solution for keeping and storing waste over the last century has been landfilling as its costs are the lowest. A sustainable approach such as landfill mining (LFM) can be applied to recover rare earth elements (REEs) and other valuable metals from waste that make fundamental assets in terms of economy and essential for developing industrial technologies. This study investigated concentrations of REEs and other metals in waste material. Samples from Ida-Virumaa (Estonia) landfilled waste fine fraction were taken to estimate the element concentration proceeded through sequential extraction. Additionally, the method of clay modification was developed that may serve as a sorbent to extract the REEs from the inert landfill fine fraction waste using hydroxyapatite modified clay. The amount of REEs might become of industrial interest if a feasible landfill mining approach for remediation of landfills and degraded industrial soils is applied together with innovative recovery methods, e.g., sorption by modified clays.
Key words: landfill mining, modified clay sorbents, resources recovery, waste valorization.

Introduction

We can assess seventeen Sustainable Development Goals (Nations, 2015) in case if six transformations of our economies are made (Sachs *et al*., 2019). The Europe Green Deal is based on six transformations, but the decarbonization and digitalization increase the demand for rare elements (REEs) and intensify risks of environmental pollution and hazardous waste disposal problem. The only solution is to transform from a linear economy to a circular economy, where waste is transformed into a resource.

Maintenance and storage of the waste is a key goal for the circular economy, and the purpose for that is the lowest possible cost with maximum environmental benefit. A kind of sustainable approach called landfill mining (LFM), means digging out and processing untreated old dump deposited materials (Krook, Svensson, & Eklund, 2012). Environmental concerns are respective to contaminated areas, often old dumpsites included (Kabata-Pendias, 2000). Mixed half-degraded and degraded inert material often create pollution problems with contamination leaching out to the environment. The problem is also the stability and bioavailability of potential contaminants as a threat to the environment (Burlakovs *et al*., 2013; Saaremäe *et al*., 2013). Waste could contain toxic chemical elements deeming it hazardous (Burlakovs *et al*., 2013). Dumpsites and landfills are extensive resources – it is as stock for the future that we can mine as a resource. Valuable materials might appear nevertheless of chemical extraction difficulties with nowadays technology – the rare earth elements resources (Burlakovs *et al*., 2020).

Technology advances at the highest level move on the electronic device market. More powerful, more efficient, and faster devices are released each year. As a result, thousands of tons of electronic devices are discarded annually as consumers upgrade to newer versions. These components are becoming one of the fastest-growing waste segments globally (Ruan & Xu, 2016). Fluctuating 'supercycles' of commodity markets are sharply affecting minerals and – especially, rare earth resource prices. Demand is high; supply is low. It is the market game. LFM might be one of the extra solutions when rising prices play a greater role in raising the value of previously unconsidered resources for use (Burlakovs *et al*., 2013).

Overall, the largest opportunity is mining from historical dumps macroelements such as Zn, Al, Fe, P, Ni, Cu, and others; on the other hand, in this way, we diminish the dissipation of unwanted concentrations to the environment (Burlakovs *et al*., 2015; Vincēviča-Gaile, 2014).

There are many sorption materials (raw as well as modified) that are used for the removal of REEs from aqueous solutions, e.g., carbonized polydopamine nano carbon shells (Xiaoqi *et al*., 2016), granular hybrid (Zhu, Zheng, & Wang, 2015), modified clays

Figure 1. Clay modification with hydroxyapatite and possible usage in REEs recovery.

(Gładysz-Płaska, Majdan, & Grabias, 2014), and many others (Krauklis *et al*., 2017; Ozola *et al*., 2019; Ozola, Klavins, & Burlakovs, 2018). After the removal of REEs from aqueous solutions, clay sorbents can also be used to recover these valuable elements (Iannicelli-Zubiani *et al*., 2017) (Figure 1).

The work aimed to explore the concentration of various elements in the samples derived from a landfill site situated in Ida-Virumaa (Estonia), taken from fine fraction of waste, as well as try to develop an innovative type of sorbent that can be used to recover lost REEs through the process of sorption.

Materials and Methods

Materials, sampling, and preparation

The waste sampling was done in the Ida-Virumaa landfill site (Estonia), and preparation was done according to the methodology described in previous works (Burlakovs *et al*., 2016; Hogland *et al*., 2018).

To develop a clay sorbent montmorillonite (Mt), the material with the trade name Montmorillonite K10 was used. According to the product specification, montmorillonite is a faint grey powder with pH 2.5-3.5, with a specific weight 300-370 kg m^{-3} and surface area 220-270 m^2 g^{-1}. The cation exchange capacity (CEC) of the Mt clay is 0.50±0.03 mmol g^{-1} (determined by the methylene blue test). Lanthanum (III), neodymium (III), and cerium (III) as model REEs were chosen for sorption experiments. Analytical grade chemicals and deionized water was used in experiments (10-15 MΩ cm^{-1}) purified in a standard way.

Sequential extraction

To obtain the results and analyze the bioavailability and mobility of metals, fine fraction was performed by sequential extraction. These areas have future potential recovery materials (Burlakovs *et al*., 2013).

The extraction procedure was worked out in various steps, water-soluble fraction was determined as the first one. A sample of 3 g was taken in 100 mL glass beaker; 40 °C water was added, and the beaker was shaken mechanically. It was filtered by 0.45 µm membrane filter, and acidified in a tube with 0.2 mL of HNO_3 (1:1) solution, then left at +4 °C.

Sequentially, acid-soluble fraction was determined through the use of 40 mL of 0.11 M CH_3COOH; afterward, extraction of 16 hours was performed. Filtering followed again with acidification.

The last step was a reducible fraction where 0.5 M $NH_2OH{\times}HCl$ was added. The same procedures with shaking and acidification were done as in the previous two steps.

Sorbent development and sorption experiments

Mt clay modification with synthetic hydroxyapatite (Hap, $Ca_{10}(PO_4)_6(OH)_2$) was prepared by the precipitation method under continuous mechanical stirring as described in previous research (Ozola-Davidane *et al*., 2017). 20 g of clay sample was mixed with 100 mL 0.5 M $CaCl_2$. Then 5 mL of 2 M KH_2PO_4 was slowly added to get 1.667 equimolar proportions of Ca and P. pH for reactions was adjusted with 0.5 M NH_4OH to maintain the range of pH 9 and 9.5. The reaction temperature

was kept at 50 °C. After that, the synthesis mixture was left overnight, then decanted and washed with deionized water until a neutral environment was achieved. Drying was done 24 h at 40 °C. As a result, the composite material has increased sorption sites for positively charged elements, such as model rare earth elements, lanthanum (III), neodymium (III), and cerium (III).

La(III), Ce(III), and Nd(III) from aqueous solutions removal were determined. Sorption-isotherm research included 0.1 g prepared material (Mt-Hap) that was placed in a 100 mL glass vessel and added with 100 mL of La(III), Ce(III), or Nd(III)with concentrations of 5 mg L^{-1} to 1000 mg L^{-1}. Agitation of 24 h followed by centrifugation at 3000 rpm for 12 min was done, and the supernatants were analyzed using an iCAP7000 coupled plasma-optical emission spectroscopy. The quantity of the model REEs sorbed was calculated as in the formula:

$$q_e = \frac{C_i - C_e}{m * v} \quad (1)$$

where q_e is the amount of La(III), Ce(III), or Nd(III) adsorbed on the sorbent (mg g^{-1}), C_i and C_e are initial and equilibrium liquid-phase concentrations of La(III), Ce(III) or Nd(III) (mg L^{-1}), respectively, v is the volume of solution (mL), and m is mass of sorbent used (g).

Results and Discussion

Results from element fractionation analysis by sequential extraction and total content in Ida-Virumaa landfill have shown a wide range of elements in the inert fine fraction. The highest average concentrations were detected for macro elements as Ca (>55%), Fe (>20%), Al (>12%), and Mg (>5%), followed by microelements. Seemingly one of the reasons for Ca, Fe, Al, and Mg come from the addition of construction and demolition waste in municipal masses as well as from the dissipation of other inert municipal waste after the organic fractions are gone. REEs have also been detected in ranges from 1-40 ppm, which is not a high amount compared to average Clark numbers in geochemistry; however, with improved technologies of separation in the future, the latter's recovery additionally to macroelements might be of the particular interest.

Results of this study presented that the municipal landfill in Ida-Virumaa has slight potential for recovery of metals, and certain REEs might also be of interest. The second part of the study involved modification of the raw clay with hydroxyapatite in order to test theoretical opportunities to recover the REEs from the landfill leachate or other aquatic media linked to industrial wastewaters.

The initial concentration of La(III), Ce(III), and Nd(III) in the range of 5 mg L^{-1} to 1000 mg L^{-1} influenced the sorption of chosen model REEs on the raw and modified Mt clay with hydroxyapatite. Raising La(III), Ce(III), and Nd(III) concentration also increased the sorption capacity of modified clay (Figure 2). It happens due to less occupied sites, i.e., when concentrations are lower, these sites are free. However, sorption capacity of La(III), Ce(III), and Nd(III) by the selected sorbent (Srivastava & Sillanpää, 2017) increases.

The sorption capacity increased more than two times after Mt modification with hydroxyapatite; these ranged from the highest of 284 mg g^{-1} to 252 mg g^{-1} and 255 mg g^{-1} for La(III), Ce(III), and Nd(III), respectively. Ranges of respective concentrations were 1000 mg L^{-1}, 600 mg L^{-1}, and 600 mg L^{-1}.

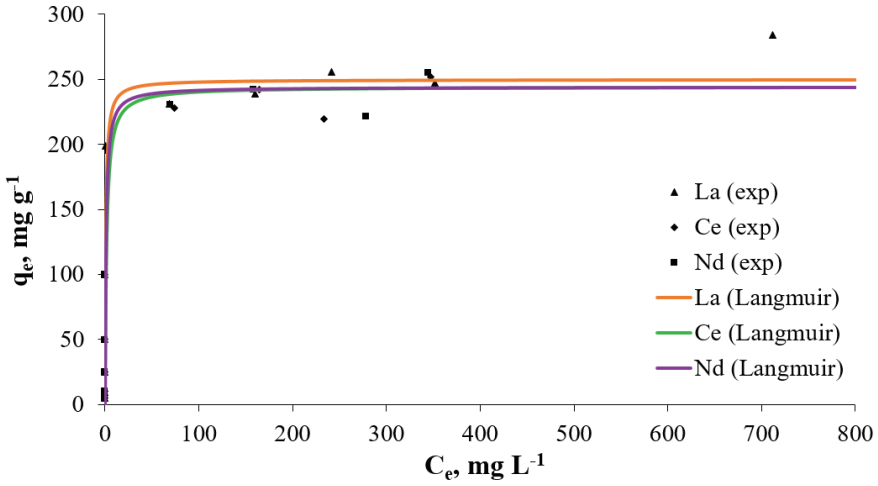

Figure 2. Effect of initial concentration on the removal of lanthanum (III), neodymium (III), and cerium (III) by modified montmorillonite with hydroxyapatite (experimental conditions: Ci = 5–1000 mg L^{-1}, pH = 6, contact time = 24 h, T = 24 °C).

The LFM approach in former dumpsites might play an essential role in the recycling of so-called lost material – it can be called 'hunting the valuables'. The excavated waste provides a theoretical collection of considerably large amounts of rare earth, macro- and microelements. Studies are a part of the complete picture from a circular economy perspective, which in this paper is given as the sketch. On the other hand, new technologies, such as innovative sorbents, should be developed and elaborated to make this action feasible from an economic perspective.

REEs are at significantly lower concentrations than in geological prospects; however, it might be of distinct interest in the future due to scarce supplies and improvement in technology and prices. An innovative approach needed, and further research of sorbents and sorbates for that reason should be performed. Some of the elements regarding preliminary results might be called 'reserves', as we are forced to remediate the land by the law anyway if the concern is about contamination. The most important is to fulfill the SDGs and implement innovation for the recovery of rare earth and other elements, and if it might be done by specific sorption measures. There is additional value if low pollutant concentrations might be cached out of leachate mixtures.

Conclusions

Hereby the study has approved the paradigm of valuables' recovery possible from lost material in dumps and wastewater discharges. The amount of REEs might become of industrial interest if a feasible LFM approach for the reconstruction of past landfills and degraded industrial soils is applied together with innovative recovery methods, e.g., sorption by modified clays. The circular economy perspective is taking a brave course to the resurrection of the last material from the industrial cycle whereas saving the environment from the degradation through reconstruction of ecosystem services and even landscapes. The zero waste and the beyond the zero waste concept must be developed and improved, resulting in higher material standards, but it is not likely that the style of life and attitude of society will change significantly during the foreseeable future.

Acknowledgements

The work was supported by the PASIFIC program GeoReco project funding from the European Union's Horizon2020 research and innovation program under the Marie Sklodowska-Curie grant agreement No 847639 and from the Ministry of Education and Science.

References

Burlakovs, J., Kriipsalu, M., Arina, D., Kaczala, F., Shmarin, S., Denafas, G., & Hogland, W. (2013). Former dump sites and the landfill mining perspectives in Baltic countries and Sweden: the status. In *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM* (Vol. 1, pp. 485–492). DOI: 10.5593/SGEM2013/BA1.V1/S03.035.

Burlakovs, J., Vincevica-Gaile, Z., Krievans, M., Jani, Y., Horttanainen, M., Pehme, K.-M., … Klavins, M. (2020). Platinum group elements in geosphere and anthroposphere: Interplay among the global reserves, urban ores, markets and circular economy. *Minerals*, *10*(6), 1–19. DOI: 10.3390/min10060558.

Burlakovs, J., Kaczala, F., Vincevica-Gaile, Z., Rudovica, V., Orupõld, K., Stapkevica, M., … Hogland, W. (2016). Mobility of Metals and Valorization of Sorted Fine Fraction of Waste After Landfill Excavation. *Waste and Biomass Valorization*, *7*(3), 593–602. DOI: 10.1007/s12649-016-9478-4.

Burlakovs, J., Kaczala, F., Orupõld, K., Bhatnagar, A., Vincevica-Gaile, Z., Rudovica, V., … Klavins, M. (2015). Field-portable X-ray fluorescence spectrometry as rapid measurement tool for landfill mining operations: comparison of field data vs. laboratory analysis. *International Journal of Environmental Analytical Chemistry*, *95*(7), 609–617. DOI: 10.1080/03067319.2015.1036865.

Gładysz-Płaska, A., Majdan, M., & Grabias, E. (2014). Adsorption of La, Eu and Lu on raw and modified red clay. *Journal of Radioanalytical and Nuclear Chemistry*, *301*(1), 33–40. DOI: 10.1007/s10967-014-3111-4.

Hogland, M., Āriņa, D., Kriipsalu, M., Jani, Y., Kaczala, F., de Sá Salomão, A.L., … Hogland, W. (2018). Remarks on four novel landfill mining case studies in Estonia and Sweden. *Journal of Material Cycles and Waste Management*, *20*(2), 1355–1363. DOI: 10.1007/s10163-017-0683-4.

Iannicelli-Zubiani, E.M., Cristiani, C., Dotelli, G., Stampino, P.G., Pelosato, R., & Finocchio, E. (2017). Effect of pH in the synthesis of organo-clays for rare earths removal. *Environmental Engineering and Management Journal*, *16*(8), 1719–1728. DOI: 10.30638/eemj.2017.187.

Kabata-Pendias, A. (2000). *Trace Elements in Soils and Plants*. CRC Press. DOI: 10.1201/9781420039900.

Krauklis, A., Ozola, R., Burlakovs, J., Rugele, K., Kirillov, K., Trubaca-Boginska, A., … Klavins, M. (2017). FeOOH and Mn8O10Cl3 modified zeolites for As(V) removal in aqueous medium. *Journal of Chemical Technology & Biotechnology*, *92*(8), 1948–1960. DOI: 10.1002/jctb.5283.

Krook, J., Svensson, N., & Eklund, M. (2012). Landfill mining: A critical review of two decades of research. *Waste Management*, *32*(3), 513–520. DOI: 10.1016/j.wasman.2011.10.015.

Nations, U. (2015). No Title. *Transforming Our World: The 2030 Agenda for Sustainable Development*.

Ozola-Davidane, R., Krauklis, A., Burlakovs, J., Vincevica-Gaile, Z., Rudovica, V., Trubača-Boginska, A., … Klavins, M. (2017). Illite clay modified with hydroxyapatite – innovative perspectives for soil remediation from lead(II). *Int. J. Agri and Env Res.*, *3*, 177–189.

Ozola, R., Klavins, M., & Burlakovs, J. (2018). Clays, intercalated with organic substances for environmental technologies. In *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM* (Vol. 18, pp. 197–202). DOI: 10.5593/sgem2018/5.2/S20.026.

Ozola, R., Krauklis, A., Burlakovs, J., Klavins, M., Vincevica-Gaile, Z., & Hogland, W. (2019). Surfactant-Modified Clay Sorbents for the Removal of p-nitrophenol. *Clays and Clay Minerals*, *67*(2), 132–142. DOI: 10.1007/s42860-019-00015-2.

Ruan, J., & Xu, Z. (2016). Constructing environment-friendly return road of metals from e-waste: Combination of physical separation technologies. *Renewable and Sustainable Energy Reviews*, *54*, 745–760. DOI: 10.1016/j.rser.2015.10.114.

Saaremäe, E., Liira, M., Poolakese, M., & Tamm, T. (2013). Removing phosphorus with Ca-Fe oxide granules – a possible wetlands filter material. *Hydrology Research*, *45*(3), 368–378. DOI: 10.2166/nh.2013.101.

Sachs, J.D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, *2*(9), 805–814. DOI: 10.1038/s41893-019-0352-9.

Srivastava, V., & Sillanpää, M. (2017). Synthesis of malachite@clay nanocomposite for rapid scavenging of cationic and anionic dyes from synthetic wastewater. *Journal of Environmental Sciences*, *51*, 97–110. DOI: 10.1016/j.jes.2016.08.011.

Vincēviča-Gaile, Z. (2014). *Impact of Environmental Conditions on Micro- and Macroelement Content in Selected Food from Latvia*. University of Latvia.

Xiaoqi, S., Huimin, L., Mahurin, S. M., Rui, L., Xisen, H., & Sheng, D. (2016). Adsorption of rare earth ions using carbonized polydopamine nano carbon shells. *Journal of Rare Earths*, *34*(1), 77–82. DOI: 10.1016/S1002-0721(14)60582-2.

Zhu, Y., Zheng, Y., & Wang, A. (2015). Preparation of granular hydrogel composite by the redox couple for efficient and fast adsorption of La(III) and Ce(III). *Journal of Environmental Chemical Engineering*, *3*(2), 1416–1425. DOI: 10.1016/j.jece.2014.11.028.

CHALLENGES FOR THE DEVELOPMENT OF LOWLAND RIVERS ECOSYSTEM SERVICES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT GOALS

***Dace Grazule[1], Inga Grinfelde[1], Anda Bakute[1], Jovita Pilecka-Ulcugaceva[1], Juris Burlakovs[2], Kristaps Siltumens[1]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Poland
*Corresponding author's email: dace.grazule@tvnet.lv

Abstract
In 2015, the United Nations General Assembly adopted a resolution for sustainable development – the 2030 Agenda. It sets 17 Sustainable Development Goals to reduce global poverty and encourage sustainable international development. Governments worldwide have adopted sustainable development goals for water quality improvement and the revitalization of freshwater ecosystems. They have set ambitious targets for improving water quality by reducing pollution, removing landfills, reducing releases of hazardous chemicals and materials, and protecting and restoring water-related ecosystems, including mountains, forests, wetlands, rivers, and lakes. It is an opportunity to change the degradation of the environment for decades or even centuries and focus seriously on the recovery of the environment. The aim of this study is to analyze the opportunities provided by the ecosystem services of the Svete River at the Jelgava municipal level in the context of the United Nations 17 sustainable development goals. The created matrix offers a deeper understanding of the role of ecosystem services at the local authority level and provides a framework for the further development of ecosystem services. The results of this pilot study can be used as a basis for the development of ecosystem services in municipalities with lowlands.
Key words: Ecosystem services, water quality, ecosystem health, sustainable hydrology.

Introduction

The implementation of sustainable development in Latvia started in early 1990 when the initial national environmental policy was formed, aware of the need to reconcile sustainable economic and social processes with ecological protection needs. In 2002, the guidelines for sustainable development in Latvia were approved, based on the 1992 United Nations (UN) Declaration of the Conference on Sustainable Development. Following the review of the EU Sustainable Development Strategy in 2006, the planning process for the sustainable development of Latvia was based on the UN launch, in which citizens expressed their vision on what Latvia should be in all sustainability dimensions in 2030 (United Nations, 2015).

Latvia's Sustainable Development Strategy until 2030 sets out a spatial development perspective to preserve Latvia's specific natural and cultural heritage, its inherent and unique landscapes. Ecosystem services are part of natural capital. Natural capital shall be allocated to renewable resources, non-renewable resources and ecosystems in services.

Ecosystem services are services such as 'ecological processes that provide and meet the needs of human existence'; services such as the 'benefits that people get from nature' services as 'ecology components directly used to ensure human well-being' (Adukia, 2017; Fisher &Turner, 2008).

The aim of this study is to analyze the opportunities provided by the ecosystem services of the Svete River at the Jelgava municipality level in the context of the UN 17 Sustainable Development Goals (SDG).

Materials and Methods

The Svete River has been chosen as a pilot area because the ecosystem services of the Svete River catchment area in the Jelgava region represent all ecosystem service groups according to Common International Classification of Ecosystem Services (CICES). The Svete River is a water drain of national importance, which according to the Civil Law, is a public river. It is a tributary of the left bank of the Lielupe. The total length of the Svete River is 123 km, of which 75 km are located in the territory of Latvia (Figure 1) and 65.4 km in the Jelgava region, but 48 km – in Lithuania.

In the first reaches of Svete River, on the left bank, there are primary forests, but on the right bank is the city of Jelgava. In this part, the Svete River flows through the nature park 'Svete floodplain', which is part of the Natura2000 network of protected areas. The low areas of the floodplain are delimited from the Svete River by polder dams. The central part of the Svete River mostly flows through intensively managed agricultural areas. Hydroelectric power plants (HPPs) and water reservoirs have been built in three places upstream of Svete River.

This study takes the same approach CICE, and it is a hierarchically formed classification system that categorizes ecosystem services into three main categories: 1) supply services, 2) environmental and support services, 3) cultural services.

The assessment of ecosystem services has been carried out in determining the practical value of ecosystem services: 1) biophysical assessment (the structure and functions of the ecosystem); 2) social

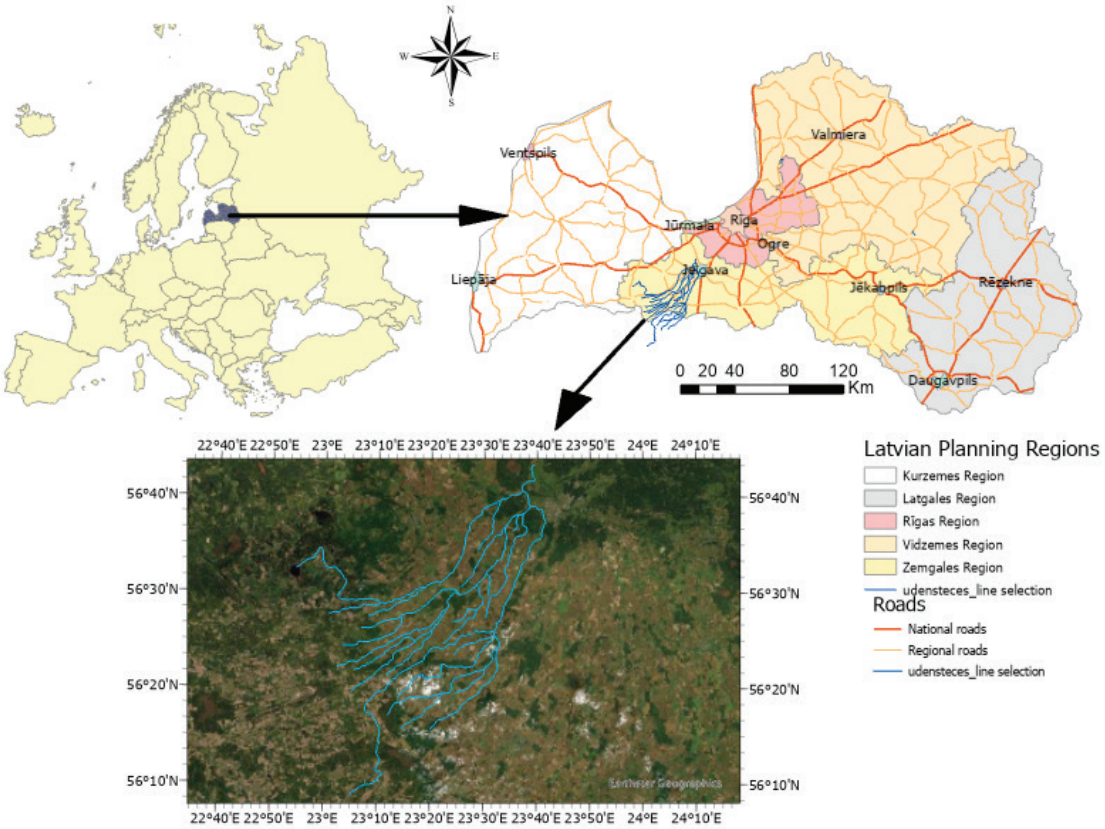

Figure 1. The analysed Svete River catchment area (created by K. Siltumens).

assessment (clarifying ecosystem services of relevance to society); 3) economic assessment.

The values of ecosystem services are allocated to the use-value, the importance accorded by a person, to use nature to meet their needs, to ensure their existence; and fair value arising from the assumption that nature has a 'right of its own' to 'its own existence', regardless of whether people benefit from it.

In this study, ecosystem services were analysed in the context of SDG. A set of ecosystem services for the Svete River was identified for each purpose, geared towards achieving the specific objective.

Results and Discussion

Sustainability is the transmission of the environment we live in to future generations without compromising future generations' living standards and opportunities. Social sustainability is a responsible treatment of people in various contexts but is mainly related to including all sections of society. Environmental sustainability – responsible action to the environment and diversity, focusing primarily on preserving the environment. In turn, economic sustainability is a responsible action from a financial point of view. Economic failure cannot be sustainable.

17 SDG is a new global environmental understanding of economic transformation and sustainable development through responsible consumption and production patterns and clean and affordable energy. It is becoming clear that climate policy, sustainable development and poverty reduction are inextricably linked (United Nations, 2015).

In this study, ecosystem services in the pilot area are identified and analysed in the context of the UN 17 SDG (Figure 2).

SDG-1 Water is an essential resource that affects economic and social systems and is critical in transferring substances and energy. According to United Nations data (Barnaby, 2009), 80% of all jobs worldwide depend on sustainably managed water resources and water-related services, including sanitation and sewage services. The objective falls within the supply, environment, aid, and cultural services. The river provides a safe buffer zone for flood control and drought prevention while at the same time reducing vulnerability to extreme environmental and climate events. The river can give a small niche of its tourism business. Tourism, hotel business, cultural monuments, manor, spas, guest houses, walking trails, restaurants, cafeterias, intact wild landscapes provide everyone with mental recreation and well-being the benefits of ecosystem services and hydro and substantial water resources and sustainable energy generation opportunities.

SDG-2 The objective falls into supply and environment and support services. Crop production in the Svete River catchment is higher in the drained soil. Irrigation options are available during drought. The drainage of forest areas increases the productivity of forests and wood quality. The Svete River provides food production, boosting agricultural productivity and the income of small food producers. Everyone can supply themselves with berries, mushrooms, wild fish, cancers and herbs. By focusing on more sustainable strategies for implementing agricultural policy, water use efficiency can be increased by using water from the river. On the other hand, intensified agricultural activity may increase nitrogen, phosphorus and toxic substances in the river (Boyd & Banzhaf, 2007) contradicting SDG-14.

SDG-3 Includes the category of environmental and support and cultural services. Safe and clean drinking water is essential for the well-being of society, whether it is used for household, food or leisure purposes. Providing people with clean and healthy water can improve their quality of life. The Svete River offers the opportunity to relax and promotes relaxation in coastal areas. Water tourism, recreation by the water, SPA area, plants, physical enjoyment of the landscape, walks, swimming, sunbathing, sports activities on the coast improve people's mental and physical health and ensure human well-being. With predictable water storage capacity for drinking water and recreational activities, the sustainable development of lakes and reservoirs is essential to reduce water-related diseases, deaths and water pollution and pollution-related diseases. However, the lack of a sanitation system outlined sources from agricultural remarks and the primary sources of high-level amenities in rivers, lakes, and reservoirs (Craun, Calderon, & Kreuns, 2005). To achieve improvements in health care systems, obtaining a quality water resource is recommended.

SDG-4 The Svete River provides environmental education as well as education for sustainable development. Everyone involved in education has the opportunity to change the world to reduce the threats posed by climate change, biodiversity loss and over-consumption. However, water pollution can cause health problems for young children and be a significant barrier to obtaining proper education in the absence of children (Adukia, 2017). Good quality education can contribute to an active future in biodiversity conservation and waste management with higher knowledge, attitudes and skills of trained students.

SDG-5 Women play a vital role in providing, managing, and protecting water resources.

Women and girls are considered 'water carriers' in the world. According to a UNICEF study (WHO & UNICEF, 2014), women spend at least 16 million hours each day collecting drinking water. It significantly reduces the time spent on productive work and learning, which in many places leads to a broader gender gap (Jayachandran, 2015). Higher gender equality means better education for girls and women, leading to a greater understanding of environmental protection, which benefits ecosystems (Adukia, 2017). The objective falls into supply, environment and support, and cultural services.

SDG-6 Safe drinking water and sanitation are recognized as fundamental human rights, as these

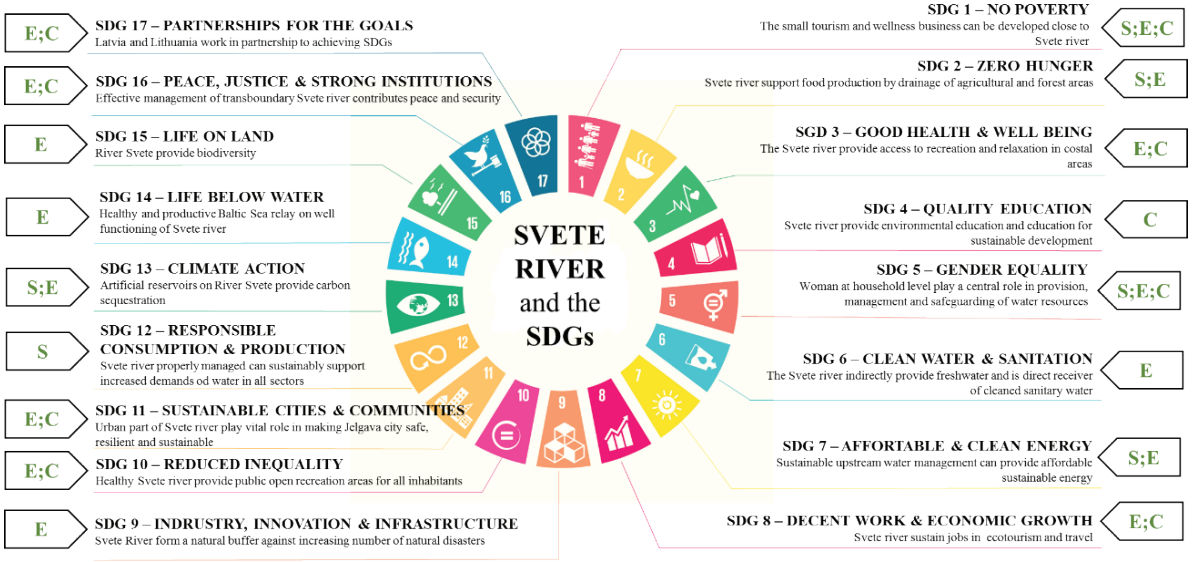

Figure 2. SDG analysis by Svete River catchment ecosystem services (Supply services (S); Environmental and support services (E); Cultural services (C)) (created by I. Grinfelde).

factors are essential to ensure a healthy lifestyle and are necessary for each person's self-assurance. However, without active action today, in 2030, the world will not be able to guarantee everyone access to clean and safe drinking water and sanitation (United nations, 2015; WHO, 2019). Data from the World Health Organization (WHO, 2019) shows that 14 people die daily from stomach diseases caused by polluted water in the world. The Svete River is a direct provider of freshwater and sanitary water receivers. The objective falls into the category of environmental and support services.

SDG-7 The objective is Renewable energy, where sustainable water management provides sustainable energy. The goal falls into the category of supply and environment and support services.

The main objectives of the target are to extend renewable energy into energy consumption, ensure access to stable, affordable, sustainable and modern energy as well as to promote a sustainable and inclusive economy. Thus, the operation of hydropower plants makes a significant contribution to achieving this goal.

SDG-8 The objective can promote sustainable tourism and the sustainable use of recreational reservoir services. Tourism, hotel business, cultural monuments, manors, spas, guest houses, walking trails, restaurants, cafes, untouched wild landscapes provide an opportunity to develop tourism for anyone and anywhere. Creating opportunities for people's well-being and mental recovery provides decent jobs. The objective falls into environmental and support services and cultural services.

SDG-9 The Svete River forms a natural buffer zone against the growing number of natural disasters and reduces pollution. Reconstruction and renewal of environmentally friendly agricultural drainage systems are required, including ecologically friendly elements, such as installing two-stage drainage ditch systems and creating sedimentation ponds or pools in them. Cascade can also reduce nutrient accumulation. As a result, the run-off of nutrients (nitrogen and phosphorus) from the fields to the waters is diminished; the development of eutrophication in the water body decreases. The objective falls into the category of environmental and support services.

SDG-10 The aim is to reduce inequality. A healthy Svete River provides public recreation areas for all residents. The 48 km long Svete River flows through the Republic of Lithuania. Lithuania's impact on river waters accounts for 50% of its pollution. To improve water quality, transnational cooperation with Lithuanians is needed. There are relatively slow-flowing rivers in Zemgale. The groundwater level is relatively high, filtration in intensive agricultural conditions is fast enough; therefore, a relatively large amount of nutrients enters the water.

Lithuania is more involved in the meandering of straightened rivers – making them winding, reducing the release of nutrients into the sea – the longer the water path has to be measured, the better it is purified. As it is an expensive measure, the emphasis in Latvia is more on changing agricultural measures, such as installing two-stage drainage ditches, sedimentation ponds or pools in them. During the reconstruction, shallow ponds are installed in the ditches, where nutrients settle down, aquatic plants grow very actively, thus removing nutrients. Due to such a pond, the water is already cleaner. Cascade can also reduce nutrient accumulation. Ideally, a combination of all measures could be used. The objective falls into the category of environmental and support services and cultural services.

SDG-11 Goal - sustainable cities and communities. Part of the Svete River makes Jelgava safe, durable and sustainable. Disaster preparedness and resilience, resilience to future weather challenges, and importance to prevention and preparedness are vital. It is in the interest of every municipality to develop, be safe for the population, have a clean environment, good transport, housing, green areas, cultural heritage, it is friendly and convenient for both living and working. The Svete River ensures the ecology of the city and the adaptation of wildlife to the human environment. The city can also play its part by improving the water cycle and restoring groundwater through urban planning solutions ('green roofs', rainwater harvesting, cleaning and restoration of old riverbeds), all of which ensure a safe and sustainable city. The objective falls into the category of environmental and support services and cultural services.

SDG-12 Objective – Responsible consumption and production. Proper management of the Svete River can sustainably ensure high water requirements in all sectors. The purpose falls into the category of supply services.

In the face of global resource scarcity, the biggest challenge for producers and consumers is to take a 'do more with less effort'. The EU has implemented a wide range of policies and initiatives to achieve sustainable consumption and production. In the EU Green Course context, particularly the new Circular Economic Action Plan, a Sustainable Products Policy Legislative Initiative was announced to make products suitable for a climate-neutral and resource-efficient circular economy. By promoting healthy use and production in the 'circular economy', sustainable development aims to minimize the negative impact of mass production on the environment and human health (Griggs *et al*., 2017).

SDG-13 Purpose – Protection of the planet. The artificial water reservoirs created on the Svete River ensure carbon sequestration. Freshwater reservoirs

and climate change have a dual relationship (Berga, 2016). Hydropower reservoirs are a central renewable energy resource that helps mitigate climate change (Boehlert *et al*., 2007).

Rivers and water bodies are primary regulators of the carbon cycle and climate change (Tarnvik *et al*., 2009; Williamson *et al*., 2009). They play a crucial role in preventing extreme climatic events, such as floods or melting snow and glaciers (Schallenberg *et al*., 2013). The threats posed by climate change lead to natural disasters such as drought, extreme weather, etc. The objective falls into supply, environment, and support services.

SDG-14 Purpose – life underwater. Healthy Svete River ensures healthy Baltic Sea. Objective 14.1, which aims to protect marine ecosystems, is essential to prevent and reduce land-based activities. Each freshwater stream with a higher concentration of pollutants in the coastal area makes it challenging to reach 14.1. the objectives of "preventing and significantly reducing all forms of marine pollution, to achieve a healthy life under seawater, priority should be given to improving water quality from inland water systems. However, the possible trade-off between sea fishing and freshwater fishing should be considered. In addition, the objectives of Article 14.4 should be addressed as well as 14.6. to avoid overfishing and illegal fishing, which can lead to shortages of marine fish and put more pressure on freshwater fish in rivers and lakes. The objective falls into the category of environmental and support services and cultural services.

SDG-15 The Svete River provides biodiversity. The Svete River flows downstream through the Natura 2000 area. Svete floodplains are a significant European and Latvian territory for waterfowl during spring migration when more than 20,000 individuals gather in the floodplain territory simultaneously. There are corncrakes, long-necked eagles, the great eagle, little eagle, black stork, snake eagle, etc. 45 specially protected bird species have been discovered in the Svete floodplain. The high dams of the Svete polders are suitable for leisurely rest, nature and bird watching, from which the immediate and distant surroundings can be well seen.

Inland water bodies and terrestrial ecosystems play a critical role in many complex biogeochemical cycles, such as the carbon cycle, the water, the nitrogen and the nutrient cycle (Chapin *et al*., 1995; Schimel, 1995).

Goal 15.8 focuses on preventing and controlling invasive species to be implemented in both inland water and terrestrial ecosystems, as the life cycle of many species includes both ecosystems (Pejchar & Mooney, 2009).

The objective falls into the category of environmental and support services and cultural services.

SDG-16 Practical cross-border cooperation between neighbouring countries on river management contributes to safety and stability. The Svete River ensures people's inner and spiritual harmony. Peace in the world begins with peace in oneself and the family. Everyone can find countless examples of hatred person's nationality, gender, sexual orientation, religion or simply different views. Teaching and learning inner peace is an achievable goal in working with yourself and others. Being in nature and working with your shadow sides is a simple and effective way to develop inner peace. Strengthening internal peace should be the outcome of any education: to provide the market with the human resources and consumers it needs and build a better society and living environment. New threats to peace are also linked to global climate change and natural disasters, which may require the relocation of large numbers of people and lead to violent conflicts due to limited natural resources. In the frame of foreseeable unpredictability, more attention should be paid to the provision of peace education. And each of us can help learn peace and non-violence through our example and initiative.

The objective falls into the category of environmental and support services and cultural services.

SDG-17 Partnership to achieve goals. Recently, international conflicts over freshwater resources, especially regarding hydroelectric dams (Gleick & Heberger, 2014; Gleick, 2014) have occurred. The construction of new hydropower plants can lead to significant changes in the river's lower reaches, thus creating potential conflicts between different regions (Barnaby, 2009). Therefore, a good partnership between other countries is needed for these areas to be comprehensively managed. The objective falls into the category of environmental and support services and cultural services.

Conclusions

Water quality, a healthy ecosystem, and the restoration of biodiversity will benefit freshwater ecosystems and downstream users, including fast-growing cities and marine life in coastal areas and oceans.

The world is still experiencing a deterioration in water quality, especially from nutrients such as phosphorus and nitrogen. The main requirement is to eliminate three primary sources of pollution: the discharge of untreated wastewater from industrial and urban sources; reduction of agricultural fertilizers entering rivers, lakes and groundwater; and the deposition of nitrogen-containing compounds in the atmosphere by burning fossil fuels.

Progress is happening. However, to achieve our goals, we need to accelerate, increase and see improvement in other countries and regions. Our

efforts could be particularly successful if we turn wastewater into a source of reused water, energy, fertilizer and other valuable materials.

In addition to wastewater, one of the biggest challenges is pollution from agriculture. Precision agriculture will help, where the right amount of fertilizer is applied precisely where needed. More innovative and more environmentally friendly ways of water treatment will help. With the 2030 Agenda for Sustainable Development, the international community is convinced to solve global problems together.

Acknowledgements

The work was supported by the PASIFIC program GeoReco project funding from the European Union's Horizon2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 847639 and from the Ministry of Education and Science.

References

Adukia, A. (2017). Sanitation and education. *American Economic Journal: Applied Economics*, 9(2), 23–59. DOI: 10.1257/app.20150083.

Barnaby, W. (2009). Do nations go to war over water? *Nature 2009*, 458, 282–283. DOI: 10.1016/j.scitotenv.2007.04.008.

Berga, L. (2006). The role of hydropower in climate change mitigation and adaptation: A review. *Engineering*, 2(3), 313–318. DOI: 10.1016/J.ENG.2016.03.004.

Boehlert, B., Strzepek, K.M., Gebretsadik, Y., Swanson, R., McCluskey, A., Neumann, J.E., McFarland, J., & Martinich, J. (2016). Climate change impacts and greenhouse gas mitigation effects on us hydropower generation. *Applied Energy*, 183, 1511–1519. DOI: 10.1016/j.apenergy.2016.09.054.

Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? *Ecological Economics*, 63(2–3), 616–626. DOI: 10.1016/j.ecolecon.2007.01.002.

Chapin, F.S., Chapin, M.C., Matson, P.A., & Vitousek, P. (2011). *Principles of Terrestrial Ecosystem Ecology.* Springer. DOI: 10.1007/978-1-4419-9504-9.

Craun, G.F., Calderon, R.L., & Kreuns, M.F. (2005). Outbreaks related to recreational water in the United States. *Int. J. Environ. Health Res*., 15(4), 243–262. DOI: 10.1080/09603120500155716.

Fisher, B., & Turner, R.K. (2008). Ecosystem services: Classification for valuation. *Biological Conversation*, 141, 1167–1169. DOI: 10.1016/j.biocon.2008.02.019.

Gleick, P.H., & Heberger, M. (2014). Water conflict chronology. In The world's water. DOI: 10.5822/978-1-61091-483-3_11.

Gleick, P.H. (2014). Water, drought, climate change, and conflict in Syria. *Weather Clim. Soc.,* 6(3), 331–340. DOI: 10.1175/WCAS-D-13-00059.1.

Griggs, D., Nilsson, M., Stevance, A., & McCollum, D.A. (2017). *Guide to sdg interactions: From science to implementation. International Council for Science*, Paris, France: International Council for Science (ICSU). DOI: 10.24948/2017.01.

Jayachandran, S. (2015). The roots of gender inequality in developing countries. *Annual Review of Economics,* 7, 63–88. DOI: 10.1146/annurev-economics-080614-115404.

Pejchar, L., & Mooney, H.A. (2009). Invasive species, ecosystem services and human well-being. *Trends Ecol. Evol.*, 24, 497–504. DOI: 10.1016/j.tree.2009.03.016.

Schallenberg, M., Winton, M.D., Verburg, P., Kelly, D.J., Hamill, K.D., & Hamilton, D.P. (2013). Ecosystem services of lakes. *Ecosystem Services in New Zealand—Conditions and Trends* (pp. 203–225). Manaaki Whenua Press: Lincoln.

Schimel, D.S. (1995). Terrestrial ecosystems and the carbon cycle., *Glob. Chang. Biol.*, 1, 77–91. DOI: 10.1111/j.1365-2486.1995.tb00008.x.

Tranvik, L.J., Downing, J.A., Cotner, J.B., Loiselle, S.A., Striegl, R.G., Ballatore, T.J., Dillon, P., Finlay, K., Fortino, K., Knoll, L.B., Kortelainen, P.L., Kutser, T., Larsen, S., Laurion, I., Leech, D.M., Leigh, McCallister, S., McKnight, D.M., Melack, J.M., Overholt, E., Porter, J.A., Prairie, Y., Renwick, W.H., Roland, F., Sherman, B.S., Schindler, D.W., Sobek, S., Tremblay, A., Vanni, M.J., Verschoor, A.M., Von Wachenfeldt, E., & Weyhenmeyer, G.A. (2009). Lakes and reservoirs as regulators of carbon cycling and climate. *Limnology and Oceanography,* 54(6), 2298–2314. DOI: 10.4319/lo.2009.54.6_part_2.2298.

United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. United Nations. Retrieved February 14, 2022, from https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981.

Williamson, C.E., Saros, J.E., Vincent, W.F., & Smol, J.P. (2009). Lakes and reservoirs as sentinels, integrators, and regulators of climate change. *Limnology and Oceanography*, *54*(6part2), 2273–2282.

World Health Organization. (2019). SDG 3.9.2 – Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH)). World Health Organization. Retrieved February 14, 2022, from https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4675.

World Health Organization & United Nations Children's Fund (UNICEF). (2014). Progress on sanitation and drinking water: 2014 update. World Health Organization. Retrieved February 14, 2022, from https://apps.who.int/iris/handle/10665/112727

CHANGE IN THE AREA OF LITHUANIAN WETLANDS (2002-2021)

***Giedrė Ivavičiūtė**
Vytautas Magnus University, Lithuania
Kaunas Forestry and Environmental Engineering University of Applied Sciences, Lithuania
Klaipėda State University of Applied Sciences, Lithuania
*Corresponding author's email: ivavice@gmail.com

Abstract
The topic of the article is especially relevant, because not only in Lithuania, but also all over the world, due to human activities, climate change and other processes, the most natural component of the landscape - wetlands - is rapidly disappearing. Wetlands not only have a unique biodiversity, are valuable elements of the landscape, but also perform many important functions for humanity. Drainage of wetlands results in the loss of most of these functions, as well as secondary problems such as greenhouse gas emissions, water pollution by peat decomposition products, and many others.
Wetlands are declining or deteriorating in many parts of the world. More than 90% of former wetlands have been destroyed or severely damaged in Western Europe, more than 50% in Central Europe and about 70% in Southeast Asia.
The aim of this article is to determine the change in the areas of Lithuanian wetlands. Thus, the study found that wetland areas were declining in all counties of the country. The largest percentage decrease in wetlands was in Kaunas (67.43%) and Tauragė (54.33%) counties. During the period of 2002-2021, the area of wetlands in the Republic of Lithuania decreased by 50,893.11 ha (34.60%) and in 2021 accounted for 0.15% of the country's territory, while in 2002 – 2.25%.
In order to protect the wetlands, it is necessary to take special measures, carry out intensive projects and works for the restoration of wetlands.
Key words: wetland, change, landscape, biodiversity.

Introduction

According to the Universal Lithuanian Encyclopedia (Visuotinė, 2022) a wetland is an area of the Earth's surface that is constantly soaked, and withered vegetation gradually turns into peat under anaerobic conditions. Formed by landslides or by the growth of a body of water (usually a lake). Land is concentrated where groundwater is shallow, surface water or floodwater stagnates for a long time. Groundwater levels can rise, for example, when large areas of forest are cut down or burned, which then turn into wetlands.

The authors A. Povilaitis, J. Tuminskas, Z. Gulbinas, R. Linkevičienė and M. Pileckas (Povilaitis *et al*., 2011) describe the wetland as an area that is overgrown with wetland vegetation. A vibrant, unspoiled wetland is an ecosystem that accumulates peat.

For a long time, wetlands have been the least affected by human beings, but for the last 200 years, the destruction of wetlands was seen as an indicator of progress in almost every country, and every effort was made to replace wetlands as much as possible – to drain, dig, plow or reforest them. Wetlands are being destroyed rapidly even now (Pranaitis, 2018).

Wetlands are habitats rich in species that perform valuable ecosystem functions such as flood protection, water quality improvement, food chain maintenance and carbon sequestration. Wetlands around the world have been drained to become agricultural land or industrial and urban areas (Verhoeven & Setter, 2010).

Wetlands perform functions that support the creation of ecologically, economically and socially important values. European legislation increasingly recognizes the importance of preserving wetland ecosystems (Jassen *et al*., 2005).

The drainage of wetlands for agriculture, forestry, peat mining, urbanization and other purposes causes non-recurring but continuous greenhouse gas (GHG) emissions lasting decades or centuries, while natural and restored wetlands are able to store organic carbon in the form of peat (IUCN, 2017).

Wetlands are affected by many threats, including climate change, degradation, area loss, invasive species (types), over-harvesting and disease. Habitat loss and degradation caused by upstream development of water resources and the transition to agriculture, industry and transport, and urban development are the most serious ones (Kingsford, Basset, & Jackson, 2016).

Maintaining biodiversity, improving water quality, reducing floods and carbon sequestration are key functions that are disrupted when wetlands are lost or degraded. Restoration methods are evolving although the recovery of lost biodiversity is hampered by invasive species that thrive on disrupted and displaced locals. Not all wetland damage is reversible, but it is not always clear how much it can be maintained during restoration (Zedler & Kercher, 2005).

There is now more and more talk about the inevitable need to conserve wetlands, as they play a particularly important role, as no other terrestrial ecosystem on Earth does: it captures carbon dioxide

from the atmosphere in the form of peat, thus contributing to atmospheric stability and the destroyed wetlands and drained peatlands pose a great threat. By losing the water necessary for the wetlands to exist, they emit large amounts of carbon dioxide and other gases, increasing the greenhouse effect in the earth's atmosphere (Pranaitis, 2018).

Wetlands perform valuable functions that benefit humans and wildlife as well. These include groundwater recharge, food security, surface water storage, filtration and treatment, biodiversity habitat provision, global water cycle support, natural hazard management, livelihood support, flood protection, carbon mitigation, climate change mitigation, and they may also be of cultural and spiritual significance (Vincent & Owens, 2021).

Wetland restoration is particularly important for the conservation of biodiversity; climate regulation (carbon sequestration, storage of organic carbon in the form of peat); local air formation (reduces air temperature fluctuations, increases air humidity and the likelihood of fog, cleans the air); water treatment (improves water quality and accumulates biologically passive pollutants, especially in areas of intensive agriculture) and storage (prevention of floods, droughts and peat fires); to prevent soil erosion and peatland collapse; the supply of renewable natural resources that can be used for energy purposes in the production of feed, building materials, the food and pharmaceutical industries, handicrafts and more; aesthetic, recreational, health, scientific, etc. (Pelkių atkūrimo, 2022).

Inventory and monitoring of wetlands and adjacent uplands is important for the conservation and management of wetland resources (Ozesmi & Bauer, 2002).

Successful conservation and management of wetlands requires up-to-date and accurate information on the location, size, condition, functionality, type, services provided, stressors, and net changes in scale (Kayastha *et al*., 2012).

The object of article is wetlands of Lithuania.

The aim is to perform an analysis of the change in the wetland area of the Republic of Lithuania in 2002-2021.

Tasks to be resolved:

1. To describe Lithuanian wetlands.
2. To perform the analysis of the change in the area of Lithuanian wetlands in 2002-2021.
3. To examine the change of wetland area in the counties of the country.
4. To analyze the wetland restoration works and tendencies in the country.

Materials and Methods

Various methods have been used to conduct the research of this article: both theoretical and practical.

The introduction provides an overview of articles by Lithuanian and foreign researchers examining the concept of wetlands, the causes of their extinction, and the importance of conservation. It has been identified that this sensitive component of the landscape needs to be protected and restored.

The article formulates the aim and tasks for its implementation.

To achieve the aim, a comparative method was used, which determined the change of wetland areas in Lithuania and its ten counties in 2002-2021. The obtained change data are presented in hectares and percentages. The data of the Land Fund of the Republic of Lithuania for 2002-2021 were used for comparative analysis.

The method of analytical and logical analysis was used to determine the reasons for the decrease in the area of wetlands in Lithuania and its counties.

To supplement the study, 5 figures and one table were prepared. Figure 4 was made using ArcGIS program. This figure shows the percentage of the area occupied by wetlands in Lithuanian counties.

The paper analyzes the wetland restoration projects and works carried out in the country and describes the possibilities for the development of these works in the future.

Results and Discussion

Wetlands in Lithuania

Wetlands are described as viable terrestrial ecosystems in areas that are constantly soaked and overgrown with moisture-loving plants, where peat is constantly being built up, that is, peat accumulation. Areas with a peat layer thicker than 30 cm are included in wetlands. Most of the Lithuanian wetlands are located in the folded relief of the Baltic and Samogitian Uplands, in the Central Lowlands, in the valleys of the rivers of the South-Eastern Plain.

In the country, wetlands are mostly formed where there is a loamy impermeable subsoil and shallow-lying groundwater. Such low-nutrient soils tend to acidify and swamp. For this reason, wetlands in sandy areas, such as the South-Eastern Plain, can also be swamped. The most favorable conditions for the formation of wetlands are in the western part of Lithuania, where very calcareous and narrowed soils predominate, and the most unfavorable conditions in the Central Lowlands, where low-calcareous soils with carbonate subsoil predominate.

There are three types of wetlands identified (Figure 1):

1. Fens. About two thirds of Lithuanian wetlands are fens, which are widespread in lakes, river valleys, inter-hill valleys, on the outskirts of raised bogs.
2. Intermediate bogs. These are wetlands where fen and raised bog plants grow. They are widespread in habitats, where nutrients are insufficient for fen

Figure 1. Distribution of wetland types in Lithuania (Lietuvos pelkių, 2022).

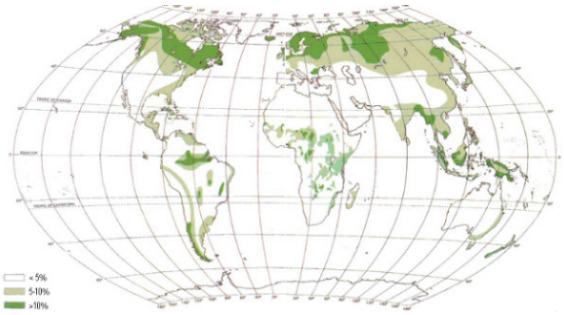

Figure 2. The % of areas covered by wetlands (Kodėl svarbu, 2022).

peat and nutrients are still too high for raised bog peatlands.

3. Raised bogs. These wetlands are fed only by rainwater and snowmelt, the excess of which flows from the raised surface of the wetland to the edges (lag).

Lakelets of various sizes and lake branches can be found in the big raised bogs.

Lithuania has 53 types of natural habitats of European Community importance (excluding those common in the Baltic Sea), which are included in the Habitats Directive (Council Directive, 1992).

Eleven of these types are associated with wetland ecosystems, i.e.: natural dystrophic lakes, active wetlands, degraded raised or intermediate bogs and marshes, bare peat bogs, calcareous springs and spring marshes, boggy marshes, boggy marshes swamp deciduous forests, swamp forests.

The largest wetlands in Lithuania are the following: Žuvinto palios – 6,847 ha, Čepkelių raistas – 5,858 ha, Didysis tyrulis – 4,717 ha, Baltosios Vokės wetland – 4,100 ha, Praviršulio tyrelis – 3,645 ha, Amalvo palios – 3,400 ha, Rupkalviai wetland – 3,410 ha, Naujienos wetland – 3,160 ha, Aukštumala – 3,020 ha, Rėkyva wetland – 2,608 ha.

The most important surviving Lithuanian wetlands are declared protected areas – state or biosphere reserves.

Changes in wetland areas.

Wetlands cover about 3% of the world's land area (Figure 2). They are mainly located in the Northern Hemisphere, in the temperate climate zone. Over the past 200 years, the area of peatlands has decreased by 10-20%. About a quarter of the surviving peatlands have been interrupted by natural processes, climate change or human activity, and peatland is currently used in about 60% of the world's former wetlands.

In Europe, more than 20% of peatlands have been destroyed, and only about 50% of all former peatlands have remained suitable for peat formation.

More than 90% of former wetlands have been destroyed or severely damaged in Western Europe, more than 50% in Central Europe and about 70% in Southeast Asia. The best condition of wetlands in North America and the Asian part of Russia. Large areas of wetlands have survived in northern Europe (Finland and Sweden). Unfortunately, climate change models predict a rise in global temperatures, which could significantly accelerate the loss of wetlands.

Wetlands in the Baltic States are a significant element of the landscape, covering a total area of 24,650 square km, but due to intensive land reclamation during the Soviet era, about 70% of Baltic wetlands are already drained and degraded (Joosten, Tanneberger, & Moen, 2017).

In Lithuania, wetlands covered about 10% of the territory, but since the beginning of larger-scale melioration works in the 19th century, about 30% of the former area remained. At present, this ratio is even more unfavorable for wetlands.

Although the country's wetlands are protected nationally, even the status of a protected area does not always ensure a favorable status and protection of natural values. There are 821 wetlands in Lithuanian state reserves, national and regional parks and reserves.

107 telmological reserves have been established in Lithuania to protect typical and unique wetland complexes. 7 Lithuanian wetland complexes are of international importance and are protected by the international Ramsar Convention.

In 2021, wetlands occupied only about 0.15% of Lithuania's territory, i.e. 96,185.73 ha (Figure 3). Most of them are small - up to 50 hectares and unevenly distributed within the country.

In 2002, the area of wetlands in Lithuania was 2.25% and occupied 147,078.84 ha. The third figure shows that between the years 2002 and 2021, the area of wetlands decreased. Thus, the examined area changed by 50,893.11 ha, which was as much as 34.60%.

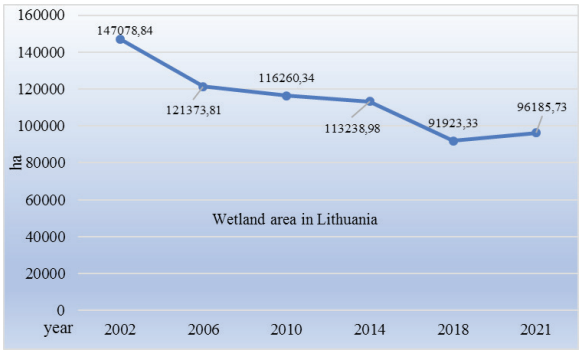

Figure 3. Wetland area change in ha in the Republic of Lithuania in 2001-2021 (Nacionalinė, 2001-2021).

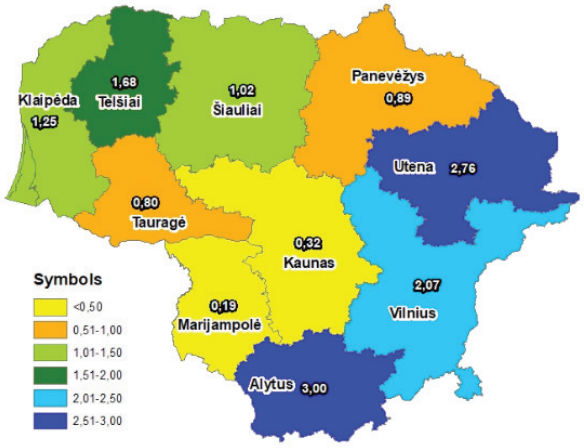

Figure 4. Wetlands in Lithuanian counties in 2021.

A small part of the wetlands disappeared due to natural landscape development processes (changes in local moisture balance, formation of river valleys, etc.). Many wetlands are disappearing due to lower groundwater levels during land reclamation and peat exploitation. Currently, wetlands are particularly threatened by the reluctance of entrepreneurs to increase peat extraction and exports.

There are ten counties in Lithuania where the areas of wetlands are unevenly distributed.

According to the data of 2021, the most wetlands in Lithuania are situated in Alytus (3.00% or 16,268.98 ha), Utena (2.76% or 19,855.37 ha) and Vilnius (2.76% or 20,179.43 ha) counties. In other seven counties, wetlands account for less than 2%. The lowest number of wetlands was found in Marijampolė county (0.19% or 4290.85 ha) (Figure 4).

After the analysis of the change of wetland areas in the counties of the Republic of Lithuania, it can be seen that in all counties this area decreased in the period of 2002-2021 (Figure 5).

Analyzing the data on the change of wetlands as a percentage, it was found that the largest decrease in this land use was in Kaunas (67.43%) and Tauragė counties (54.33%). The least change in the area of wetlands was in Telšiai County (15.07%) (Table 1).

As mentioned, some wetlands have disappeared due to natural landscape development processes, but the main cause of wetland loss is human economic activity. More than two-thirds of the wetlands in all counties of the country have become degradable peatlands. The condition of many of the surviving wetlands is gradually deteriorating due to still operating drainage systems, pollution and climate change, destabilizing the human environment and reducing the prospects for future survival.

Today, most drained wetlands are used for agriculture, forestry or peat extraction. In Lithuania, peat quarries occupy 20 thousand ha, more than half

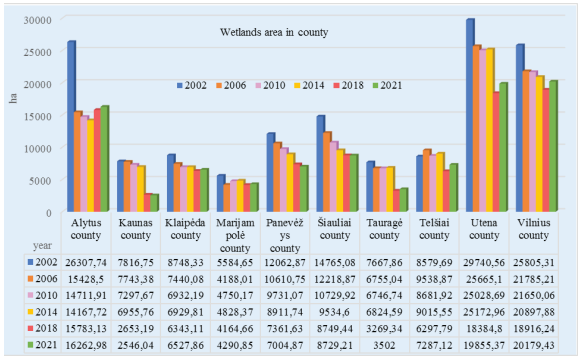

Figure 5. Wetlands area change in hectares in counties of Lithuania in 2002-2021.

Table 1

Wetlands area change in hectares and percent in counties of Lithuania in 2002-2021

County	Wetland area decreased by ha	Wetland area decreased by %
Alytus	100,44.76	38.18
Kaunas	5,270.71	67.43
Klaipėda	2,220.47	25.38
Marijampolė	1,293.80	23.17
Panevėžys	5,058.00	41.93
Šiauliai	6,035.87	40.88
Tauragė	4,165.86	54.33
Telšiai	1,292.57	15.07
Utena	9,885.19	33.24
Vilnius	5,625.88	21.80

of which are abandoned and unused. Unfortunately, their reclamation for the restoration of wetland ecosystems is still slow. Some of the areas ready for economic use have not been put to their intended use or have been used irresponsibly, and they continue to degrade. Some of the peatlands currently used on the farm are not profitable or their operation is causing difficult landscaping conflicts.

Restoration of wetlands in Lithuania.

Because wetlands are valuable elements of the landscape, with unique biodiversity and performing many functions important to humankind, i.e. regulates the local and global climate, regulates water runoff and quality, provides economic benefits, conducts research and recreation in wetlands, so it is necessary to preserve existing wetlands and restore the former ones.

The nature of the damage to wetlands can vary, leading to different methods of restoring them. Main tasks are restoration of water level and characteristic vegetation. The easiest way to restore the wetlands is to raise the water level in the drained peatlands that have retained the wetlands. In cases where vegetation is completely destroyed, the restoration of the wetland, even at high groundwater levels, can take decades or even centuries (for example, to restore raised bogs).

The following wetland restoration projects have been implemented in Lithuania:

- Restoration of the Puščia peatland (2002-2003), the aim of which is to restore the Puščia peatland in Zarasai district, restoring the water balance, renaturalising the vegetation, planting typical raised bog vegetation, removing growing shrubs and trees and invasive plant species.
- Conservation of biological diversity in Lithuanian wetlands (2004-2011). The water level was restored in Girutiškis raised bog in Švenčionys district and in a part of Kamanos raised bog in Akmenė district.
- Restoration of the raised bog in the Aukštumala Telmological Reserve (2006-2007). During the project, canals and ditches were ponded, and 100 ha of woody vegetation were cleared, thus stopping the degradation of the swamp and water evaporation. Partitions were built in the cut-out places and the water level was raised.
- Restoration of water level in the Velniabalė (Zarasai district) and Gegužinė (Vilnius district) peatlands (2008). Here, the hydrological regime of wetland ecosystems has been restored in the territory of 100 ha, as well as 388 dams have been installed, for the installation of which ecological, natural materials have been used: peat, wood, braided willow dams, etc.
- Preservation of Amalvas and Žuvintas wetlands (2009-2012). During the project, the winter polder of Amalvas was reconstructed, the water level in the southern part of the Amalvas raised bog was restored, the lock regulator was reconstructed, the drainage canals of the Žuvintas meadows were flooded, etc.
- Restoration of wetland ecosystems in Ežerėlis peatland (Kaunas district) (2020). Experimental fields have been set up here and the elements of raised bog (cumin and cranberry) and fen (reed) plants have been established.
- Renaturalization of exploited peatlands and development of plant community restoration technologies (2020). The renaturalization works carried out in the peat bog exploited by the Blind Lake (Telšiai district) are unique in that no attempt is made to artificially introduce plant species here, but to create optimal conditions for the spontaneous recovery of cumin, cranberry, rainbow and other plant species.
- LIFE project Peat Restore (2016-2021). During this project, restoration works were carried out in 5 areas (Amalva wetland, Plinkšiai, Sachara, Pūščia, Aukštumala), which cover a total area of 465 ha.
- Other projects: Restoration and management of the natural hydrological regime of Aukštasis Tyras, Užpelkiai, Paburgė, Siberia and other wetlands.

Currently, the country's conservationists offer paludiculture as an alternative to the usual use of wetland land. Paludiculture is the climate-friendly economic use of natural and restored wetlands, including the production of native wetland crops, the maintenance and/or restoration of the hydrological regime of natural wetland habitats, the promotion of peatland, the protection of wetland biodiversity to ensure the ecological stability of wetlands. Restoration of wetlands, whether targeted changes in the use of drained areas would allow to effectively achieve not only the reduction of GHG emissions, but also the improvement of surface water quality, strategic goals for the protection of biodiversity.

The Lithuanian Economic Recovery and Resilience Facility (Lithuanian Economy, 2021) provides for an amount of 16 million euros to restore 8,000 hectares of drained wetlands used in agriculture.

Farmers working in drained wetlands (peatlands) and municipalities supervising state land will be eligible for support. In particular, support will be provided to farmers in the regions and areas most affected by intensive agriculture.

The support will be used to compensate the costs of wetland restoration: assessment of water level restoration possibilities, preparation of technical design, reconstruction of drainage systems, installation of dams, locks, removal of woody vegetation; other landscaping works in the area (removal of stones, stumps, leveling of the surface). Restored wetland

ecosystems should be maintained and could be used for hay production, grazing or growing cranberries and other berries for wetland cultivation.

The measure is expected to be effective, to change land managers' attitudes towards the natural importance of wetlands and thus to conserve more wetlands in the future. The support provided to farmers in the plan "New Generation Lithuania" will encourage them to contribute to the restoration of ecosystems and climate-friendly farming in wetlands.

Conclusions

1. Most of the Lithuanian wetlands are located in the folded relief of the Baltic and Samogitian Uplands, in the Central Lowlands, in the valleys of the rivers of the South-Eastern Plain. Lithuania has 53 types of natural habitats of European Community importance (excluding those common in the Baltic Sea), which are included in the Habitats Directive. 107 telmological reserves have been established in Lithuania to protect typical and unique wetland complexes. 7 Lithuanian wetland complexes are of international importance and are protected by the international Ramsar Convention.
2. After the analysis of the change in the area of Lithuanian wetlands in 2002-2021, it was established that the area decreased by 50,893.11 ha or 34.60% and in 2021 occupied 96,185.73 ha or 0.15% of the country's territory.
3. According to the data of 2021, the most wetlands in Lithuania are situated in Alytus (3.00% or 16,268.98 ha), Utena (2.76% or 19,855.37 ha) counties. The lowest number of wetlands was found in Marijampolė county (0.19% or 4290.85 ha). After the analysis of the change of wetland areas in the counties of the Republic of Lithuania, it can be seen that in all counties this area decreased in the period of 2002-2021. Analyzing the data on the change of wetlands as a percentage, it was found that the largest decrease in this land use was in Kaunas (67.43%) and Tauragė (54.33%) counties. The least change in the area of wetlands was in Telšiai county (15.07%).
4. Various wetland restoration projects have been implemented and are being implemented in Lithuania. Currently, the country's conservationists offer paludiculture as an alternative to the usual use of wetland land. The Lithuanian Economic Recovery and Resilience Facility provides to restore 8,000 ha of drained wetlands used in agriculture.

References

Council Directive 92/43/EEC of 21 May 1992 on *the conservation of natural habitats and of wild fauna and flora*. *Official Journal L* 206, 22/07/1992 P. 0007–0050.

IUCN 2017: *International Union for Conservation of Nature. Annual report* 2017. (2017). 52 p. Retrieved January 24, 2022, from https://portals.iucn.org/library/sites/library/files/documents/2018-007-En.pdf.

Jassen, R., Goosen, H., Verhoeven, M.L., Verhoeven, J.T.A., Omtzigt, A.Q.A., & Maltby, E. (2005). Decision support for intergrated wetland management. *Environmental Modelling & Software.* Vol. 20, Issue 2, pp. 215–229.

Joosten, H., Tanneberger, F., & Moen, A. (2017). *Mires and Peatlands in Europe – Status, Distribution and Conservation Council of Europe*. Schweizerbart Science Publishers, Stuttgart, 780 p.

Kayastha, N., Thomas, V., Galbraith, J., & Banskota, A. (2012). Monitoring Wetland Change Using Inter-Annual Landsat Time-Series Data. *Wetlands.* Vol. 32, pp. 1149–1162.

Kodėl svarbu išsaugoti pelkes? (Why is it important to preserve wetlands?). WETLIFE LIFE07 NAT/LT/530. Retrieved January 24, 2022, from http://wetlife.gpf.lt/lt/kodel-svarbu-issaugoti-pelkes. (in Lithuanian).

Kingsford, R.T., Basset, A., & Jackson, L. (2016). Wetlands: conservattion's poor cousins. *Aquatic Conservation: Marine and Freshwater ecosystems.* 26, pp. 892–916.

Lietuvos ekonomikos gaivinimo ir atsparumo didinimo priemonė Naujos kartos Lietuva. (2021). (Economic Recovery and Resilience plan New Generation Lithuania). 386 p. Retrieved February 12, 2022, from https://finmin.lrv.lt/uploads/finmin/documents/files/Naujos%20kartos%20Lietuva_2021_05_14.pdf. (in Lithuanian).

Lietuvos pelkių ir durpynų duomenų rinkinys (Data collection of Lithuanian wetlands and peatlands). Retrieved January 24, 2022, from https://www.geoportal.lt/map/#. (in Lithuanian).

Nacionalinė žemės tarnyba prie Žemės ūkio ministerijos. (2002-2021). *Lietuvos Respublikos žemės fondas*. (The National Land Service under the Ministry of Agriculture. *Land Fund of the Republic of Lithuania*). Vilnius. 2002-2021.144 p. (in Lithuanian).

Ozesmi, S.L., & Bauer, M.E. (2002). Satellite remote sensing of wetlands. *Wetlands Ecology and Management*, pp. 381–402.

Pelkių atkūrimo ir gamtos fondas. (2022). *Kas yra pelkės ir durpynai?* (Foundation for Peatlands Restoration and Conservation. What are wetlands and peatlands?). Retrieved February 14, 2022, from https://www.pelkiufondas.lt/pelkes. (in Lithuanian).

Povilaitis, A., Tuminskas, J., Gulbinas, Z., Linkevičienė, R., & Pileckas, M. (2011). *Lietuvos šlapynės ir jų vandensauginė reikšmė* (Lithuanian wetlands and their water protective importance). Monografija. Vilnius, 328 p. (in Lithuanian).

Pranaitis, A. (2018). *Pelkės. Kodėl mums rūpi?* (Wetlands. Why do we care?). Gamtos pasaulis, 52 p. (in Lithuanian).

Verhoeven, J.T.A., & Setter, T.L. (2010). Agricultural use of wetlands: opportunities and limitations. *Annals of Botany*, Vol. 105, Issue 1, pp. 155–163.

Vincent, A.G.T., & Owens, K.A. (2021). Coastal wetlands of India: threats and solutions. *Wetlands Ecology and Management*, pp. 633–639.

Visuotinė Lietuvių enciklopedija. (2022). Pelkė. (Universal Encyclopedia of Lithuania. Wetland. Retrieved January 24, 2022, from https://www.vle.lt/straipsnis/pelke/. (in Lithuanian).

Zedler, J.B., & Kercher, S. (2005). Wetland Resources: Status, Trends, Ecosystem Services, and Restorability. *Annual Review of Environment and Recources.* Vol. 30, pp. 39–74.

WHAT HYDROGEN CAN BRING TO RURAL DEVELOPMENT: REVIEW AND RESULTS OF ENTREPRENEURS SURVEY IN LATVIA

***Janis Kleperis[1], Ilze Dimanta[1], Biruta Sloka[1], Laila Zemite[2]**
[1]University of Latvia, Latvia
[2]Riga Technical University, Latvia
*Corresponding author's email: janis.kleperis@cfi.lu.lv

Abstract
Biogas is an energy carrier (methane, hydrogen) produced by the fermentation of organic waste in an anaerobic digestion process and can be burned in a cogeneration plant to produce heat and electricity. Price of electricity from the grid, as well as price of fossil natural gas have been increasing recently, and farms are considering new scenarios for the economic use of produced biogas. As a possible scenario, it is desirable to consider incorporation of hydrogen that can be used for energy storage; fuel for farm electric transport and as renewable resource for the decarbonisation of agricultural processes. Researchers worldwide are working on the development of efficient microbial technologies to upgrade biogas by removing CO_2 with *hydrogenotrophic methanogens* and using external green hydrogen as electron donor. Selected case situations are analysed – renewable energy and hydrogen in the winery, hydrogen fuelled farm in future. The purpose of this article is to inform farmers through a survey about hydrogen as a local resource for energy management in farm. The article continues analyses of survey results, collected in 2021 with the aim to gather information and opinions from biogas producers in Latvia. Majority of producers is considering technology upgrades and confirm interest to follow achievements from scientific findings, but not so many cooperate with local scientists. Therefore, more proactive communication from research institutions and information availability is highly recommended by authors.
Key words: biogas, biohydrogen, bio-upgrading, hydrogen, survey.

Introduction

The World Climate Conference was held in Glasgow, Scotland, from 31 October to 12 November 2021, when 197 countries agreed to step up their efforts to curb global warming (Documents and decisions, 2021). The conference pledged to halt uncontrolled deforestation by 2030, which has suffered from severe fires around the world as the climate has changed in recent years. At the suggestion of the USA President Biden, an agreement has been reached to reduce methane emissions by at least 30% by 2030, as methane is 84 times more active in contributing to global warming than carbon dioxide. At least 90 countries have supported the phasing out of coal for energy, which not only pollutes the planet's atmosphere but also harms human health. Methane emissions are the same for natural gas and biogas and can only be reduced in the long term by replacing them with green hydrogen in all applications.

On 15 December 2021, the European Commission adopted a series of legislative proposals (European Parliament, 2021a, 2021b) to decarbonise the EU gas market by facilitating the use of renewable and low-carbon gases, including hydrogen, and ensuring security of energy supply for all European citizens.

Global climate goals may seem far away, but in this area Latvia, as a small country, has an advantage, because it is easier to operate a small farm, and we already have a very good base on which to build. For example, the agricultural sector has a great potential for biomethane production. There is already a great number of biogas plants in Latvia – 59 (Dubrovskis, 2018); therefore, raw materials and an existing production base that can be relatively easily adapted for biomethane production. Biomethane can then be used both as a transport fuel and sold on the gas network. Tandem of natural gas and biomethane could be named as one of the most promising for short and mid-term transport decarbonisation solutions both in the EU and Latvia (Savickis *et al*., 2020). In both cases, emissions from agriculture are being addressed and a renewable resource has been developed to replace fossil energy. The transition to a low-carbon economy requires the use of energy produced from renewable resources. Fraction of this green energy increases in the mix of grid electricity, but some of renewable resources, such as solar irradiation, is available in any location of our globe, and can be used without the grid – so-called distributed energy generation. The standalone solar photovoltaic, wind power as well as small hydroelectric power generation are particularly suitable for large rural areas where the cost and environmental impact of installing grid power lines are higher. It should be emphasized that hydrogen is used to reduce emissions from energy supply that contribute to climate change. Hydrogen has been shown to be a suitable substitute for fossil fuels and an excellent carrier of green energy. The production of electricity takes place by reacting hydrogen in the fuel cell with oxygen, and the end products of the reaction are electricity and pure water, that is, they do not cause local pollution. The high specific energy density is also another advantage of hydrogen, as hydrogen has the lowest weight of any fuel (Kleperis *et al*., 2021a).

This article is a continuation of the analysis of the results of the survey conducted in early 2021, and the

first part was reported at the ERDEV conference in 2021 (Kleperis *et al*., 2021b). This article contains an original summary of information on description of different case of hydrogen use from demonstration projects in agriculture and the readiness of Latvian entrepreneurs to reflect on them. Of course, with appropriate state support, both by streamlining legislation and by offering support for European funds for the production, storage, use and decarbonisation of 'green' hydrogen in the agricultural sector.

Materials and Methods

Classical research methods, such as analysis of research findings, as well as specific policy documents and existing standards are used in the analysis of scientific articles (focused on the use of specific technologies in pilot projects). Review of publications with analysis of the results of expert surveys in a specific sector are also sought and analysed, from which the questions in the questionnaire arose of hydrogen technologies, and respondents were asked about their future plans by sending e-mails. Survey was conducted during the period January – March, 2021. From all active biogas producers in Latvia (48 in 2020) the 35 were approached also by phone to make sure that the e-mail with the survey questions was received. During the survey, 10 useful responses on the survey questions were received. The part of results was presented in 20th International Scientific Conference 'Engineering for Rural Development', 26-28 May, 2021, Jelgava, LATVIA (Kleperis *et al*., 2021b). Descriptive statistical analysis methods were used for the statistical analysis of the expert survey presented in the work: central tendencies or location indicators and variability indicators, as well as cross-tabulations were assessed.

Results and Discussion

Status quo and literature analysis. There are currently 50 million micro-digesters in the world, sufficient for family needs, and around 132,000 of engineering biogas projects in the world, of which 17,783 are located in Europe with an installed capacity of 10.5 GW (Zupančič *et al*., 2022). There are 700 plants for upgrading biogas to biomethane worldwide, 540 of which are in Europe and 1 in Latvia. The price of electricity from the grid, as well as the price of fossil natural gas, has been rising sharply recently, and farms are considering new scenarios for the economic use of their own biogas. Owners of small hydro-electro-power stations in Latvia can learn from the first model of case study about hydrogen production from local electric power (Kobzars *et al*., 2022). In these scenarios, hydrogen can serve in a variety of ways, both as stored energy and as a fuel for farm electric transport, and, of course, as a renewable resource for the decarbonisation of agriculture. The following study focuses more on the technological aspects of the introduction of hydrogen into the farm and the degree of readiness of the technology, drawing on experience from the experiments described in the literature. A more complete summary of technology information can be found in the book Lamb & Pollet, 2020.

Biogas upgrading to biohydrogen. Is the only way to convert biogas to biohydrogen by separating hydrogen from biomethane in the steam-methane reformation process? Researchers are working on development of efficient microbial technologies to upgrade biogas, removing CO_2 with *hydrogenotrophic methanogens* and using external hydrogen generated by surplus electricity from renewables as electron donor (Lai *et al*., 2021). Up to now hydrogen biogas upgrading is hindered by metabolic limitations and low H_2 transfer rate, but here design of optimal reactor configurations and genetic engineering of *hydrogenotrophic methanogens* can be helpful. Microalgal biohydrogen production has attracted researchers in recent years (Perera *et al*., 2020; Siddiki *et al*., 2020); however, it must be acknowledged that commercialization is still hampered by unresolved issues in process engineering, low microalgal productivity, oxygen sensitivity, operating costs and insufficient understanding of crop capacity. The book 'Hydrogen, Biomass and Bioenergy' (Lamb & Pollet, 2020) uses the reverse path to explore the production of hydrogen by chemical and biological means from a variety of bioresources, including solid waste, industrial wastewater, farm products, and algae.

Renewable energy and hydrogen in the winery. The results of the LIFE program`s project REWIND (Carroquino, Bernal-Agustín, & Dufo-López, 2019) has demonstrated the technical and practical feasibility of local harvesting of solar energy and energy carrier – hydrogen, to supply electricity and heat to vineyard and winery consumptions. It has been proven that it is possible to completely replace a diesel car with an electric-hydrogen car in the same area for the same work. The approach includes a standalone RES electricity supply 100%, and consumption of surplus solar energy in the form of gaseous hydrogen. Energy Management System manages the loads based on real production, consumption, and stored energy (battery charging level, hydrogen pressure) status. The hydrogen production equipment consisting from a water deionizer, an electrolysis plant, a hydrogen gas compressor, a storage cylinder and a car filling system was installed to collect surplus electrical energy from photovoltaic panels. The diesel SUV was replaced with the same electric one, and the battery pack was replaced with a PEMFC and a compressed hydrogen cylinder. This all-terrain car can be classified as zero emissions and is refuelled with hydrogen produced

from surplus solar energy. The hydrogen-electric car in the vineyard and winery was able to follow the same routes and carry the same loads of crop or fertilizer as a typical diesel car.

Hydrogen fuelled farm. Farms are generating electricity from renewables (Sun, Wind) to split water in electrolysis in hydrogen and oxygen. Hydrogen can be stored in high pressure cylinders and applied as fuel for electric trucks, tractors, and harvesters, as well as to make fertilizer (ammonia) (Phillips, 2021) following the Haber-Bosch process by the reaction between gaseous nitrogen from air and hydrogen. On an average farm (USA), three tractors, two harvesters, four trucks consuming about 45 460 litres of diesel per year, spending $15,000 on fuel alone are used. On such a farm almost 80 000 kg of ammonia fertilizer are also consumed (year cost $105,000); together cost of fuel and fertilizer is $120,000. To get hydrogen, the farm must have its own source of renewable electricity. Let's just look at solar photovoltaic panels and wind generators, coupled with electrolysers. To produce one kilogram of hydrogen, 55.5 kWh energy, roughly the same as 3.8 litres of diesel are needed. The conversion efficiency of hydrogen in polymer electrolyte fuel cell (PEMFC) to electricity is around 60%, and electric motors in machinery run at about 95% efficiency, while diesel engines run at 45%, what means that hydrogen powered electric engine is at least 12% more efficient in summary. Simple calculations show that 7,900 kg of hydrogen fuel is needed for transport on the farm every year. The molecular weight of hydrogen in the ammonia molecule is 17.8%, and 14,100 kg of hydrogen per year will be used to produce 80,000 kg of fertilizer. Altogether 22,0000 kg hydrogen are required per year, what is equal to 1.2 GWh power or $50,000 (at price for electricity $0.0413 per kWh). Almost every biogas farm in Latvia is producing such an amount of electricity - in 2020, there were 49 biogas cogeneration plants in Latvia with a total capacity of 63 MW, the amount of electricity produced annually reaching 345 GWh. In Palouse (USA), the sun shines 5-7 hours a day on average per year; therefore, 4300 m^2 photo-voltage (PV) panels are needed to harvest per year 0.92-1.62 GWh, saving $38,000-$67,000 each year. Another alternative is Wind energy – annual average wind speed at high 100 m is 3 m s^{-1}. To generate half of the electricity needs, 25 wind turbines with a blade diameter of 22.9 meters are needed.

The analysed foreign examples of the introduction of hydrogen in an agricultural enterprise show that biogas producers can already switch to hydrogen today, the only investments would be in hydrogen infrastructure (electrolysers, tanks for compressed hydrogen storage, electric-hydrogen agricultural machinery (combines, tractors, trucks and hydrogen filling station), ammonia fertilizer plant). All of these facilities are available and tested in more than ten pilot projects, but their cost could be very high due to low demand.

Discussion on the intentions of biogas producing farmers. On a European scale, there is a large amount of installed electrical capacity (56 MW) for fermentation biogas plants per million inhabitants in Latvia (Dubrovskis, 2018). Most of them were built during 2009-2015. Untreated biogas is currently burned in gas generators and electricity is produced, still in the hope of state support in the form of a mandatory procurement component, but after the end of the support, investment should be made in biogas upgrading to biomethane for transport (Savickis *et al*., 2020). The Central Statistical Bureau of Latvia data indicate that in 2020 the 29.4% from renewable energy sources were produced in biogas and biomass cogeneration plants. The questions in the questionnaire arose from reading scientific publications and reports on pilot projects for the introduction of hydrogen technologies, and respondents are asked to identify gaps in local legislation and planning documents. In the course of the work, the questions and answer options in the pre-survey were clarified and used for the survey in March 2021 by sending e-mails. If the respondents did not reply within the specified time, a call was made. The part of results were presented in Proceedings of 20th International Scientific Conference 'ENGINEERING FOR RURAL DEVELOPMENT' May 26-28, 2021 (Kleperis *et al*., 2021b). Survey contained several questions for expert evaluations (with several sub-questions for each item):

1) For what practical purpose was your biogas plant set up?
2) In today's situation (expiration of mandatory procurement component), do you still think about staying with cogeneration or changing the target?
3) If you change the target, which biomethane enrichment process will you choose for your plant?
4) Do you plan to use a 'hydraulic piston' or other technology to compress biomethane at the plant?
5) Are you planning to invest in the modernization of biogas plant technologies?
6) Are you interested in modernizing technology?

Researchers in the respective paper have analysed expert evaluations on plans to use a 'hydraulic piston' or other technology to compress biomethane at the plant as it is important for future developments. The answers on the stated question and the offered options for evaluations are analysed below using main indicators of descriptive statistics and correlation analysis – tables 1-6.

Table 1

Main indicators of descriptive statistics on expert evaluations on 'Do you plan to use a 'hydraulic piston' or other technology to compress biomethane at the plant?'

Statistical indicators		Gas for car refuelling	For filling cylinders for gas stoves	Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure
N	Valid	9	8	8
	Missing	1	2	2
Mean		5.33	1.63	2.50
Std. Error of Mean		1.143	0.498	0.627
Median		7	1	2
Mode		1.8	1	1
Std. Deviation		3.428	1.408	1.773
Range		8	4	4
Minimum		1	1	1
Maximum		9	5	5

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes.

Table 2

Distribution of expert evaluations on use 'Gas for car refuelling'

Evaluation		Frequency	%	Valid %	Cumulative %
Valid	1	3	30.0	33.3	33.3
	5	1	10.0	11.1	44.4
	7	1	10.0	11.1	55.6
	8	3	30.0	33.3	88.9
	9	1	10.0	11.1	100.0
	Total	9	90.0	100.0	
Missing	System	1	10.0		
Total		10	100.0		

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes.

Table 3

Distribution of expert evaluations on use 'For filling cylinders for gas stoves'

Evaluation		Frequency	%	Valid %	Cumulative %
Valid	1	6	60.0	75.0	75.0
	2	1	10.0	12.5	87.5
	5	1	10.0	12.5	100.0
	Total	8	80.0	100.0	
Missing	System	2	20.0		
Total		10	100.0		

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes.

Table 4

Distribution of expert evaluations on use 'Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure'

Evaluation		Frequency	%	Valid %	Cumulative %
Valid	1	4	40.0	50.0	50.0
	3	2	20.0	25.0	75.0
	5	2	20.0	25.0	100.0
	Total	8	80.0	100.0	
Missing	System	2	20.0		
Total		10	100.0		

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes.

Table 5

Indicators of non-parametric correlation analysis with Spearman Correlation

Analysed aspect	Indicator on Spearman non-parametric correlation	Gas for car refuelling	For filling cylinders for gas stoves	Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure	Years
Gas for car refuelling	Correlation Coefficient	1.000	-0.016	0.517	-0.187
	Sig. (2-tailed)	.	0.970	0.189	0.658
	N	9	8	8	8
For filling cylinders for gas stoves	Correlation Coefficient	-0.016	1.000	0.572	0.212
	Sig. (2-tailed)	0.970	.	0.138	0.648
	N	8	8	8	7
Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure	Correlation Coefficient	0.517	0.572	1.000	-0.062
	Sig. (2-tailed)	0.189	0.138	.	0.895
	N	8	8	8	7
Years	Correlation Coefficient	-0.187	0.212	-0.062	1.000
	Sig. (2-tailed)	0.658	0.648	0.895	
	N	8	7	7	9

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes, for years – years of operation in the field.

The analysed results indicate that there is no statistically significant correlation between the discussed aspects and between time of operation in Latvia; there are different plans for producers even if they have operated rather long time in the respective market – even 13 years. Unfortunately, still in Latvia the use of hydrogen is not regulated by national legislation; therefore, the strategic planning guidelines contained in the relevant EU directives and other agreements should be taken into account.

Conclusions

The analysed cases of the introduction of hydrogen in an agricultural enterprise show that biogas producers in Latvia can already switch to hydrogen today; the only investments would be in hydrogen infrastructure that are available and tested in several pilot projects, but their cost could be very high due to low demand.

The largest majority of more than 50 biogas plants in Latvia emerged at the beginning of the 21st century with the aim of producing electricity for sale.

Table 6

Indicators of correlation analysis with Pearson Correlation

Analysed aspect	Indicator	Gas for car refuelling	For filling cylinders for gas stoves	Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure	Years
Gas for car refuelling	Pearson Correlation	1	0.058	0.552	-0.103
	Sig. (2-tailed)		0.892	0.156	0.809
	N	9	8	8	8
For filling cylinders for gas stoves	Pearson Correlation	0.058	1	0.601	0.162
	Sig. (2-tailed)	0.892		0.115	0.729
	N	8	8	8	7
Provision of cylinder gas for heating of public buildings or individual households in places where there is no centralized natural gas infrastructure	Pearson Correlation	0.552	0.601	1	-0.052
	Sig. (2-tailed)	0.156	0.115		0.912
	N	8	8	8	7
Years	Pearson Correlation	-0.103	0.162	-0.052	1
	Sig. (2-tailed)	0.809	0.729	0.912	
	N	8	7	7	9

Evaluation scale 1-10, where 1 – definitely no; 10 definitely yes, for years – years of operation in the field.

Their gas generators, with a total installed electricity capacity of about 56 MW, burn untreated biogas. Currently, the vague change in the conditions and requirements in the country in regulatory enactments threatens the goals set by biogas producers in the production of renewable energy. There is a risk of reducing the share of renewable energy already achieved in the energy sector, or even of closing down a number of large agricultural holdings. Given that the right to state aid in the framework of mandatory procurement of electricity generation is no longer granted, the government should plan investments for the conversion of biogas plants to biomethane production for the decarbonisation of the natural gas network and road transport. Therefore, more proactive communication from research institutions and information availability is highly recommended by authors. Expert evaluations on question 'Do you plan to use a 'hydraulic piston' or other technology to compress biomethane at the plant?' with several proposed options for evaluations indicate that the highest evaluations by experts were for 'Gas for car refuelling' with highest average evaluations but also with the highest variability of evaluations, the lowest average evaluations were 'For filling cylinders for gas stoves', there was also the lowest variability of expert evaluations. There was no correlation between the time operating biogas plant in the respective field and the evaluated aspects.

Acknowledgement

This research is funded by the Ministry of Economics of the Republic of Latvia, project 'Trends, Challenges and Solutions of Latvian Gas Infrastructure Development (LAGAS)', project No. VPP-EM-INFRA-2018/1-0003.

References

Carroquino, J., Bernal-Agustín, J-L., & Dufo-López, R. (2019). Standalone Renewable Energy and Hydrogen in an Agricultural Context: A Demonstrative Case, *Sustainability*, 11, 951. DOI: 10.3390/su11040951.

Dubrovskis, V. (2018). Biogas from landfills in Latvia. 6th International Conference on Renewable Energy Gas Technology Malmö, Sweden. Retrieved February 12, 2022, from https://lfg-baltic.beic.nu/Resources/P89_Vilis_Dubrovskis.pdf.

European Parliament, (2021a). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal markets for renewable and natural gases and for hydrogen (recast). Brussels, 15.12.2021 COM (2021) 804 final, 2021/0424 (COD).

European Parliament, (2021b). Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal markets in renewable and natural gases and in hydrogen. Brussels, 15.12.2021 COM (2021) 803 final 2021/0425 (COD).

Documents and decisions. (2021). Glasgow`s World Climate Conference. Retrieved February 21, 2022, from https://unfccc.int/event/cop-26.

Kleperis, J., Boss, D., Mezulis, A., Zemite, L., Lesņičenoks, P., Knoks, A., & Dimanta, I. (2021a). Analysis of the Role of Latvian Natural Gas Network for the Use of Future Energy Systems: Hydrogen from RES. *Latvian Journal of Physics and Technical Sciences*, 58(3), 214–226. DOI: 10.2478/lpts-2021-0027.

Kleperis, J., Dimanta, I., Sloka, B., & Zemite, L. (2021b). Hydrogen Supported Bioconversion of Biogas CO_2 to Upgrade Biomethane in Fuel for Vehicles: Recent Findings in Farmers Survey. Materials of Conference: 20th International Scientific Conference Engineering for Rural Development, May 26-28, 2021, Jelgava, Latvia. DOI: 10.22616/ERDev.2021.20.TF390.

Kobzars, V., Zemite, L., Jasevics, A., Kleperis, J., Dimanta, I., Knoks, A., & Lesņičenoks, P. (2022). Appropriateness of Hydrogen Production in Low-Power Hydropower Plant. 2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON 2021), 18 February 2022. DOI: 10.1109/RTUCON53541.2021.9711687.

Lai, C.-Y., Zhou, L., Yuan, Z., & Guo, J. (2021). Hydrogen-driven microbial biogas upgrading: Advances, challenges and solutions. *Water Research*, 197, 117120. DOI: 10.1016/j.watres.2021.117120.

Lamb, J.J., & Pollet, B.G. (Editors) (2020). Hydrogen, Biomass and Bioenergy. Book, Academic Press, ISBN 978-0-08-102629-8, DOI: 10.1016/C2017-0-02975-0.

Pererva, Y., Miler, C.D., & Sims, R.C. (2020). Sulfur, Phosphorus and Metals in the Stoichiometric Estimation of Biomethane and Biohydrogen Yields. *Processes*, 8(6), 714; DOI:10.3390/pr8060714.

Phillips, C. (2021). The hydrogen fuelled farm of the future. Retrieved February 28, 2022, from https://hydrogen.wsu.edu/2021/08/04/the-hydrogen-fueled-farm-of-the-future/.

Savickis, J., Zemite, L., Zeltins, N., Bode, I., & Jansons, L. (2020). Natural gas and biomethane in the European road transport: the Latvian perspective. *Latvian Journal of Physics and Technical Sciences*, 3, 57–72. DOI: 10.2478/lpts-2020-0016.

Siddiki, S.Y.A., Mofijur, M., Kumar, P.S., Ahmed, S.F., Inayat, A., Kusumo, F., Badrudding, I.A., Yunus Khan, T.M., Nghiem, L.D., Ong, H.C., & Mahlia, T.M.I. (2020). Microalgae Biomass as a Sustainable Source for Biofuel, Biochemical and Biobased Value-Added Products: An Integrated Biorefinery Concept. *Fuel*, 307, 121782. DOI: 10.1016/j.fuel.2021.121782.

Zupančič, M., Možic, V., Može, M., Cimerman, F., & Golobič, I. (2022). Current Status and Review of Waste-to-Biogas Conversion for Selected European Countries and Worldwide. *Sustainability*, 14(3), 1823; DOI: 10.3390/su14031823.

Yue, M., Lambert, H., Pahon, E., Roche, R., Jemei, S., & Hissel, D. (2021). Hydrogen energy systems: A critical review of technologies, applications, trends and challenges, *Renewable and Sustainable Energy Reviews*, 146, 111180. DOI: 10.1016/j.rser.2021.111180.

LEGAL FRAMEWORK OF URBAN FORESTRY MANAGEMENT IN LATVIA

***Ieva Kraukle**, **Ilze Stokmane**, **Kristine Vugule**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: ieva.kraukle@hotmail.lv

Abstract
Urban forestry is a relatively new branch where such issues as planning, governance and management of urban forests play an important role considering spatial planning of urban or suburban territory. The aim of the article is to find out the extent to which urban forests are reflected in European and Latvian regulatory enactments and planning documents, as well as to define the main recommendations for further actions; therefore, the regulatory enactments and planning documents of the European Union and Latvia were studied. Research showed that urban forests do not have any specific regulatory and planning framework at a European or Latvian scale. The standards that apply to urban forests can be found in regulatory enactments applicable to forest management, environmental protection, preservation of biological diversity, protection zones, plant protection, etc. In both European and local strategies, the forest issues as such and the issues of urban forests in particular appear as general, indirect issues, usually as the matters of biodiversity preservation or environmental sustainability. At the scale of Latvian legislation (laws and regulations of the Cabinet of Ministers), forests are mentioned in general, except for certain forestry laws, where forests are the main subject, which contain some provisions that are also directly applicable to urban forests. Urban forests are not reflected in these documents; to some extent they only appear in the plans as forest protection zones around cities.
Key words: Urban forests, urban forestry, legislation, planning documents, management of urban forestry.

Introduction

Compared to the general history of forestry, urban forestry planning and management is a new branch not only for Latvia, but also in the world scale. Urban forests do not have any specific regulatory standards and planning framework, it can be seen within the regulatory context of European Union, state and municipal forest management and development planning. The European Commission (EC) recognizes green infrastructure as one of the planning tools that contributes to the implementation from many field of the policy, such as biodiversity and nature protection, regional development, climate change adaptation, catastrophe risk management, etc. (EC. Green Infrastructure (GI) – Enhancing Europe's Natural Capital. Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Region, 2013). EU member states are expected to contribute to the implementation of these policies. Green infrastructure is defined as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' (EC. Green Infrastructure (GI) – Enhancing Europe's Natural Capital. Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2013).

Forest legislation has always been and still is a part of forest policy. Forest legislation is a set of legal rules regulating the relationship between the forest and a human. As it follows from Heinrihs Strods (Strods *et al*., 1999), forestry policy is a part of the economic policy of the state or its influential groups, a set of management tools and methods of action. Forest legislation has always been particularly closely linked to public economic policy. In Latvia, more serious actualization of nature protection issues in forest legislation began only shortly before the 1990s. Respecting of public interest in forestry has only begun in recent decades. Public participation in forestry processes is a topical issue that is still difficult for conservative foresters to accept, but it is increasingly a matter of solving difficult situations.

The aim of the article is to find out the extent to which urban forests are reflected in European and Latvian regulatory enactments and planning documents, as well as to define the main recommendations for further actions.

Urban forestry has become a professional and scientific field and partly horticulture, and it is used for urban management and the management of urban forests (Konijnendijk, 2003).

This concept gradually acquired importance in Europe in the 1990s (Konijnendijk, 2003; Krajter & Konijnendijk, 2015). However, there are different interpretations of what is or should be considered urban forests and urban forestry (Randrup *et al*., 2005).

It is widely acknowledged that urban forestry is a cross-sectoral and cross-disciplinary concept, and the forestry sector is only a stakeholder in the urban forestry mosaic (Randrup *et al*., 2005). An important role in this belongs to forestry and foresters, a number of other industries and / or disciplines, such as landscape architects, urban planners, gardeners, arborists (Krajter Ostoi *et al*., 2020).

The authors believe that an urban forest is a natural, semi-natural or artificial ecosystem at all stages of its

development, dominated by trees that can reach a height of at least seven meters and have a current or potential crown projection of at least 20% of the forest stand. Forest, which serves as a public outdoor space within and outside urban administrative boundaries, where the primary social and environmental functions require regular maintenance and renewal, preserving or enhancing the social, aesthetic, cultural and economic value of the territory (Kraukle, 2013).

In terms of urban forests, nowadays we can no longer talk about traditional forestry but about social forestry, whose main tasks are related to the provision of social functions and services (Konijnendijk *et al*., 2006), as well as environmental education (Akmar *et al*., 2011).

More and more studies provide data that there are areas in urban forests with relatively high biodiversity (Alvey, 2006); it is also considered to be one of the functions of urban forests.

Materials and Methods

To investigate the level of understanding and implementation of regulatory frameworks and policies of the European Union and Latvia applicable to the forestry sector, especially to urban forest issues, the policy documents were reviewed and analysed. In order to assess the regulations and policies related to urban forests and the effectiveness of institutional arrangements to enforce them, available and documented policies, legislations and strategic plans of three local counties of Latvia – Ikskile, Ogre and Jurmala, were reviewed. The planning documents of Ikskile, Ogre and Jurmala were selected for the study, because the urban forest areas are located in a large part of the territory of these municipalities; therefore, it is useful to study the local planning documents of these territories, taking into account that Ikskile county has merged with the new Ogre county.

Results and Discussion

International framework. The international and especially EU regulatory framework is also a regulatory instrument in Latvia; it sometimes serves as a basis for the provisions of local laws.

The Rio Convention on Biological Diversity, which has been in force in Latvia since 1995, stipulates that Latvia must take measures to ensure the preservation of biological diversity. Existing national strategies, plans and programs for biodiversity preservation must be developed or adapted (The Rio Convention on Biological Diversity, 1995). Urban forests are not explicitly mentioned in the convention, it is mentioned only in the context of preserving environmental diversity.

The Berne Convention on the Conservation of European Wildlife and Natural Habitats, the aim of which is to protect wild species and their natural habitats, has been in force in Latvia since 1996. Urban forests are not explicitly mentioned in the Convention, they are mentioned only in the context of the protection of wildlife and natural habitats. These are just two of a number of international documents to which Latvia has acceded and which indirectly and generally regulate the sustainable management of all forests, including urban forests.

The aim of the European Landscape Convention is to promote landscape protection, management and planning, and to organize cooperation on landscape issues in Europe. The Convention applies to the territories of all the parties and includes natural, rural, urban and suburban areas. It includes land and sea areas and inland waters. It applies to landscapes that can be considered outstanding, as well as to everyday or degraded landscapes (European Landscape Convention, 2000).

Green Paper on Forest Protection and Information in the EU: Preparing forests for climate change; the aim of this Green Paper is to launch a debate on the EU's approach to forest protection and forest information in line with the EU Forest Action Plan. Forest protection in the EU must be planned to ensure that all the productive, social economic and ecological functions of forests are maintained in the future (Green Paper, 2010).

Law on the Convention on the European Forest Institute (EFI), acceding to the Convention is necessary for Latvia to become more actively involved in international cooperation in forestry and the research of forest, including urban forest. The tasks of the EFI is to promote, lead and cooperate in research on forests, forestry and forest products at European scale, and to report on the results of research, in particular in the field of policy formulation and implementation, to promote the preservation and sustainable management of forests in Europe (Convention on the European Forest Institute, 2005).

The area of the development of forests and urban forests is also influenced by various statements and decisions of the European Commission and the Parliament.

Vienna Resolution – The MCPFE Ministerial Conference on the Protection of Forests in Europe in Vienna in 2003 emphasized the interrelationship between the forest sector and other sectoral policies. The documents of this conference mark the necessity to balance the economic, ecological and social role of forests and to continue working to protect European forests and ensure their sustainable management. The role of sustainable forest management in overall sustainable development was stated in Vienna. The Vienna Declaration on European Forests – Common Benefits, Shared Responsibilities and a number

of resolutions were signed on this conference, including: strengthening synergies for sustainable forest management in Europe through cross-sectoral cooperation and national forest programmes; preserving and enhancing the social and cultural dimensions of sustainable forest management in Europe (Ministerial Conference on the Protection of Forests in Europe, 2003).

On 11 December 2019, the European Commission presented the European Green Deal, proposed as a new EU growth strategy to transform the EU into a climate-neutral, fair and prosperous society with a modern, resource-efficient and competitive economy (European Green Deal, 2019). The Green Deal is a cornerstone of the European Commission's (EC) strategy to achieve the United Nations 2030 Agenda and the sustainable development. The issue of forests is considered indirectly, through the prism of climate neutrality. United Nations Forum on Forests (UNFF) Subdivision of the United Nations ECOSOC organization, a Working Party on Forestry. https://www.consilium.europa.eu/lv/council-eu/preparatory-bodies/working-party-forestry/

In the European region, voluntary cooperation at the political (ministerial) level takes place within the framework of the Ministerial Conferences on the Protection of Forests in Europe (Forest Europe). As part of the Forest Europe process, the Oslo ministerial decision was taken at the 2011 Oslo Conference and a new EU Forest Strategy for the State of Europe's Forests 2020 was developed in 2013, (EU Forest Strategy for 2030, 2021).

Under the auspices of the United Nations, various internationally important documents have been developed, which indirectly include the conservation and development of forests and urban forests. There are many protocols to the United Nations Framework Convention on Climate Change. For example, the Kyoto Protocol to the United Nations Framework Convention on Climate Change of 11 December 1997 stipulates, among other issues, that a specific target is set for forest management, the so-called forest management reference level of 16.302 million tonnes of CO2 eq.

National framework. In Latvia, with the legislation related to planning, it is difficult to find any indications about the forest, especially on planning of urban forests. Forests in Latvia, including urban forests, are planned and managed in accordance with the guidelines for forest management in the documents mentioned further on.

The Sustainable Development Strategy of Latvia for 2030 generally determines the need for the development of the forest sector while preserving biological diversity (Sustainable Development Strategy of Latvia until 2030, 2010).

The National Development Plan of Latvia 2021-2027 generally determines the need for the development of the forest sector. Direction 'Nature and environment – The Green Deal', Preservation of biological diversity, Implemented environmental, sustainable management of natural resources and energy policy, creation of green zones in urban environment (National Development Plan of Latvia 2021-2027, 2020).

Latvia's Forest Policy - adopted in 1998 defines the long-term strategic and tactic goals of forest sector development and the basic principles which among others included objectives such as to ensure avoiding of reduction of the forest areas by defining the limits of forest land transformation; to ensure the preservation and increase of the productivity and value of the forest lands; to promote afforestation of lands which are not used in agriculture of other unused lands, to apply the promotion mechanisms at the disposal of the state. The economical goal of the Forest Policy is to ensure the sustainable development and profitability of the forest sector considering the ecological and social requirements, as well as to create the higher possible growth of added value (Latvia's Forest Policy, 1998).

One of the most important principles included in the Forest Policy is that forest management needs to be improved, considering the role of the forest ecosystems in local and global processes – carbon sequestration and stabilization, protection of watercourses and water bodies, soils and landscapes, etc. In forestry, methods reproducing natural processes are desirable, bringing ecosystems closer to their natural structure and preserving elements that maintain biodiversity (Latvia's Forest Policy, 1998).

There are also some social principles issued within the Forest Policy, for example, that in forest management, the cultural and historical value and the protection of landscapes should be taken into account, or that the state promotes the development of social infrastructure in forest.

Guidelines for the development of the forest and related sectors for 2015-2020 - a medium term policy planning document, which formulates the medium term (2015-2020) strategic goals (development policy) for the development of forests and related sectors, the basic principles of the development policy, directions for actions to achieve the goals of development policy, problems hindering the achievement of these goals, as well as the results of the policies and activities, thus marking the future development of the forest sector.

Forest and its products and services are an important source of social welfare. Forest gives wood for construction and furniture making, as well as wood biomass for energy production, a place for living and also food. Forest protects water resources and soil from erosion, it is also a home for a significant part of

biodiversity. Forest is the source of income for people and their families, as well as it provides recreation possibilities. Due to these functions, forest policy and forest management at the global, national and regional levels are changing along with the change of society needs.

Environmental Policy Guidelines for 2021-2027 generally determine the need for the development of the forest sector based on sustainable development activities, preserving the quality of the environment and biodiversity, ensuring the sustainable use of natural resources (Environmental Policy Guidelines for 2021-2027, 2021).

Landscape Policy Guidelines for 2013-2019 generally determine the need for the development of the forest sector. One of its goals is creation of multifunctional and high-quality landscapes that improve the life quality throughout Latvia, promote economic activities and recognition of places, regions and the state, as well as ensure biodiversity (Landscape Policy Guidelines for 2013-2019, 2013).

The Law on Forests - its aim is to regulate the sustainable management of all Latvian forests by assuring equal rights, inviolability of property rights, independence of economic activity and defining equal obligations to all forest owners or legal possessors. (Law on Forests, 2000). References to urban forest planning and its link with spatial planning are given in Section 2 Paragraph 4 of the Law, which provides that 'Binding regulations of local governments shall also provide for additional conditions for the forest management in city and village territories' and in Section 2 Paragraph 5 (Law on Forests, 2000) – 'Forest management may not be in contradiction with the requirements specified in the spatial development planning documents'.

The Protection Zone Law, among other things, defines forest protection zones around cities (Protection Zone Law, 1997).

The Law on Specially Protected Nature Territories provides for the activities in specially protected nature territories located in forest lands (Law on Specially Protected Nature Territories, 1993).

The Environmental Protection Law, the Law on Protection of Species and Habitat, the Plant Protection Law – forest and urban forest issues are included indirectly through environmental and habitat protection issues (Environmental Protection Law, 2006).

Applicable Cabinet regulations are usually linked to a specific sector of forest issues, which they define specifically.

- Cabinet Regulations No.248 'Procedure for Assessment of Sustainable Forest Management' define the procedure for sustainable forest management (Cabinet Regulations No. 248 'Procedure for Assessment of Sustainable Forest Management', 2003).
- Cabinet Regulations No.63 'Methods of Establishing Forest Protection Belt around Cities' define the methodology for the establishing of forest protection zones around cities (Cabinet Regulations No. 63 'Methods of Establishing Forest Protection Belt around Cities', 2003).
- Cabinet Regulations No.264 'General Regulations on Protection and Use of Specially Protected Nature Territories' define the actions on the specially protected nature territories in forest lands (Cabinet Regulations No.264 'General Regulations on Protection and Use of Specially Protected Nature Territories', 2010).
- Cabinet Regulations No.628 'On Local Government Territorial Development Planning Documents' relates to the forest, urban forest, more often – to specially protected nature territories included in the planning documents (Cabinet Regulations No.628 'On Local Government Territorial Development Planning Documents', 2014).

The hierarchy of regulatory enactments and planning documents related to urban forests is presented in Figure 1.

Territorial planning documents have been selected from Ikskile, Ogre (within the territorial reform 2021 Ikskile is included in the territory of Ogre county) and Jurmala city, as these areas contain territories of urban forests (right now they do not have a specific title of urban forest territories though), and they can be used as pilot territories in Latvia to examine urban forestry management in the future. Besides the territories of Ogre and Jurmala urban forests are located on specially protected nature areas. During the research the guidelines for territorial planning of certain territories in relation to urban forests were studied (Table 1).

The documents on territorial planning contain a very limited and general information on forest areas. The long-term development strategy of Ikskile county for 2011-2030 determines that the main values of the county are natural and landscape resources (The long-term development strategy of Ikskile county for 2011-2030, 2011).

The strategy of sustainable development of Ogre county for 2013-2037 sets the goal-of responsible nature management. The use of natural resources (forests and natural resources, including those found in swamps and waters) must be careful and complex, making maximum use of all the extracted materials and performing high-quality restoration / development of forest stands or transforming the used areas into other economically usable territories (Ogre 2013). The strategy of sustainable development

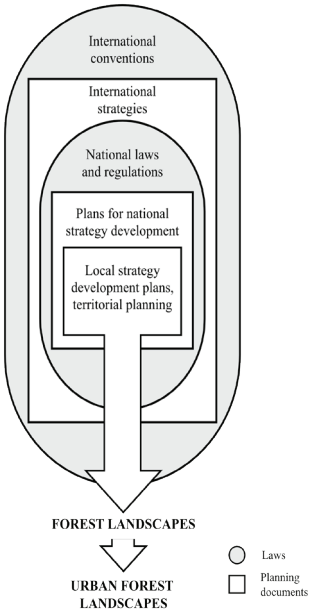

Figure 1. The hierarchy of regulatory enactments and planning documents related to urban forests.
Source: Created by author.

of Ogre county for 2013-2037 guidelines that in the long run Ogre county will take care of the reasonable, complex and reduced-impact use of natural resources in the economic activities and will protect landscapes and biotopes that are important for the preservation of the biological and landscape diversity of the county and high-quality living environment (The strategy of sustainable development of Ogre county for 2013-2037, 2013).

Sustainable Development Strategy of Jurmala City for 2010-2030 states that the city successfully combines careful use of local rich natural resources (forests, vast beaches, mineral water and healing mud, coastal climate), the preservation of cultural and historical heritage and gaining economic benefits from resorts, sports, health, cultural and conference tourism services. Priority sets the protection of natural values insuring the preservation of the resort environment, without fragmenting large forest massifs (Jurmala, 2010). Forests appear on the map of Jurmala resort possibilities, Appendix 2 'The Resources for the Development of a Resort Town' and Appendix 'Green Areas of the City'.

Concerning the local spatial development programmes forest areas as such do not appear in the title of the such programmes, it refers to specific actions that appear under the section Specially Protected Areas as a general description.

- Ikskile County Development Program for 2019-2025 – action 'Natural resources and environmental protection' provides the implemented environmental protection projects in the nature park 'Ogres Zilie kalni' (Blue Mountains in Ogre) (Ikskile County Development Program for 2019-2025, 2019).
- In Ogre County Development Programme for 2014-2020, in section 'Forests and swamps', notes that the diversity of bedrock, relief forms and the differences in rainfall resulted in great diversity of soils and vegetation. Forests play an important role in the formation of landscape and economic activity (Ogre, 2014). The areas of the Blue Mountains are mentioned in Specially Protected Areas section and are also marked as a recreation area (Ogre County Development Programme for 2014-2020, 2015).
- The Development Programme of Jurmala City for 2014-2022 only provides for certain activity Implementation of the infrastructure improvement plan of the Nature Reserve 'Ragakapa', which envisages the creation of walking paths, observation tower, information signs, toilets provided by the Nature Protection Plan, which will be implemented by Jurmala City Council (Development Programme of Jurmala City for 2014-2022, 2013).

The territory planning documents in Latvia usually show forest areas and specially protected nature areas, but, in some cases, they include only nature areas without separating forest areas. Forest protection zones of adjacent cities appear in regional plans.

- Ikskile County Territory Planning documentation contains regulations for the use and building development of the territory, where nature and greenery territories and forest territories appear, as well as other forest protection zones around the

Table 1

Representation of forests in the territorial planning documents

Territory planning	Representation of the forest protection zone	Representation of the specially protected areas	The forest territories are shown in the plan
Ikskile county	The planned use of the territory on the map	The planned use of the territory on the map	Forest territories
Ogre county	The planned use of the territory on the map	The planned use of the territory on the map	Green areas
Jurmala city	Encumbrances on the map	Encumbrances on the map	Natural territories and green spaces

cities; the explanatory article briefly mentions the nature park 'Ogres Zilie kalni' (Blue Mountains in Ogre) (Ikskile County Territory Planning, 2021).

- In the Territorial Plan of Ogre County, only the green areas appear on the map, while forests are not even singled out. The map also shows the forest protection zone around the city of Ogre (Territorial Plan of Ogre County, 2012).
- The Territorial Plan of Jurmala defines only natural area and green spaces, which include also forests (Territorial Plan of Jurmala, 2016).

Conclusions

EU scale resolutions, conventions and conferences, as all strategic documents, are very general and therefore can be applied in general to the necessary areas, including urban forests. Latvia has ratified and actively supports many resolutions and conventions and is using them in its legislation and strategic planning; ideas on urban forests are also indirectly and generally expressed in these planning documents, as it is used to be in strategic documents. It would be important to mention the role of forests already in the top-level documents, such as the Berne Convention on the Conservation of European Wildlife and the Rio Convention on Biodiversity, emphasising the topicality of forests and urban forests in maintaining and preserving biodiversity and natural habitats as well as in the main governing documents. It is important because forest is relatively stable ecosystem, and it requires much less resources to maintain than man-made parks.

Considering the international conventions and resolutions, national scale planning documents are also very general and mention forests in some cases only, never singling out urban forests, which in some cases are more important than regular forests, given their location in the urban environment, where their contribution to biodiversity is especially important.

Laws and Cabinet regulations already contain more specific information on forests, but the concept of urban forests does not yet appear although forests located in or near urban areas are definitely mentioned (forest protection zones around cities). Failure to single out urban forests makes it difficult to identify their specific functions and, consequently, to manage ensure their further proper management.

Local planning documents and binding regulations at the strategic level mention forests in general terms when referring to the forests located on the territory, and also indirectly mentioning specially protected areas. As indicated in Table 1, separately allotted forest areas may not appear in the territorial plans at all, they are included in the maps under other names - green spaces or natural and green areas. The name 'urban forests' does not appear at all, but it would be the most precise way to define the forest areas located in a city or nearby, also demonstrating the special functions of urban forests.

When reviewing the above regulatory enactments and planning documents, it is necessary to introduce a unified definition of urban forests in general. There is a lack of legislation identifying and regulating urban forests although urban (suburban) forests actually exist. The issues of urban forest management may need more comprehensive regulation with less emphasis on strategic planning. Forests, including urban forests, should be more specifically mentioned in the international and local legislation and planning documents, considering their substantial significance in reducing CO_2 emissions, providing biodiversity and social services.

References

Akmar, A.A., Konijnendijk, C.C., Streetheran, M., & Nilsson, K. (2011). Greenspace planning and management in Klang Valley, Peninsular Malaysia. *Arboriculture&UrbanForestry*, *37*(3), 99–107.

Alvey, A.A. (2006). Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening*, *5*(4), 195–201. DOI: 10.1016/j.ufug.2006.09.003.

European Commission. (2019). *The European Green Deal. COM(2019) 640 Final*. Brussels: European Commission.

European Commission. (2021). *EU Forest strategy for 2030*. European Commission. (2021). *New EU Forest Strategy for 2030. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2021) 572 Final*. Brussels: European Commission.

Green Infrastructure (GI) – Enhancing Europe's Natural Capital (2013). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*. Retrieved January 21, 2022, from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249.

Ikšķiles novada attīstības programma 2019.-2025.gadam. (2019). (Ikskile County Development Program for 2019-2025). Retrieved January 4, 2022, from https://www.ikskile.lv/lv/attistiba/attistibas-planosana/ikskiles-novada-attistibas-programma-2019-2025. (in Latvian).

Ikšķiles novada ilgtermiņa attīstības stratēģija 2011-2030 gadam. (2011). (Long-Term Development Strategy of Ikskile County for 2011-2030). Retrieved January 4, 2022, from https://www.ikskile.lv/sites/default/files/inline-files/9101_IKSKILE_AS_22062011_vF.pdf. (in Latvian).

Ikšķiles novada teritorijas plānojums. (2021). (Ikskile County Territory Planning). Retrieved January 4, 2022, from https://www.ikskile.lv/lv/jaunumi/ikskiles-novada-teritorijas-planojuma-2011-2023gadam-saistosa-dala. (in Latvian).

Jūrmalas pilsētas attīstības programma 2014.-2022.gadam. (2013). (Development Programme of Jurmala City for 2014-2022). Retrieved January 18, 2022, from https://www.jurmala.lv/lv/attistibas-planosanas-dokumenti. (in Latvian).

Jūrmalas pilsētas teritorijas plānojums. (2016). (The Territory Plan of Jurmala). Retrieved January 18, 2022, from https://www.jurmala.lv/lv/attistibas-planosanas-dokumenti. (in Latvian).

Konijnendijk, C.C. (2003). A decade of urban forestry in Europe. *Forest Policy and Economics*, *5*(2), 173–186. DOI: 10.1016/S1389-9341(03)00023-6.

Konijnendijk, C.C., Ricard, R.M., Kenney, A., & Randrup, T.B. (2006). Defining urban forestry - A comparative perspective of North America and Europe. *Urban Forestry and Urban Greening*, *4*(3-4), 93–103. DOI: 10.1016/j.ufug.2005.11.003.

Krajter Ostoi, S., Dijana, V., Špela, P., Urša, V., & Japelj, A. (2020). Three Decades of Urban Forest and Green Space Research and Practice in Croatia and Slovenia. *Forests*, *11*. DOI: 10.3390/f11020136.

Krajter, S., & Konijnendijk, C.C. (2015). Exploring global scientific discourses on urban forestry. *Urban Forestry & Urban Greening*, *14*, 129–138. DOI: 10.1016/j.ufug.2015.01.001.

Kraukle, I. (2013). *Pilsētmežu plānošana un pārvaldība: Lielrīgas piemērs*. (*Urban forest planning and management: Greater Riga example).* Latvijas Universitāte. (in Latvian).

Latvijas Republikas Ministru kabinets (2010). *Ministru kabineta noteikumi Nr.264 Īpaši aizsargājamo dabas teritoriju vispārējie aizsardzības un izmantošanas noteikumi (Cabinet Regulation No.264 'General Regulations on Protection and Use of Specially Protected Nature Territories').* Rīga: Latvijas Republikas Ministru kabinets. (in Latvian).

Latvijas Republikas Ministru kabinets. (2003). *Ministru kabineta noteikumi Nr.63 Meža aizsargjoslu ap pilsētām noteikšanas metodika (Cabinet Regulations No.63 'Methods of Establishing Forest Protection Belt around Cities').* Rīga: Latvijas Republikas Ministru kabinets. (in Latvian).

Latvijas Republikas Ministru kabinets. (2013). *Ainavu politikas pamatnostādnes 2013.-2019.gadam* (*Landscape Policy Guidelines for 2013-2019*). Rīga: Latvijas Republikas Ministru kabinets. (in Latvian).

Latvijas Republikas Ministru kabinets. (2014). *Ministru kabineta noteikumi Nr.628 Noteikumi par pašvaldību teritorijas attīstības plānošanas dokumentiem (Cabinet Regulations No.628 'On Local Government Territorial Development Planning Documents').* Rīga: Latvijas Republikas Ministru kabinets. (in Latvian).

Latvijas Republikas Saeima. (1993). *Par īpaši aizsargājamām dabas teritorijām. (On Specially Protected Nature Territories).* Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (1995). *Riodežaneiro konvencija 'Par bioloģisko daudzveidību' (Rio Convention on Biodiversity)*. Rīga: Latvijas Republikas Saeima. (in Latvian)

Latvijas Republikas Saeima. (1997). *Aizsargjoslu likums (Protection Zone Law).* Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (1998). *Latvijas meža politika* (*Latvia's Forest Policy*). Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2000). *Eiropas ainavu konvencija* (*European Landscape Convention*). Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2000). *Meža likums (Law on Forests).* Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2006). *Vides aizsardzības likums (Environmental Protection Law).* Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2007). *Konvencija par Eiropas Meža institūtu* (*Convention on the European Forest Institute*). Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2010). *Latvijas ilgtspējīgas attīstības stratēģija 2030.gadam. (Sustainable Development Strategy of Latvia for 2030)*. Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2010). *Zaļā grāmata, Meža aizsardzība un meža informācija ES* – gādājot par mežu *gatavību klimata pārmaiņām SEC (2010)163 final. (Green Paper Forest protection and forest information in the EU: preparing forests for climate change SEC (2010) 163 final).* Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2020). *Latvijas Nacionālais attīstības plāns 2021.-2027. gadam. (National Development Plan of Latvia 2021-2027)*. Rīga: Latvijas Republikas Saeima. (in Latvian).

Latvijas Republikas Saeima. (2020). *Vides politikas pamatnostādnes 2021.–2027. gadam (Environmental Policy Guidelines for 2021-2027).* (2021). Rīga: Latvijas Republikas Saeima. (in Latvian).

Ministerial Conference on the Protection of Forests in Europe. (2003). Retrieved December 20, 2021, from https://foresteurope.org/.

Ogres novada attīstības programma 2014.-2020.gadam, (2015). (Ogre County Development Programme for 2014). Retrieved January 28, 2022, from https://www.ogresnovads.lv/lv/attistibas-dokumenti. (in Latvian).

Ogres novada ilgtspējīgas attīstības stratēģija 2013.-2037. gadam. (2013). (Strategy of sustainable development of Ogre county for 2013-2037). Retrieved January 28, 2022, from https://www.ogresnovads.lv/lv/attistibas-dokumenti. (in Latvian).

Ogres novada teritorijas plānojums. (2012). (Ogre County Territory Planning). Retrieved January 28, 2022, from https://www.ogresnovads.lv/lv/attistibas-dokumenti. (in Latvian).

Randrup, T.B., Konijnendijk, C., Dobbertin, M.K., & Prüller, R. (2005). The concept of urban forestry in Europe. In Konijnendijk, C., Nilsson, K., Randrup, T.B., Schipperijn, J. (Ed.), *In Urban Forests and Trees* (pp. 9–21). Springer.

Strods, H., Zunde, M., Mugurevičs, Ē., Mugurēvičs, A., Liepiņa, D., & Dumpe, L. (1999). *Latvijas mežu vēsture līdz 1940. gadam (History of Latvain Forests until 1940)*. WWF – Pasaules Dabas Fonds. (in Latvian).

PREVALENCE OF LONG-TERM AND SHORT-TERM POLLUTION OF CHEMICAL ELEMENTS IN THE CITY OF JELGAVA

***Jovita Pilecka-Ulcugaceva**, **Anda Bakute**, **Inga Grinfelde**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: jovita.pilecka@llu.lv

Abstract
Air pollution is a global environmental problem. More than 92% of the world's population lives in areas where air pollution exceeds limit values. The aim of the research is to analyse the pollution of chemical elements and their distribution in the environment of Jelgava city, using long-term and short-term pollution detection methods. City air quality is a critical factor in ensuring the quality of life in the city.
Methods for the identification of contamination of chemical elements can be divided into two broad groups: 1. for the determination of short-term pollution and 2. for the determination of long-term pollution. Temporary pollution is determined using two methods: the analysis of snow samples and the placement of lichen transplants in the city. Long-term pollution is determined by analysing the chemical composition of lichen (*Xanthoria parietina*) and determining the air purity index I.A.P.
During the work, snow samples were collected on 10 January and 14 February 2017 to detect temporary contamination; samples were collected in 20 sampling areas of the urban area and one sampling area of the natural site with three repetitions. Chemical elements were identified in 120 snow samples and 60 lichen samples (*Xanthoria parietina*) from the city and six snow samples and three lichen samples (*Xanthoria parietina*) from the forest, which is on the southwest side of the city and represents background pollution with chemical elements.
Preliminary results vividly reflect the effect of transport corridors on the chemical composition of snow samples. Snow analyses indicate pollution from heat supply and road transport.
Key words: environment, pollution, heavy metals in the city, snow.

Introduction

Air pollution is one of the most significant environmental problems, as well as it is the biggest environmental threat to health (She *et al*., 2017). People living in cities, especially large cities, face serious health threats from urban air pollution (Shi, Ka-Lun Lau, & Ng, 2017). Industrial development and urbanisation worldwide have led to chemical pollution of the environment. About 92% of the world's population lives in places where the level of air pollution does not meet the permissible limits (Battista & de Letto Vollare, 2017). Pollution in the air causes various diseases or even death in many parts of the world. The number of premature deaths due to air pollution in the world has risen from 0.22 million in 2010 to 3.7 million in 2012, highlighting the high health risk. For example, air pollution has become the fourth most significant risk factor for deaths in China (She *et al*., 2017).

Economic activity increases every year, and it promotes the intensive use of natural resources. The use of chemicals in agriculture, households, mineral extraction and industrial use cause significant air pollution with various chemical elements (Tchounwou, Yedjou, Patlolla, & Sutton, 2014). Several studies use snow as an indicator of urban air pollution (Dossi *et al*., 2007; Engelhard *et al*., 2007).

The idea that lichen is affected by air pollution was first expressed in 1790 by studying lichen at metal foundries in North Wales (Nimis, Scheidegger, & Wolseley, 2002). The environmental monitoring method, based on the viability of lichen, is based on various environments. The development phase of lichen indication developed most rapidly in the 20th century. In the 1960s and 1970s, when the theoretical bases for lichen indications were formed, essential methods of lichenoindiation were developed, such as the Index of Atmospheric Purity – I.A.P. (LeBlanc & DeSloover, 1970). The benefits of lihenoindication are the low cost and ability to characterise long-term pollution. The objective of the research is to analyse the pollution and distribution of chemical elements in Jelgava city's environment using long-term and short-term pollution detection methods.

Tasks of the research are:

1. To get acquainted with the experience of previous research to identify chemical element pollution in the urban environment;
2. To develop a methodology for chemical element pollution identification and to select a pilot site for conducting a study;
3. To carry out sampling and sample analysis;
4. Analyse the prevalence of pollution of chemical elements and provide proposals to limit pollution.

Materials and Methods

Jelgava has more than 59,000 inhabitants (Office of Citizenship and Migration Affairs Republic of Latvia) and it is located in the middle of Latvia next to the Lielupe (Figure 1). It is located in the temperate climate zone. The average annual rainfall is 180 mm in autumn, 117 mm in winter, 124 mm in spring and 217 mm in summer. The snow typically ranges from November to March, and the length of the snow

Figure 1. The geographical location of Jelgava city (created by the author).

exposure period is affected by local meteorological conditions, such as the effects of urban heat islands. The region is dominated by westerly and south-westerly winds (LEGMC).

The territory of Jelgava city (60.32 km^2) for air quality mapping depending on the building density, location of highways and production companies is divided into 104 plots (green dots in Figure 2) – centre 500 m x 500 m (52 plots) and the rest area – 1 km x 1 km (52 plots). The sample plots were established in 1996, where repeated research was carried out according to a standard methodology also in 2006 and 2016. Considering the intensity of construction and the development trends of the city of Jelgava, 21 additional sample plots (read dots in Figure 2) have been created in this study (Figure 2).

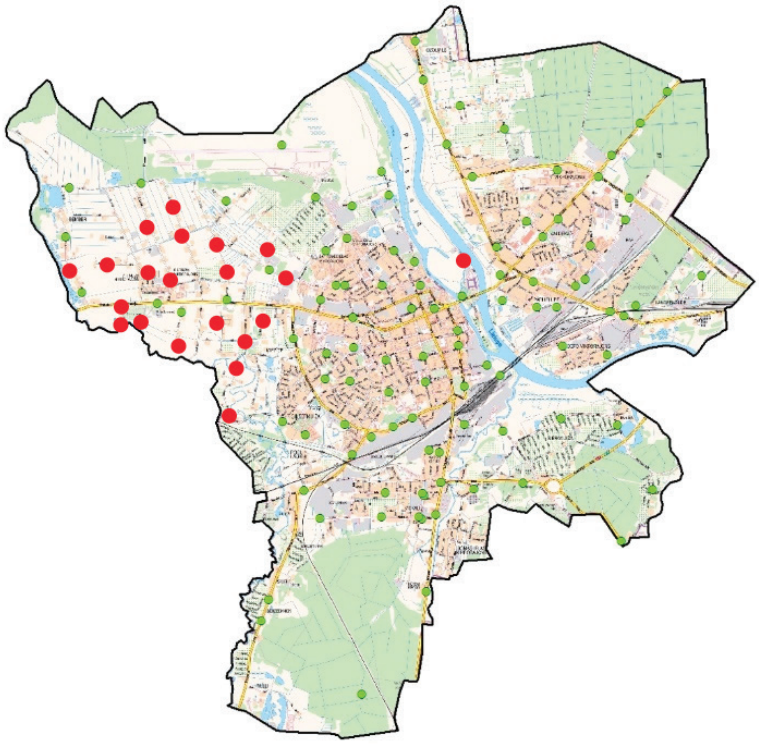

Figure 2. Location of lichen indication plots in Jelgava city, added plots in read (created by the author).

Quantitative assessment of lichen diversity is one of the simplest and most effective methods for lichen indication. Air purity index I.A.P. (Index of Atmospheric Purity) method (LeBlanc & De Sloover, 1970) is considered the most popular bioindication solution globally for air quality assessment obtained data reflect the long-term level of pollution. An inventory of all lichen species was made on ten tree trunks at the height of 30 cm to 2 m in each plot. The percentage of lichens by species is estimated on the side of the trunk where the most lichens are found.

The air purity index or I.A.P. is determined for each plot and consists of the sum of the product of the toxicological tolerance factor Q for all lichen species and the values for the degree of coverage f.

It is calculated by the following equation:

$$IAP = \sum_{l}^{n} \frac{(Q \times f)}{10} \quad (1)$$

where: I.A.P. – air purity index; n – number of lichen species in the study area; Q – toxic tolerance factor (constant for each lichen species) (1).

$$Q = {}^{n_1}/_{n_2} \quad (2)$$

where: n_1 – the total number of all lichen species in all plots containing the species of interest; n_2 – the sum of the sample plots in which the species of interest is found; f – degree of cover occurrence, which is determined by the combination of the percentage cover of the lichen species and the frequency of occurrence of the lichen species in each plot (2).

f values:

1 – species rare, with little cover; 2 – species rare or with 1-5% coverage; 3 – species not common or with 5-10% coverage; 4 – species often or with 10-20% coverage; 5 – species widespread with a coverage of more than 20%.

The study selected 1250 deciduous trees, possibly with similar ages, crown shapes and exposures, and similar growing sites, mainly on the side of streets and roads.

Analysis of snow samples is one of the methods for monitoring pollution with chemical elements in urban areas. As part of the work, snow samples were collected on 10 January and 14 February 2017 to determine transient chemical contamination. Samples were collected at 20 urban sampling sites and one natural site sampling site with three replicates, averaging from 1.0-1.5 kg of snow. The average snow depth was 6-10 cm. Inductively coupled plasma-optical emission spectroscopy (ICP-OES) method was used to determine chemical elements in melting snow water.

In order to determine the long-term pollution in the city area, lichen samples were collected. They were harvested from deciduous trees, about 1.3-1.5 m above the ground. Preparation of the samples to determine the chemical elements: (a) The lichens are dried and then weighed in a 50 ml glass beaker with an analytical balance of 0.3000 ± 0.0002 g. (b) Add 10 ml of concentrated HNO_3 and 5 ml of concentrated H_2O_2 (analytical reagents); (c) after 12 hours, the solutions were extracted by heating in a block at 160 °C; (d) After cooling the extract (7.5 ml), filter the sample solutions and makeup to 20 ml with ultrapure deionised water in polypropylene tubes. Metal concentrations and chemical elements were measured with an ICP-OES spectrometer. Chemical elements were determined in 120 snow samples and 60 lichen samples (*Xanthoria parietina*) from the city, six snow samples, and three lichen samples (*Xanthoria parietina*) from the forest outside the city.

Results and Discussion

The air purity index in the territory of Jelgava was calculated using data from 104 plots, and air pollution zones were divided into three groups:

I High pollution zone: With a minimal lichen population or lichen survival zones (I.A.P. from 0-110); II Medium pollution zone: With limited lichen population or transition zone (I.A.P. = 111 – 200); III Low Pollution Zone: Lichen-rich or natural environment zone (I.A.P.> over 200).

The high air pollution zone in Jelgava in 2016 occupied 1.66 km^2 or 2.75% of the entire city territory: it was found in 4 sample plots: in the centre of Jelgava – in 3 sample plots (part of wastewater treatment plants; the territory of LTD. Larelini, Palīdzības street) and outside the centre - in one sample plot (near Langervalde park).

The average air pollution zone in Jelgava in 2016 occupied 26.54 km^2, or 44.0% of the total area. Compared to the previous results in 1996, its area had slightly increased – from 25.76 km^2 or 44.0% to 26.54 km^2 or 44.0%, respectively, but compared to the results of 2006, it had decreased from 29, respectively, 26 km^2 or 48.51%, 26.54 km^2 or 44.0%.

In 2016, the low air pollution or clean air zone in the city of Jelgava occupied more than half of the city territory – 32.12 km^2 or 53.25%. Compared to the previous results in 1996 and 2006, in general, it had slightly increased in Jelgava: in 1996 – 32.11 km^2 or 53.23% and 2006 – 29.56 km^2 or 49.01%. However, compared to the previous results in the city centre, the clean air area now occupies only 3 km^2 or 23.08% of the area; moreover, it tends to decrease (5.75 km^2 or 44.25% and 5 km^2 or 38.46% respectively in 1996 and 2006).

The KL_SM_4 cluster is characterised by extremely high pollution, where the primary source is transport exhaust. The KL_SM_3 cluster is characterised by

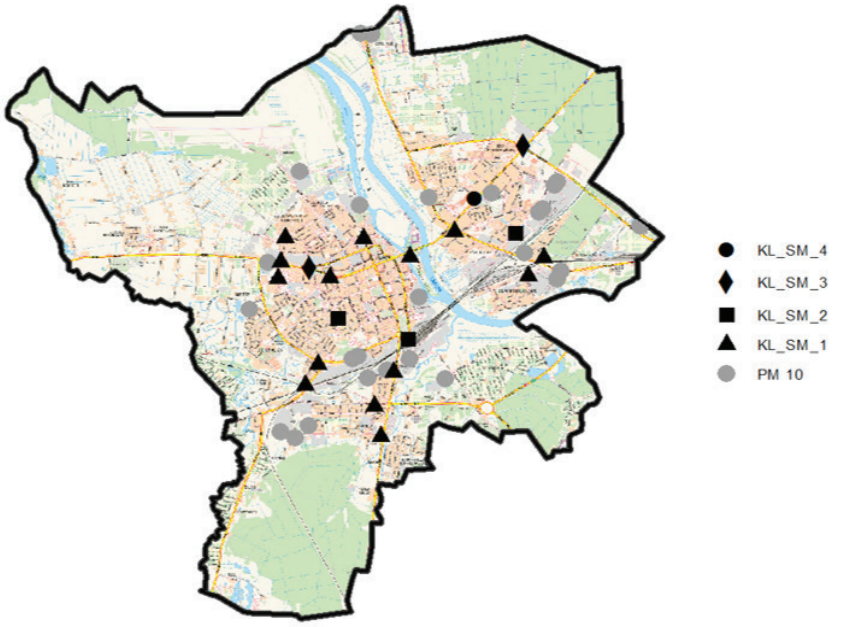

Figure 3. Cluster analysis results of short term air pollution by chemical composition of snow samples collected 14.02.2017 (created by the author).

high levels of pollution from transport exhaust. The KL_SM_2 cluster is characterised by high pollution resulting from industrial processes. The KL_SM_1 cluster is characterised by relatively clean air, with little pollution from transport (Figure 3).

Conclusions

According to the long-term air pollution monitoring data, there is 2.75% high pollution zone, 44.0% medium pollution zone and 53.25% low pollution zone in the territory of Jelgava city. According to the long-term air pollution monitoring data, there is 2.75% high pollution zone, 44.0% medium pollution zone and 53.25% low pollution zone in the territory of Jelgava city. According to short-term air pollution monitoring data, 2 points have very high transport pollution, but surprisingly high air pollution, the primary source of transport exhaust, is at one point.

For further research, it is recommended to establish a more uniform sampling network to obtain more detailed information on the spatial variability of chemical element concentrations.

References

Battista, G., & Letto Vollare de R. (2017). Correlation between air pollution and weather data in urban areas: Assessment of the city of Rome (Italy) as spatially and temporally independent regarding pollutants. *Atmospheric Environment*, 165, 240–247. DOI: 10.1016/j.atmosenv.2017.06.050.

Dossi, C., Ciceri, E., Giussani, B., Pozzi, A., Galgaro, A., Viero, A., & Viagano, A. (2007). Water and snow chemistry of main ions and trace elements in the Karst system of Monte Pelmo massif (Dolomites, Eastern Alps, Italy). *Marine and Freshwater Research*, 58, 649–656. DOI: 10.1071/MF06170.

Engelhard, C., De Toffol, S., Lek, I., Rauch, W., & Dallinger, R. (2007). Environmental impacts of urban management the alpine case study of Innsbruck. *Science of the Total Environment*, 32, 286–294. DOI: 10.1016/j.scitotenv.2007.04.008.

Office of Citizenship and Migration Affairs Republic of Latvia. Retrieved February 14, 2022, from https://www.pmlp.gov.lv/lv/media/1921/download. (in Latvian).

LeBlanc, F., & DeSloover, J. (1970). Relations between industrialisation and the distribution and growth of epiphytic lichens and mosses in Montreal. *Canadian Journal of Botany*, 48, 1485–1496. DOI: 10.1139/b70-224.

Latvian Environment, Geology and Meteorology Centre (LEGMC). Retrieved February 14, 2022, from https://www.meteo.lv/lapas/laika-apstakli/klimatiska-informacija/laika-apstaklu-raksturojums/si-gada-laika-apstakli/janvaris-2017/laika-apstaklu-raksturojums-2017-gada-janvari?id=2200&nid=1089. (in Latvian).

Nimis, P.L., Scheidegger, C., & Wolseley, P.A. (Eds.). (2002). Monitoring with lichens – monitoring lichens. NATO science series. Series IV: earth and environmental sciences: Vol. 7, NATO advanced research workshop on lichen monitoring. DOI: 10.1007/978-94-010-0423-7.

She, Q., Peng, X., Xu, Q., Long, L., Wei, N., Liu, M., Jia, W., Zhou, T., Han, J., & Xiang, W. (2017). Air quality and response to satellite-derived urban form in the Yangtze River Delta, China. *Ecological Indicators.*75, 297–306. DOI: 10.1016/j.ecolind.2016.12.045.

Shi, Y., Ka-Lun Lau, K., & Ng, E. (2017). Incorporating wind availability into land use regression modelling of air quality in mountainous high-density urban environment. *Environmental Research*, 157, 17–29. DOI: 10.1016/j.envres.2017.05.007.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K., & Sutton, D.Y. (2014). Heavy Metals Toxicity and the Environment. H.H.S. Public Access. Author manuscript. E.X.S. 2012; 101: 133–164. DOI: 10.1007/978-3-7643-8340-4_6.

USING THE ECOSYSTEM SERVICES APPROACH TO ASSESS LANDSCAPE QUALITY

***Aiga Spage**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: aiga.spage@llu.lv

Abstract
Globally Covid-19 has proven how important nature and landscape are to ensure human well-being physically and mentally. This research used a systematic literature review method to get an overview of existing research articles that specifically assess landscape quality in large scale landscapes using nowadays widely used ecosystem service approach. Research answers four key questions – (1) Which ES were assessed to evaluate the quality of landscape? (2) Which methods were used to assess ES? (3) Which ES indicators were used to determine the quality of landscape? (4) What data were used to conduct the research? The most widely assessed ecosystem service group is focused on the visual quality of the landscape. The most frequently used method group includes statistical analysis and surveys and questionnaires, followed by spatial assessment methods. Indicators that were frequently used in research included general land-use types and separate landscape elements. In order to use such indicators, qualitative and large amount of spatial data are needed to evaluate the quality of the landscape. Wider research is needed to understand landscape quality assessment methods before the ecosystem service term appeared in the research field.
Key words: ecosystem services, landscape quality, systematic literature review, assessment.

Introduction

Nowadays society faces major challenges globally, and the Covid-19 pandemic has demonstrated how important and integral nature and landscape are in our everyday lives (Havinga *et al*., 2021). Landscape quality and all ecosystem services (ES) that landscape provides are vital for our mental and physical well-being. People's perception of landscape is formed from both – biophysical features (elevation, vegetation, etc.) and personal or cognitive perception, but there are still discussions on which approach is more accurate to evaluate visual landscape quality (Jovanovska *et al*., 2020; Price, 2013) or how to quantify landscape quality in general (Swetnam, Harrison-Curran, & Smith, 2017). People's understanding of landscape quality varies from the perception of visual or sensual qualities to the overall understanding of ecological processes, history and culture that affects landscape character and our personal feelings towards specific landscape (cognitive perception) (Gottero, Cassatella, & Larcher, 2021; Solecka *et al*., 2022; Swetnam, Harrison-Curran, & Smith, 2017; Wartmann *et al*., 2021).

ES approach is widely researched and used to evaluate different features of nature, landscape and urban environments, to produce trustworthy evidence of ecosystem function and public goods to support decision making. ES are being described differently in different sources, but one of the first definitions in Millennium Ecosystem Assessment stated that ES are benefits that people gain from ecosystems (Millennium Ecosystem Assessment, 2005). The definition of ES had a snowball effect and a large number of research articles concentrated on ES and their evaluation (Brzoska & Spāģe, 2020).

The urban environment has been researched widely from different perspectives, including the landscape quality in urban environments, especially because of rapid urbanisation. Many more residents move to cities and to ensure their well-being urban ecosystems and their services are vital (Gómez-Baggethun & Barton, 2013; Haase, Frantzeskaki, & Elmqvist, 2014). For large scale landscapes, ES assessment needs more high-quality data and method choice may differ. Usage of spatial data in ES assessment has increasingly shown that a large amount of data can provide an overview of potentially high-quality areas that provides a range of ES (Ungaro *et al*., 2016). As the assessment of landscape quality has become increasingly important in recent years, interest in assessing the quality of landscapes through ES is also growing (Swetnam & Tweed, 2018). Defining high-quality landscapes can point out landscape sensitivity in specific places to specific changes or transformations (Senes *et al*., 2020) and that sort of information can help decision-makers to protect landscapes from degradation. Before mentioned aspects forms an aim for this research – get an overview of how frequently the ES approach was used to assess the quality of the landscape, which indicators and methods were used to do so and which data categories were used. In order to achieve the aim of this research four key questions were defined in the Materials and Methods section.

Materials and Methods

The research method presented in this paper is a systematic literature review after Pickering and Byrne (Pickering & Byrne, 2014) (Figure 1). The aim of using this method was to gather an overview of the research field that specifically concentrates on ES assessment to evaluate the landscape quality. The first step was to understand the search key words and attributes, define the aim of this research – to understand how often and how the ES approach was used to determine

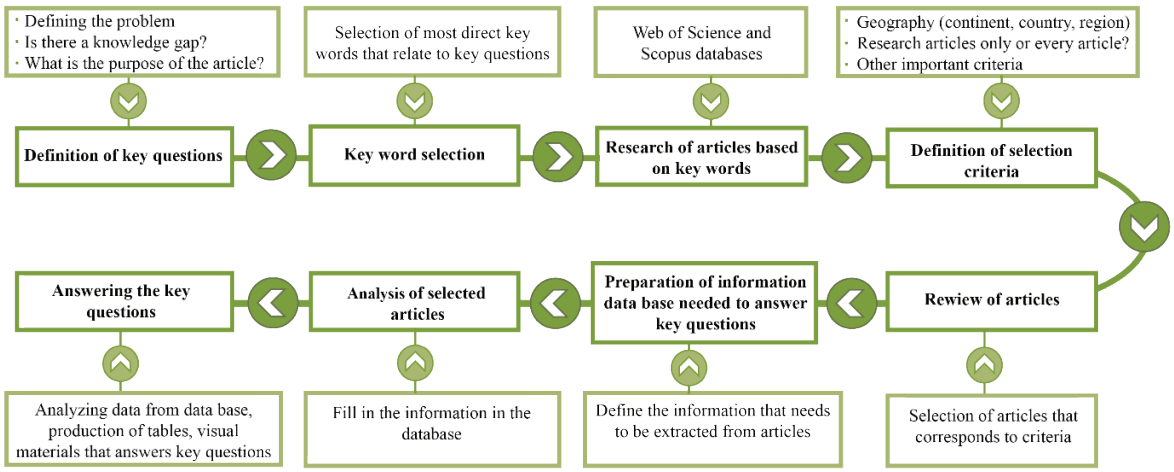

Figure 1. Flowchart of the systematic literature review method used in this article (Source: after Pickering, & Byrne, 2014).

the landscape quality, which methods were used, and based on which ES indicators research was done and to assess the possibility of particular method repetition. Also, used data was analysed. To achieve the aim of this paper, four key questions were defined: (1) Which ES were assessed to evaluate the quality of landscape? (2) Which methods were used to assess ES? (3) Which ES indicators were used to determine the quality of landscape? (4) What data were used to conduct the research?

The next step included a selection of key words that were used to conduct a search in two databases – 'Web of Science' and 'Scopus'. Searches were conducted by adding the search terms 'ecosystem services' and 'landscape quality' in both databases, the search was narrowed to specific fields – title, key words, or abstract. After the search was finished, cross-check was done to exclude repeated articles. At the starting stage key words like 'landscape character' and 'landscape aesthetics' were included, but when reviewing search outcomes, it was concluded that these key words are focusing on a different area of landscape evaluation. The search identified 47 results in the 'Web of Science' database and 36 results in the 'Scopus' database. After cross-checking search concluded with 51 research articles that were evaluated afterwards based on the following steps of the method.

To avoid possible misunderstandings and misleading results of the research, some selection criteria were defined. Firstly, as the interest of this research is to target large-scale landscapes, the research area must be on a regional or other large spatial scale and exclude evaluation just in an urban environment. As the landscape is very specific to each geographical region and even more continental differences are too significant, the second selection criteria stated that the research article must evaluate landscape in Europe. To understand the applicability of methods used in research articles, the third selection criteria stated that the article must use a real case study. After the first review of search results, another criterion was determined; it was related to the main focus of a research article, whether the ES assessment is used to measure the quality of landscape or it is mentioned in the abstract just based on the topicality of this research field nowadays, and that is the reason it turned up in the systematic search.

The next step included the first review of the selection of articles and cross-checking which articles correspond to all of the selection criteria. Reviewing of articles concluded with 18 articles that met all criteria. Most of the articles were excluded from research, because the aim of the articles was not to evaluate landscape quality or they were not using the ES approach, just mentioned specific key words in the abstract. A few articles were excluded because of the research scale being only urban environment and research was not conducted in Europe and not having a case study.

After the initial article review, the next step included the preparation of a database for analysis of selected articles. The database included the main characteristics of the article like title, authors, year of publishing, location of case study, and other basic information. The aim of the database was to extract specific information from articles that can answer stated key questions. Main information in the database included methods that were used in articles, which ES were examined, which indicators were used and what kind of data was used for a specific article. In addition, the differences in the tools that were used in articles also were extracted from articles. The final step was to combine and analyse the information in

the database to answer the key questions and draw conclusions.

Results and Discussion

Figure 2 represents an answer to the first key question, which ES were examined in selected articles. ES were classified according to the Common International Classification of Ecosystem Services (CICES) V5.1 (European Environment Agency, 2018) groups and includes three groups of the Cultural ES section, six groups of the Regulation & Maintenance section, and one group from the Provisioning ES section (Figure 2). Unfortunately, most of the reviewed articles were not using CICES to specifically define which ES classes were examined, to correctly demonstrate the results; therefore, ES were not divided into ES classes (more specific distribution) but divided into groups instead. Each ES group includes several ES classes, as several articles assess several ES. The results in Figure 2 depict the number of times a specific ES group was assessed, sometimes more than once in one article. The most assessed ES section was Cultural which mostly focused on such ES that correspond to the beauty of nature, sense of place, etc., which is directly connected to the assessment of visual landscape quality, then followed by ES group related to recreation. Most researchers on reviewed articles relate landscape quality to aesthetics, which is shown also by the results of the first key question. Cultural ES are one of the most complicated ES to quantify (Swetnam, Harrison-Curran, & Smith, 2017) and the assessment of aesthetics of landscape has been a challenge for decades. New technologies and data sets like Geographic Information Systems (GIS) are enabling new ways and methods how to quantify and measure the visual quality of ES (Jovanovska *et al*., 2020). The second most assessed ES section was Regulation & Maintenance, more specifically, several ES on the ES group of regulation of baseline flows and extreme events (Senes *et al*., 2020), which relates to facts that vegetation, green spaces, forests, etc. are accumulating water runoff, controlling the erosion rates, etc. Several articles assessed ES group of lifecycle maintenance, habitat and gene pool protection by assessing the natural habitats for wild plants and animals (Gottero, Cassatella, & Larcher,

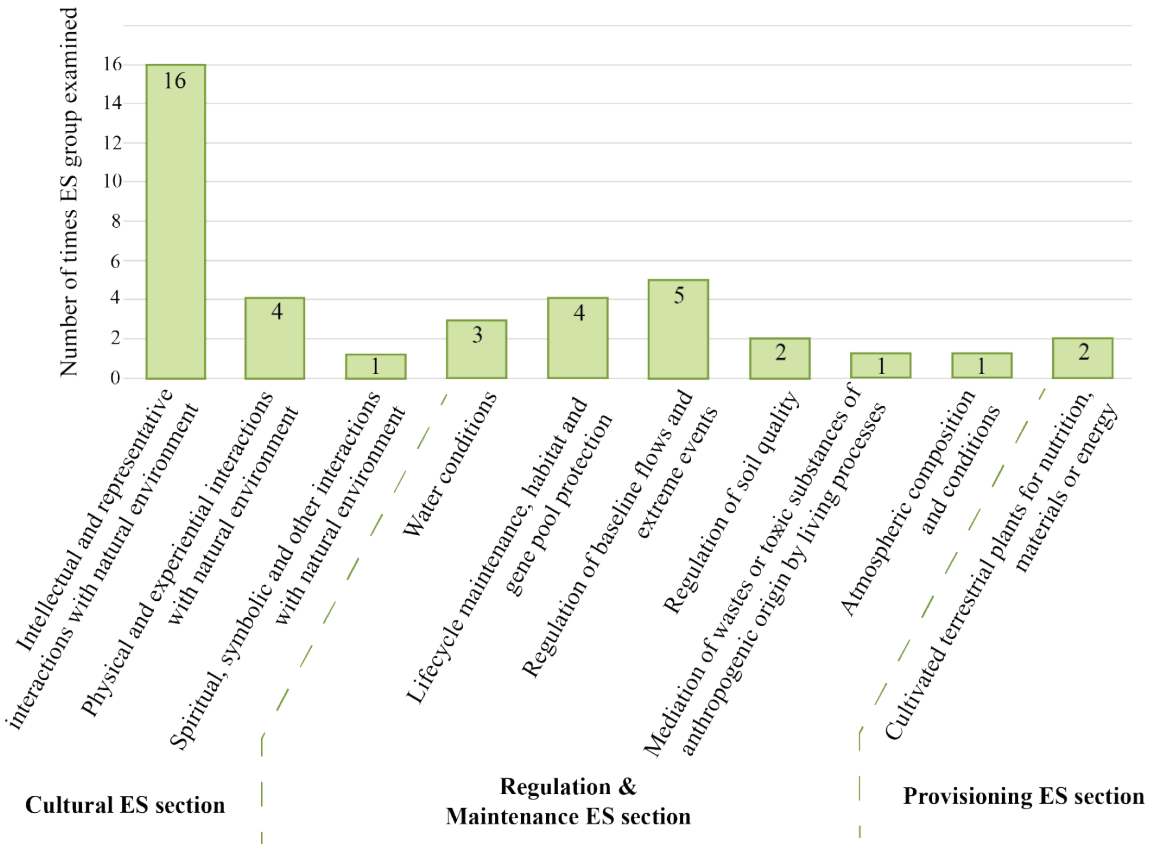

Figure 2. ES groups assessed by analysed articles, according to CICES V5.1, values in the graph depict the number of times ES were assessed, not the number of articles (several articles examine multiple ES, e.g. Gottero, Cassatella, & Larcher, 2021; Mäntymaa *et al*., 2018; Niedermayr *et al*., 2018; Senes *et al*., 2020). (Source: all selected research articles).

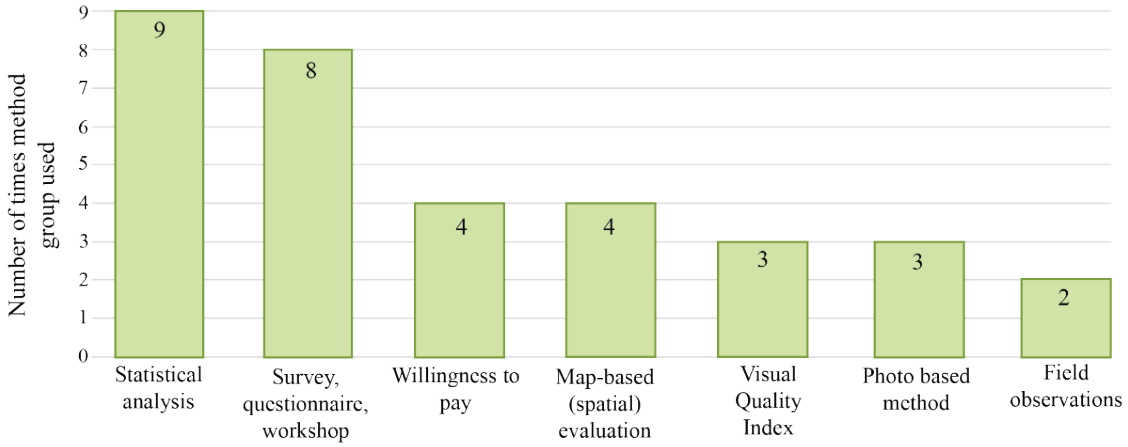

Figure 3. Method groups used in analysed research articles, values in the graph depict the number of times the method in the specific group was used, and several articles used multiple methods (Source: all selected research articles).

2021; Mäntymaa *et al*., 2018; Niedermayr *et al*., 2018; Senes *et al*., 2020). Only two articles assessed the Provisioning ES section, both taking into account the presence of agricultural land as a source of food production (Gottero, Cassatella, & Larcher, 2021; Senes *et al*., 2020).

The results of the first key question provide a basis for a discussion on how researchers understand the term 'landscape quality. Results reveal a large portion of articles that research visual landscape quality, which is only one of the ways how to interpret landscape quality. European Landscape Convention states that landscape quality objective, for the specific landscape, needs to be formulated by competent public authorities, which includes the needs of the public taking into account landscape features (Council of Europe, 2020). This formulation means that every country or region can formulate its understanding of landscape quality, and there is no common understanding of what landscape quality is and what it encompasses.

The second key question explores which methods were used in selected articles (Figure 3). Results in Figure 3 represent the times that a specific method group was used, most of the cases research articles used several different methods. As the researched topic is related to ES and mostly deals with a large amount of data, the most used method group is statistical analysis, which includes different variations of methods differentiating based on specifics of analysed data and amount of it. The previous key question referred to the frequent evaluation of cultural ES and because of that, the results of the second key question are self-evident, as the most frequent approach to evaluate cultural ES is based on society's choices or perceptions involving the public in surveys and questionnaires. As technologies are advancing, the usage of GIS is becoming more precise and is being used more often (Jovanovska *et al*., 2020). Whether spatial evaluation is included in a method called Visual Quality Index or used for map-based evaluation methods, it has been popular for the past decade, mostly by assessing regulation & maintenance ES (Brzoska & Spāģe, 2020). Technologies in this field are increasingly showing more potential also in the evaluation of cultural ES, by using tools that allow active public participation in the process, for example, participatory GIS. Spatial analysis methods can be time and labour saving methods, but only when high-quality data is available to work with (Sowińska-Świerkosz & Michalik-Śniezek, 2020; Vannoppen, Degerickx, & Gobin, 2021). Equally the same amount of times method called willingness to pay was used. It economically expresses stakeholder, visitor, or local people's perception of the improvement of landscape quality in the monetary form, by stating how much they would be willing to pay for specific actions or plans to improve landscape quality (Mäntymaa *et al*., 2018; Niedermayr *et al*., 2018). Finland has presented Payments for Ecosystem Services system called Landscape and Recreation Value Trade that proposes that forest owners are compensated for voluntarily enhancing and maintaining the landscape value (Mäntymaa *et al*., 2021). To set up this initiative, the research is needed beforehand to understand the amount of money that tourists or stakeholders are willing to pay to improve the quality of the landscape, and at the same time make their business more attractive.

Figure 3 also represents that photo-based methods (Martín *et al*., 2018) appear in researched articles that are mostly based on photos from social media databases (Havinga *et al*., 2021; Sottini *et al*., 2019). There is a reason to believe that methods involving social media will become more popular to evaluate

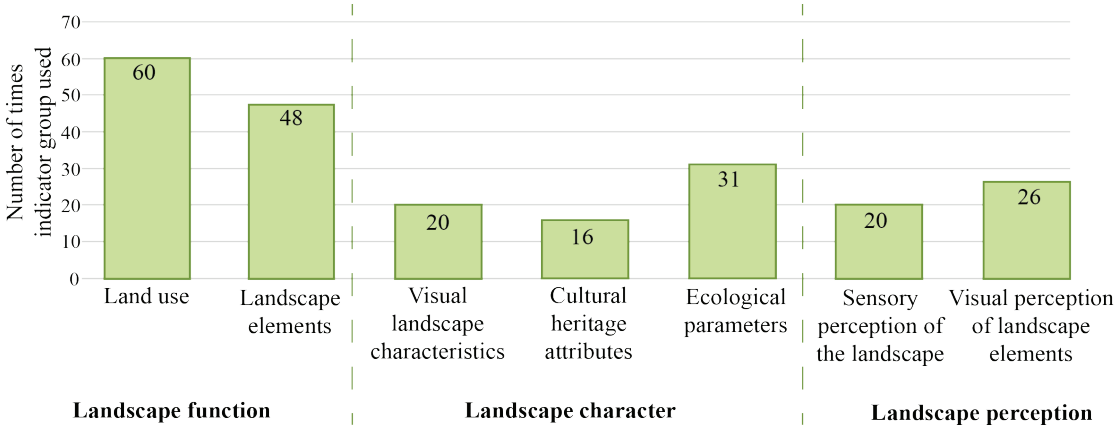

Figure 4. Indicator groups used to assess ES, values in graph depicts the number of times indicator in the specific group was used and several articles used multiple indicators (Source: all selected research articles).

people's preferences towards the landscape. The most rarely used method group was field observations, which is a result of fieldwork usually being time-consuming and asking for quite big expenses.

Figure 4 represents the indicator group type and frequency of times a specific indicator group was used to assess ES, which is the result of the third key question. The most frequently used indicator groups were related to landscape function – land use and landscape element assessment. These two indicator groups were most assessed using GIS or other spatial evaluation methods and mostly corresponded to visual landscape quality. Results in Figure 4 depict how many times specific indicator group was used in research articles, for example, several articles used land use indicator group to assess ES, articles used multiple land use types in the assessment (e.g. Gottero, Cassatella, & Larcher, 2021; Sottini *et al*., 2019; Vannoppen, Degerickx, & Gobin, 2021, etc.).

The second most frequently used indicator section is related to landscape character and the most assessed indicator group in this section refers to ecological parameters, which are connected to evaluating regulation and maintenance ES. An interesting result is that cultural heritage attributes are the least used indicator group, either the cultural heritage elements are not fully linked to the quality of the landscape in the article author's opinion or the availability of such data is scarce. Commendable is the tendency to evaluate people's perception of landscape, either sensory or visual. Several authors point out the necessity to evaluate not only biophysical indicators but also people's perception of landscape (Jovanovska *et al*., 2020; Swetnam & Tweed, 2018; Swetnam, Harrison-Curran, & Smith, 2017). People's perception of landscape leads to a better understanding of the necessity of nature protection and landscape preservation (Gobster *et al*., 2007; Jovanovska *et al*., 2020; Pueyo-Ros, Ribas, & Fraguell, 2018). When talking about landscape quality not always it is perceived as a visually appealing landscape, because most of the landscapes that provide a wide range of ES are natural, not managed (Wartmann *et al*., 2021), and even not accessible, when asking people's opinion about visually appealing landscape, results can be quite opposite compared with biophysical evaluation; for example, a road in a landscape is evaluated as negative aspect for visual landscape quality by biophysical evaluation, but from people perspective that is not the case, because the same road can provide accessibility to landscape (Solecka *et al*., 2022).

Figure 5 represents the results of the fourth key question by showing the frequency of specific data categories used to assess ES and evaluate the landscape

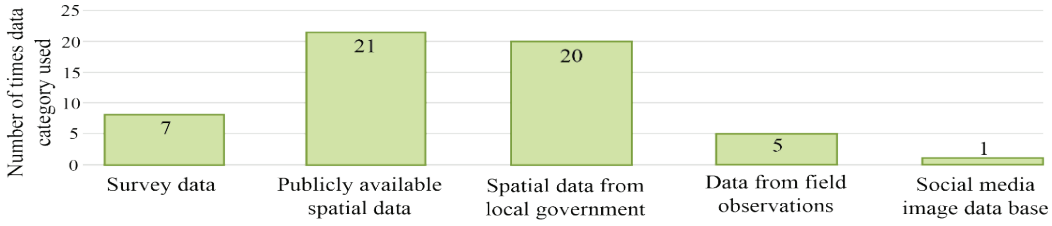

Figure 5. Data categories used in analysed research articles, values in the graph depict the number of times data category was used and several articles used multiple data sources (Source: all selected research articles).

quality. Even though the results of the second key question showed that surveys and questionnaires were between the most used method groups, used data categories represent different results. The reason behind this situation is that research articles that assessed ES with methods using spatial data mostly used several data sources and several kinds of spatial data to perform their research and that raises the count of times spatial data sources were used. Most of the articles with different methods used some type of spatial data to conduct their research or to represent the results.

Several methods used spatial data provided by national surveys or local municipalities enabling more precise data with much less labour and time involved to perform such research. To use ecological indicators (biodiversity, presence of specific flora species, etc.) there is a need for specific, precise data about species diversity in a specific landscape, and that sort of information in reviewed articles is provided by municipalities, but not all municipalities have such detailed data available. To repeat the research method, it is necessary to have the same type and amount of data or there is a need of adjusting the method (Jovanovska *et al*., 2020; Swetnam & Tweed, 2018; Swetnam, Harrison-Curran, & Smith, 2017), but in some cases the method is not applicable because the data in a specific place is scarce or not existent.

Conclusions

The ecosystem services approach nowadays is being widely used, but this research proves that there is still a gap when using ES to assess the quality of the landscape on a large scale. Landscape quality and ecosystem services, in general, are very popular topics to research which is proven by the results after a systematic search in databases, where only a third part of the articles that were found evaluated the quality of landscape using the ES approach. Other articles mention these terms in abstracts to point out the relevance of these topics in general. This article points out the problem with the term 'landscape quality' definition and understanding, while several articles assess the visual quality of the landscape, other researches are wider including ecological and cultural aspects of the landscape.

In order to achieve the aim of this research, four key questions were answered. The first key question analysed which ES were assessed to evaluate the quality of landscape, where the most assessed ES section was cultural ES, followed by Regulation & Maintenance ES, and only few articles considered Provisioning ES section in the assessment of landscape quality. The second key question analysed used methods in selected articles for assessing the ES. Most of the articles used different types of statistical analysis, where a large amount of data was processed, gathered by GIS enabled mapping methods or surveys and questionnaires, which points out the need for computed analysis method usage more frequently. The third key question analysed which ES indicators were used to evaluate the quality of landscape, where ES indicators were combined into groups. The most used indicator group was land use where the distinction of several different land-use types was used to assess the quality of landscape. To analyse the possible repetition of used methods, the fourth key question analysed the data used in selected research articles. Most of the analysed research articles used spatial data either publicly available or derived from local governments.

The topic of this study can be further explored in-depth by analysing articles that have studied landscape quality prior to the creation of the term 'ecosystem services', accordingly using a different set of key words.

References

Brzoska, P., & Spaǵe, A. (2020). From city-to site-dimension: Assessing the urban ecosystem services of different types of green infrastructure. *Land*, 9 (5), article No. 150. DOI: 10.3390/LAND9050150.

Council of Europe. (2020). *The European Landscape Convention*. Preamble. ETS No. 176., Florence.

European Environment Agency. (2018, January). *The Common International Classification of Ecosystem Services* (*CICES) V5.1*. Retrieved February 2, 2022, from https://cices.eu/.

Gobster, P.H., Nassauer, J.I., Daniel, T.C., & Fry, G. (2007). The shared landscape: What does aesthetics have to do with ecology? *Landscape Ecology,* 22 (7), 959–972. DOI: 10.1007/s10980-007-9110-x.

Gómez-Baggethun, E., & Barton, D.N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245. DOI: 10.1016/J.ECOLECON.2012.08.019.

Gottero, E., Cassatella, C., & Larcher, F. (2021). Planning peri-urban open spaces: Methods and tools for interpretation and classification. *Land*, *10 (8)*, article No. 802. DOI: 10.3390/land10080802.

Haase, D., Frantzeskaki, N., & Elmqvist, T. (2014). Ecosystem services in urban landscapes: Practical applications and governance implications. *Ambio*, 43(4), 407–412. DOI: 10.1007/s13280-014-0503-1.

Havinga, I., Marcos, D., Bogaart, P.W., Hein, L., & Tuia, D. (2021). Social media and deep learning capture the aesthetic quality of the landscape. *Scientific Reports*, 11 (1). DOI: 10.1038/s41598-021-99282-0.

Jovanovska, D., Swetnam, R.D., Tweed, F.S., & Melovski, L. (2020). Assessing the landscape visual quality of Shar Planina, North Macedonia. *Landscape Ecology*, *35* (12), 2805–2823. DOI: 10.1007/s10980-020-01122-5.

Mäntymaa, E., Ovaskainen, V., Juutinen, A., & Tyrväinen, L. (2018). Integrating nature-based tourism and forestry in private lands under heterogeneous visitor preferences for forest attributes. *Journal of Environmental Planning and Management*, 61 (4), 724–746. DOI: 10.1080/09640568.2017.1333408.

Mäntymaa, E., Tyrväinen, L., Juutinen, A., & Kurttila, M. (2021). Importance of forest landscape quality for companies operating in nature tourism areas. *Land Use Policy*, 107, article No. 104095. DOI: 10.1016/j.landusepol.2019.104095.

Martin, B., Arce, R., Otero, I., & Loro, M. (2018). Visual landscape quality as viewed from motorways in Spain. *Sustainability (Switzerland)*, 10 (8), article No. 2592. DOI: 10.3390/su10082592.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Wellbeing*: Synthesis. Island Press. Washington, DC

Niedermayr, A., Schaller, L., Mariel, P., Kieninger, P., & Kantelhardt, J. (2018). Heterogeneous preferences for public goods provided by agriculture in a region of intensive agricultural production: The case of the Marshfield. *Sustainability (Switzerland)*, 10 (6), article No. 2061. DOI: 10.3390/su10062061.

Pickering, C., & Byrne, J. (2014). The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early-career researchers. *Higher Education Research and Development*, 33 (3), 534–548. DOI: 10.1080/07294360.2013.841651.

Price, C. (2013). Subjectivity and objectivity in landscape evaluation: an old topic revisited. In van der Heide CM, Heijman WJM (Eds.). *The economic value of landscapes* (pp. 53–76). London, Routledge.

Pueyo-Ros, J., Ribas, A., & Fraguell, R.M. (2018). Uses and Preferences of Visitors to Coastal Wetlands in Tourism Destinations (Costa Brava, Spain). *Wetlands*, 38 (6), 1183–1197. DOI: 10.1007/s13157-017-0954-9.

Senes, G., Fumagalli, N., Ferrario, P.S., Rovelli, R., & Sigon, R. (2020). Definition of a land quality index to preserve the best territories from future land take. An application to a study area in Lombardy (Italy). *Journal of Agricultural Engineering*, 51 (1), 43–55. DOI: 10.4081/jae.2020.1006.

Solecka, I., Rinne, T., Caracciolo Martins, R., Kytta, M., & Albert, C. (2022). Important places in landscape – investigating the determinants of perceived landscape value in the suburban area of Wrocław, Poland. *Landscape and Urban Planning*, 218, article No. 104289. DOI: 10.1016/j.landurbplan.2021.104289.

Sottini, V.A., Barbierato, E., Bernetti, I., Capecchi, I., Fabbrizzi, S., & Menghini, S. (2019). Rural environment and landscape quality: An evaluation model integrating social media analysis and geostatistics techniques. *Aestimum*, 74, 43–62. DOI: 10.13128/aestim-7379.

Sowińska-Świerkosz, B., & Michalik-Śniezek, M. (2020). The methodology of landscape quality (LQ) indicators analysis based on remote sensing data: Polish national parks case study. *Sustainability (Switzerland),* 12 (7), article No. 2810. DOI: 10.3390/su12072810.

Swetnam, R.D., & Tweed, F.S. (2018). A tale of two landscapes: Transferring landscape quality metrics from Wales to Iceland. *Land Use Policy*, 76, 565–576. DOI: 10.1016/j.landusepol.2018.02.037.

Swetnam, R.D., Harrison-Curran, S.K., & Smith, G.R. (2017). Quantifying visual landscape quality in rural Wales: A GIS-enabled method for extensive monitoring of a valued cultural ecosystem service. *Ecosystem Services*, 26, 451–464. DOI: 10.1016/j.ecoser.2016.11.004.

Ungaro, F., Häfner, K., Zasada, I., & Piorr, A. (2016). Mapping cultural ecosystem services: Connecting visual landscape quality to cost estimations for enhanced services provision. *Land Use Policy*, 54, 399–412. DOI: 10.1016/j.landusepol.2016.02.007.

Vannoppen, A., Degerickx, J., & Gobin, A. (2021). Evaluating landscape attractiveness with geospatial data, a case study in Flanders, Belgium. *Land*, 10 (7), article No. 703. DOI: 10.3390/land10070703.

Wartmann, F.M., Frick, J., Kienast, F., & Hunziker, M. (2021). Factors influencing visual landscape quality perceived by the public. Results from a national survey. *Landscape and Urban Planning*, 208, article No. 104024. DOI: 10.1016/j.landurbplan.2020.104024.

USER EXPERIENCE-BASED DESIGN METHOD APPLICATION IN ELECTRONIC MEDICAL RESEARCH DATA COLLECTION TOOL DEVELOPMENT

***Signe Balina[1,2], Liene Viluma[1], Andris Kikans[2], Edgars Salna[2]**
[1]University of Latvia, Latvia
[2]Datorzinibu centrs Ltd., Latvia
*Corresponding author's email: signe.balina@lu.lv

Abstract
The functional requirements of a data collection automation tool for medical research projects are based on existing data collection automation tools and the current research project experience of Institute of Clinical and Preventive Medicine of the University of Latvia and were generalized to be applicable to a wider range of medical research projects. The tool use scenarios include design of the whole research project dataset content and its individual elements, as well as the creation of a data-recording interface application. The tool is designed as an Angular-based Web application that is used to provide prolific client-side functionality, NET REST services for server-side functionality, and SQL database and SMTP server for user management.
Key words: codebook, research data collection automation, user experience design.

Introduction

Medical research is very important because one of its main challenges is to find new methods and tools for the prevention and treatment of diseases. Compared to other industries, healthcare is facing many strict regulations which govern data collection and use. Data are being collected by using various methods and from various sources. Many data are acquired from filled-in forms (such as patient intake forms, consent forms, and health assessment forms), as well as from information systems that contain patient data – electronic health record (EHR), customer relationship management systems (CRM), and other sources.

Medical research data is usually highly sensitive. All documentation concerning data capture, storage and processing permissions must be approved before starting the data collection activities. Data entry template should correspond to the particular study, which means that besides the potential data quality issues (errors caused by manual data entry) there are also financial costs associated with all the major elements of data collection process, including database, codebook, and form design.

Analysis of the ongoing medical research projects at the Institute of Clinical and Preventive Medicine of the University of Latvia clearly shows that effort for the data collection effort and its costs vary from project to project and can be quite significant. Efficient use of information technologies in the data collection process will allow to reduce costs and to improve data quality.

Proper identification of user experience variables (Utility, Usability, Aesthetics, Identification and Value) leads to the better understanding of software user requirements which result in complete requirements and specifications and continually changing them through the suitable change management to control the different processes of the software development life cycle, identifying user's constantly changing opinions (Badran & Al-Haddad, 2018).

Therefore, the research goal was to develop a cloud-based tool for the automation of data collection and following main tasks were completed to reach this goal: (1) thorough analysis of data collection process and definition of the functional requirements of the IT tool, (2) analysis of the role of user experience as a facilitator of higher IT tool effectiveness, applying human-centred system design theory and carrying out practical UX (user experience) testing, (3) development of the data collection automation tool and its experimental testing.

Thus, the paper describes the main results achieved in this research, as well as the features of the developed automation tool, its experimental testing results, and the conclusions drawn from the study.

Materials and Methods

Human-centred system design and user experience

Already as early as in 1969 it was acknowledged that the future will need not so much computer-oriented people as people-oriented computers. The design of user/human-centred systems, user experience (UX), and human-computer interaction (HCI) are areas of research that are concerned with improving the interaction between people and computers. The early work in this field dealt with the design of visual layouts and the optimization of input devices (Ritter, Baxter, & Churchill, 2014).

During the 1970s and 1980s researchers studied human capabilities in computer use, focusing on cognitive psychology and ergonomics. The user was seen as a passive, unmotivated individual trying to efficiently use a computer. Later came a new and more insightful idea of the user as an active individual who controls the system, and the focus shifted to the ease of use and user-friendliness (Bødker, 2006). Since the advent of mass-market consumer electronic devices

created an ever-growing number of users with no prior experience, usability emerged to the forefront of the research of interface design and human-computer interaction.

Usability is characterized as a task-oriented and performance-based feature, it emphasizes the achievement of goals. However, this approach tends to see the person as a 'user' and the artefact as a tool, thus taking a limited view of people. Three canonical usability metrics – effectiveness, efficiency and satisfaction – define usability in ISO standard 9241-11 (International Organization for Standardization, 1998). Effectiveness characterizes the accuracy and completeness with which users achieve specified goals. Efficiency measures the resources spent in relation to the accuracy and completeness of achieving goals. Satisfaction is seen as freedom from discomfort and positive attitude towards the use of the product. In practice, the testing of the satisfaction element of usability often means investigating whether the product frustrates the user or not (Blythe *et al.*, 2005).

In the 1980s the approach to system design progressed towards user-centred design (Norman & Draper, 1986). It involves focusing on the user's needs, and the adoption of this approach means following six principles: (1) the design is based upon an explicit understanding of users, tasks and environments, (2) users are involved throughout the design and development, (3) the design is driven and refined by user-centred evaluation, (4) the process is iterative, (5) the design addresses the whole user experience, (6) the design team includes multidisciplinary skills and perspectives (International Organization for Standardization, 2010).

As computers moved out of the workplace and entered homes, leisure usage became more important. When technology is integrated into a user's everyday life, such aspects as satisfaction, entertainment, enjoyment, and a sense of community and identity play a significant role (Wright, McCarthy, & Meekison, 2003). All this contributes to a shift of focus from concrete functional aspects of the product design towards more abstract, subjective qualities of interaction, thus shaping user experience as a distinct concept (Hassenzahl & Tractinsky, 2006).

The term 'user experience' was first used by Donald Norman, Jim Miller and Austin Henderson (Norman, Miller, & Henderson, 1995) more than two decades ago. UX is influenced by 'the user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.), and the context (or the environment) within which the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.)' (Hassenzahl & Tractinsky, 2006). UX accentuates the importance of the subjectivity of users' experiences and quality judgements. These personal interpretations of a system quality can influence the future interaction with the system and can be communicated to other users with the potential of influencing their subjective experiences (Hassenzahl & Tractinsky, 2006).

'User experience' is often used interchangeably with the concept of 'usability', but there is a different focus: usability and usability engineering focus on task-related aspects, while UX and experience design focus on the users feelings, emotions, and values, as well as their immediate and delayed responses (Ritter, Baxter, & Churchill, 2014). However, when interpreted from the perspective of the users' personal goals, usability can include perceptual and emotional aspects that are typically associated with UX. Usability criteria can be used to assess aspects of user experience (International Organization for Standardization, 2010). The classic usability concept focused on single behavioural episodes and momentary evaluations, while UX can also be felt before the interaction and it can change over time. Furthermore, the relative importance of different qualities can also change over time (Roto *et al.*, 2011). As the user becomes more familiar with the product, its novelty wears off and the product becomes less exciting. At the same time, with prolonged use it can also become less frustrating. As a result, the perceived quality of a product is likely to change.

As a result of this shift of focus towards a more holistic view of users and interaction, the movement of human-centred design emerged. It expanded the focus to considering how human capabilities and characteristics are affected by the system beyond the direct interaction with the interface or system itself. According to this approach, humans should be seen as the most important element of the information systems (Ritter, Baxter, & Churchill, 2014).

User-centred (and human-centred) design methods tend to emphasize user participation in the design process for the ideation and evaluation of design options. The wide spectrum of methods allows for different degrees of active participation. Human-centred design consists of four activities that structure the development process: understanding and specifying the context of use; defining the user requirements; drafting the design solutions to meet user requirements; testing and evaluating the solutions against requirements (International Organization for Standardization, 2010).

The context of use analysis is a structured method for eliciting information about the context of using a system as a foundation for later activities, particularly user requirements. The context of use includes such factors as the user group, tasks, technical environment,

physical environment, and organizational environment (Maguire, 2001).

Design solutions arise through a logical progression from previous designs or ideas and go through an iterative development as they develop. Prototypes and simulation of the system are necessary to support this iterative design lifecycle. They can be produced quickly and easily in the early stages for evaluation by usability experts and prospective users. Changes in the design can be made rapidly in response to user feedback, so that major problems can be identified and corrected before the system development begins. Methods include brainstorming, use of design guidelines and standards, storyboarding, and low to high fidelity prototyping (Maguire, 2001).

Evaluation is a very important activity as it demonstrates how far the requirements have been met and provides information for refining the design. There are three levels of formality when performing evaluation studies: (1) participative (least formal) – suitable in the early stages of design process; includes asking the participants about their impressions of a prototype, what they think different elements may do, and what result they expect from their next action. The participants may also be asked to suggest how individual elements could be improved; (2) assisted (intermediate) – the participant is requested to perform tasks and is invited to 'think aloud'. The objective is to obtain the maximum feedback from the user while trying to maintain as realistic an operational environment as possible; (3) controlled evaluation (most formal) – replicates the real environment as closely as possible; can be used to determine whether people can use product successfully via usability metrics (Maguire, 2001).

Functional requirements of data collection automation tool

General requirements for an automation tool of research project data collection should address several key aspects – the development of the research protocol, the generation of data registration application and data acquisition from external data sources.

After the analysis of research data collection process and the evaluation of most popular existing EDC software (MedRED, OpenClinica, Castor, Dacima Clinical Suite), the functional requirements were defined and divided into several categories – dataset identification and data logistics description, data collection phase and data acquisition from external data sources.

Dataset identification and data logistics description requirements are related to the research protocol development phase. In this phase, the research team members must discuss and agree upon all the relevant issues and tasks to minimise mistakes in the research protocol. The following requirements relate to this category:

Requirement 1. The development of datasets in the research protocol by means of the pre-prepared templates (codebook elements and codebook element versions). Designed codebook elements should represent the realisation of individual medical concepts that can be added to the research project datasets.

Requirement 2. Accruation and reuse of existing experience. Codebook elements and their versions are a way of formalizing the already existing experience. It should be noted that a research team mostly works within a specific domain (e.g. a team that works with cancer is more likely to continue to work with cancer). As a result, the codebooks created in previous research projects can be used to prepare research protocols for future projects, thus reducing the time needed to completely redefine the datasets.

Requirement 3. In the process of preparing datasets, it is necessary to provide their visualization that allows to demonstrate the potential data input form.

Requirement 4. Ensuring the possibility to generate a part of the research protocol documentation by describing the datasets required for the research project.

When the research protocol is approved, it is necessary to ensure an operational transition to the data collection (capture) phase. At this point, a fully operational data registration application is needed. The following requirements apply to this phase:

Requirement 5. It is necessary to generate an application and user interface that allows data capture as it is defined in the research protocol. It is possible if the research project datasets were created by using the codebook element version templates.

Requirement 6. It is necessary to allow an easy regeneration of the data collection application in case of changes to the research project.

If the data required for a research project are available in an external data source, an automated data acquisition process can reduce the workload when dealing with these data. However, it should be noted that the acquisition of data from an external source should be critically evaluated, as not all data from external sources are available for such purposes. The following requirements relate to accomplishment of these tasks:

Requirement 7: Ensuring the import of data into the data collection tool from a pre-prepared file.

Requirement 8: Ensuring the response to the personalized (using a patient identifier) data request to the external system in the generated data registration capture system.

Requirement 9: To simplify the design of the generated data capture system, requests to external

data sources should be made through the interlayer of web services. Therefore, encapsulating the interfaces of the different external data sources shall be applied.

All above mentioned requirements were implemented into the data collection automation tool which is evaluated in this research project.

Adaptive design development through UX testing process

After the analysis of literature on prototyping and usability evaluation methods, it was decided to use two-step prototyping: starting with a low-fidelity original prototype and further refining it into a medium-fidelity prototype. Such an approach is effective when it is necessary to identify potential problems as early as possible in the design process, before they become too significant and difficult to resolve. A medium-fidelity prototype later allows for a more detailed user interaction with the interface elements and is more suitable for interface testing and presentation purposes for stakeholders.

From the perspective of the prototype dimensions, it was decided that: (1) the prototype would be designed with medium visual fidelity, containing wireframes for assessing the layout and perception and readability of visual elements, (2) the prototype would be horizontal and shallow, providing the maximum possible range of functions but with little detail, as opposed to a vertical prototype which focuses on only a few functions but with a lot of detail.

The low-fidelity prototyping included iterative usability reviews. Review sessions were organised remotely, in the form of videoconferencing that involved a moderator, participants who were medical researchers, medical IT support staff, and a UX expert. Review sessions were held over a period of 3 calendar months. During a session the moderator demonstrated the prototype to the prospective end-users and other participants and explained the sequence of steps necessary to carry out typical user tasks. The participants were encouraged to offer their comments and suggestions for improvement. The shortcomings identified during a review session were addressed and corrected before the next review session. Detailed recommendations covered general usability aspects, layout, form field types, adaptive design, keyboard navigation, and touch-sensitive interfaces.

Although the general principles of usability and methods for evaluating the user experience are also relevant to the software in the medical sector, literature studies show that the importance of user experience in the medical field is mainly addressed in the context of medical software and healthcare critical information systems, focusing on user performance and security. Very few studies address the usability aspects of the software used in medical studies. It was also concluded that the most recent user experience studies mainly focus on the following directions – the experience of specific user groups (children, seniors, people with special needs such as dementia, autism, dyslexia, etc.), and a limited range of products (games, mobile apps, virtual reality, interactive installations).

Therefore, the particular prototype of this project does not fall within any of the above categories. Seeing that the prospective users of the data collection tool being designed were pre-trained and experienced, attention was devoted to more specific recommendations applicable to user experience design of generated data recording interfaces. Even though the form design has been studied very extensively, considering that forms are an important interaction technique, and the recent sources are just referring to previous studies, it should be noted that there has been no detailed investigation of form design for specific domains and contexts of use.

Data recording interfaces were designed by combining versions of mutually independent codebook elements that are specific to the field of medical research, thus resulting in a single data-recording interface. In order to produce a uniform and harmonious interface for data recording, the following optimal subset of usability requirements was defined for the codebook element version: (1) visual representation of the codebook element version must contain standardized CSS class markers so that they can be overwritten at the dataset level, providing a single stylistic solution, (2) the validation included in the version of the codebook element must provide a standardized validation method, allowing the visual presentation of error messages to be defined at the dataset level, (3) when adding a new data field to the codebook element, the default visual representation of the field (generation path) must be provided in accordance with the basic principles for creating interface elements. (4) the generated data fields should have expanded 'clickable areas', (5) data fields for each version of the codebook element should be adaptive, (6) the data field interface elements should allow data entry and moving to the next data field by using keyboard features solely, (7) interface should be compatible with tablet computers.

Additional parameters and requirements for codebook elements were introduced in the research project dataset:

(1) CSS to define a uniform style for all the codebook element versions added to the dataset, (2) a group name that allows to group the versions of the codebook element defined in a single dataset while maintaining a visual hierarchy, aesthetics, and minimalist design, (3) a mechanism to determine how the user will transfer the data entry focus (cursor) from one version of the codebook element to the next by using keyboard only, (4) data registration interfaces

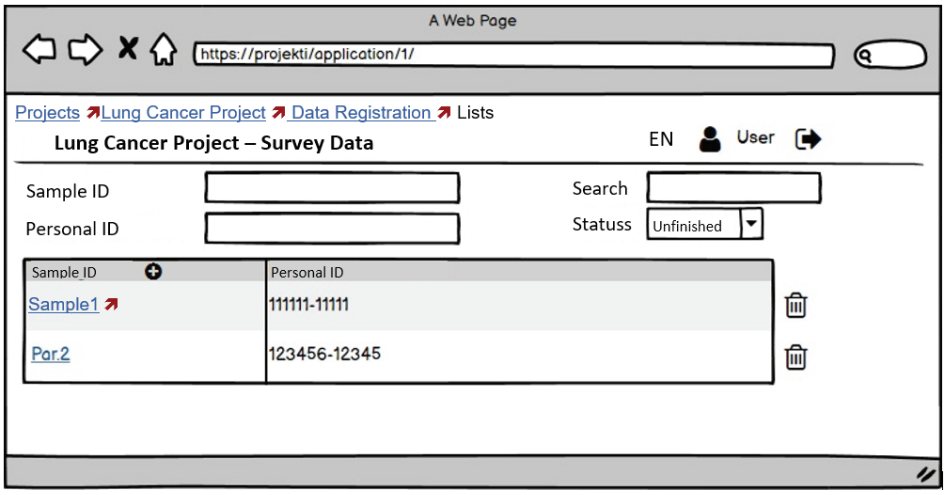

Figure 1. Codebook element example.

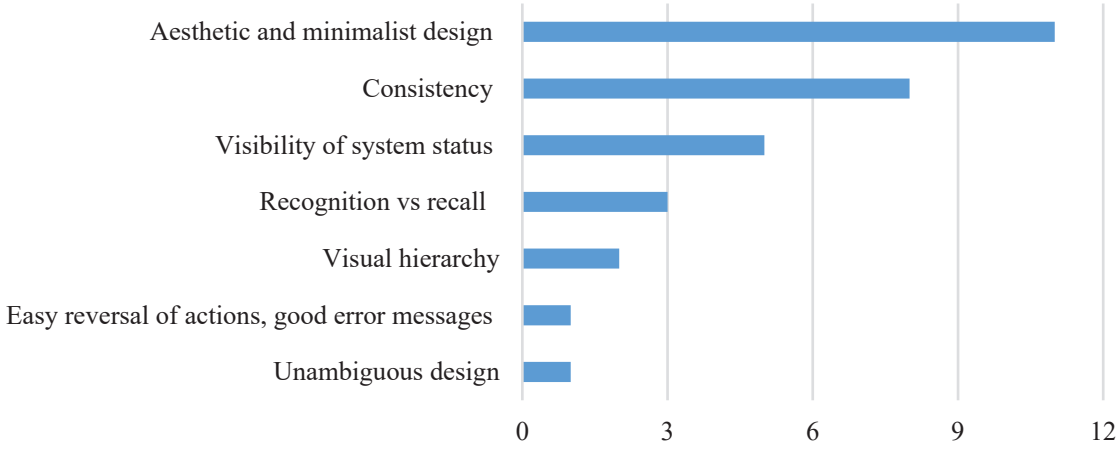

Figure 2. Number of recommended changes per category.

may include datasets with dozens of data elements; therefore, it is important to provide feedback to the user through a progress indicator solution.

After the evaluation of the low-fidelity prototype, a medium fidelity prototype was designed. It included the following major improvements: (1) visual interface adjustments, minimizing the cognitive load of users (including the features identified during the best practices research), (2) devoting more attention to medium-sized devices, including tablets, (3) supplementing the prototype with a partial interactivity that allows limited simulation of the system behaviour and user interaction.

Versions of 31 codebook elements had been created and associated with the project dataset 'Patient Survey'. When creating a version of a codebook element, a visualization of the default (automatically generated) its version of the codebook element had been used (Figure 1).

Two interrelated testing sessions took place for the medium-fidelity prototype. The first test session was organized as a remote usability test (with a moderator), involving two medical researchers, one IT support specialist in the field of medical research, one UX expert, and two system analysts. A prototype demonstration was performed by the moderator, following the user story step by step. The testing session was recorded for review after the testing session. The recording was then analysed by the UX expert assessing interaction affordances and prototype conformance to general usability heuristics and guidelines (Johnson, 2014).

During the second testing session, users had to interact independently with the medium-fidelity prototype by performing typical user tasks. The testing resulted in recommendations for improvement (total number of recommendations 31). These recommendations can be categorized into several groups (Figure 2). The categories were derived from the most widely used usability heuristics and guidelines summarized by J. Johnson (Johnson, 2014).

After the testing sessions, recommendations were reviewed by the UX expert and implemented into the medium-fidelity prototype. At the end of the prototyping process, the medium-fidelity prototype was demonstrated to a group of end-users, with no important outstanding problems identified.

Results and Discussion

Assessment of the tool impact on the effectiveness of the medical trial data collection process was performed to validate success of the study. Such an assessment is complex because the tool is intended to be used in real research, and its impact on the research project can only be fully evaluated at the end of the research project, but projects can last up to 2-3 years and do not fit into the timeframe of this research project. In addition, the impact assessment requires finding another, equivalent research project that has already been carried out without using the prototype.

For these reasons, an alternative approach was chosen. A project 'Screening for cancer with respirable volatile organic compounds using a hybrid capture approach' of the Institute of Clinical and Preventive Medicine of the University of Latvia, where the research protocol preparation phase was already completed, was selected as a research facility. Information was available about the progress of the development phase of the research protocol, the project team, the problems identified during the protocol development phase and the implementation of the data recording solution and the technological platform.

For the purposes of assessment, a partial execution of the research protocol was carried out and an interface for data recording was developed by using the tool. Attention was also paid to the problems identified during the project and on how the use of the prototype could reduce the potential problems and their impact. The result was an estimation of the required effort for carrying out a research project with and without using the tool.

The assessment process focused on three prototype functions: (1) supporting the development of a research protocol by reducing the necessary work capacity and potential errors, (2) reducing work effort to develop a research project data registration solution, (3) enabling an online retrieval of individual data fields from external information systems.

The actions included obtaining patient data and tissue samples from patients, where an invasive manipulation for obtaining a sample of suspicious tissue was risky because of the patient's health status. The duration of the project is 3 years. The development of the research protocol was completed in 12 months, and the matching of datasets for the active research project had been done in 6 months. The rest of the time was spent on starting the project, completing the research protocol, and elaborating and approving the accompanying documentation.

The following problems were noted during the development phase of the research project protocol. Their impact extended the time period of developing the protocol: (1) The dataset could not be properly visualized to the researchers during the development of the protocol. The dataset had been created as a Microsoft Word document table and was difficult to review. Only at the final stage of drafting the protocol, when the development of the data registration solution was already underway, a number of misconceptions in the definition of datasets were identified, and the developed data registration solution had to be adjusted; (2) An outdated technology (Microsoft Access, connected to SQL database) was used to develop the data registration solution.

The total amount of data for the research project consists of 8 datasets and 294 data fields. An assessment of the datasets in the lung cancer project showed that the highest level of variation in the fields used was in the patient survey dataset, and the number of fields in the patient survey was sufficiently representative. It was decided to carry out one set of data in the research project during the approval process and to extrapolate the results to the other datasets.

The time taken to implement this dataset within the prototype was 2:44 hours. By extrapolating the results to the creation of all project datasets, it was assumed that the total time for this task was approximately 25 hours.

As a practice during the development of the research protocol, meetings of the project participants were held to discuss the datasets required for the research project. The use of the tool allows to use a dataset template, demonstrating the overall content of datasets and the content of each individual element. Such approach takes much less time to get the field sequence, look, validation conditions and potential value issues by putting a substantial part of the decisions in real time into the datasets, while leaving the rest for the next meeting.

Consequently, the development and refinement of datasets in the research protocol, which took approximately 6 months for the reviewed project, could be reduced by 3–4 months, thus significantly saving time spent on this phase of the research. Moreover, the creation of a data-recording interface app took about one month, which can be reduced to one week in the case of tool involvement. Generating a data-recording interface app also reduced the likelihood of potential errors in the research project, as well as the costs of these error.

Conclusions

The research produced requirements and prerequisites for the development of a functioning

prototype of the data collection tool, based on a medium-fidelity prototype that considers recommendations related to existing good practices in the field of user experience and to the prototype testing carried out with the involvement of a user experience expert and the target group (medical researchers).

The new tool made it possible to significantly improve the conduct of project team meetings during the development of the research protocol where the datasets needed for the research project are discussed. If, during the initial meeting, the IT support person is able to use a real-time data collection support tool, it helps to define the datasets and at least a part of the dataset fields already during the meeting by registering a missing dataset or by preparing them until the next meeting.

At the next meeting, the data collection tool enables researchers to discuss the dataset template by demonstrating the whole content of datasets and the content of each individual element. Consequently, the field sequence, visualization, validation conditions and potential value issues can be solved during the second meeting.

Such an approach allows to hold only two to three meetings to reach the content matter of the datasets needed for the research project, and to start a discussion on data acquisition and transportation solutions, incorporating validation conditions into the datasets, and improving visual layout in parallel. As a result, significant economy of research team time and resources for development and refinement of the research protocol datasets can be achieved.

Acknowledgements

This research was funded by the European Regional Development Fund project 'Competence Centre of Information and Communication Technologies', (1.2.1.1/18/A/003), individual research project 1.5 'Creating a research support model for improving the process of collecting medical research data'.

References

Badran, O., & Al-Haddad, S. (2018). The impact of software user experience on customer satisfaction. In: *Journal of Management Information and Decision Sciences*. Vol. 21, Issue 1, 2018.

Blythe, M.A., Overbeeke, K., Monk, A.F., & Wright, P.C. (eds.). (2005). Funology: From Usability to Enjoyment. Springer Netherlands. DOI: 10.1007/1-4020-2967-5.

Bødker, S. (2006). When Second Wave HCI Meets Third Wave Challenges. In: Proceedings of the 4th Nordic Conference on Human-computer Interaction: Changing Roles (pp. 14–18). Oslo, Norway: ACM New York, NY, USA. DOI: 10.1145/1182475.1182476.

Camacho Rodriguez, J., Stäubert, S., & Löbe, M. (2016). Automated Import of Clinical Data from HL7 Messages into OpenClinica and tranSMART Using Mirth Connect. Studies Health Technology and Informatics. 2016; 228:317–21, Retrieved February 14, 2022, from https://pubmed.ncbi.nlm.nih.gov/27577395/.

Hassenzahl, M., & Tractinsky, N. (2006). User experience – a research agenda. Behaviour & Information Technology, 25(2), 91–97. DOI: 10.1080/01449290500330331.

International Organization for Standardization. (1998). ISO 9241-11:1998 Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability.

International Organization for Standardization. (2010). ISO 9241 Ergonomics of Human-System Interaction – Part 210: Human-Centred Design for Interactive Systems.

Johnson, J. (2014). Designing with the Mind in Mind: Simple Guide to Understanding User Interface Design Guidelines (2nd ed.). Amsterdam, Boston: Morgan Kaufmann Elsevier Inc.

Maguire, M. (2001). Methods to support human-centred design. *International Journal of Human-Computer Studies*. DOI: 10.1006/ijhc.2001.0503.

Norman, D.A., & Draper, S.W. (eds.). (1986). User Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Norman, D., Miller, J., & Henderson, A. (1995). What you see, some of what's in the future, and how we go about doing it: HI at Apple Computer. In Proceedings of CHI 95 Conference Companion on Human Factors in Computing Systems (p. 155). Denver, Colorado, USA: ACM New York, NY, USA. DOI: 10.1145/223355.223477.

Ritter, F.E., Baxter, G.D., & Churchill, E.F. (2014). User-Centered Systems Design: A Brief History. In Foundations for Designing User-Centered Systems. London: Springer-Verlag London. DOI: 10.1007/978-1-4471-5134-0_2.

Roto, V., Law, E., Vermeeren, A., & Hoonhout, J. (2011). User Experience White Paper: Bringing Clarity to the Concept of User Experience. In V. Roto, E. Law, A. Vermeeren, & J. Hoonhout (eds.), Dagstuhl Seminar on Demarcating User Experience.

Wright, P.C., McCarthy, J.C., & Meekison, L. (2003). Making sense of experience. In M. Blythe, A. Monk, K. Overbeeke, & P.C. Wright (eds.), Funology: From usability to user enjoyment (pp. 43–53). Kluwer Academic Publishers.

 DOI: 10.22616/rrd.28.2022.044

EVALUATION OF MEETING EFFECTIVENESS FOR IMPROVEMENT OF DIGITAL TOOLS

***Natalija Sergejeva[1], Julija Mangale[1], Kristaps Vergins[2]**
[1]Latvia University of Life Sciences and Technologies, Latvia
[2]WeAreDots, LLC, Latvia
*Corresponding author's e-mail: natalija.sergejeva@llu.lv

Abstract
Meetings are an integral part of every company. During the meeting new ideas are generated, experiences are shared, decisions are made; therefore, it is necessary to make meetings more effective and productive. In today's digital age, which development was accelerated by the COVID-19 pandemic, different digital tools are being created which help to organise various meeting management stages in a more qualitative way. With the help of digital tools, it is possible to significantly facilitate the observance of meeting plans, preparation of the meeting minutes and sending meeting minutes to the participants. This study is based on data collected from a specific focus group that provided information about their company and meeting management experience. This group was selected as potential clients of meeting management tool Meetinch. Using the Chi-square Independence Test and Principal component analysis the quality of meeting organisation and the readiness of meeting organisers to pay for a meeting management tool depending on other factors were examined. It was concluded that planning a meeting and summarizing the results are important for a quality meeting organisation. The readiness of companies to pay for a meeting management tool depends on the sector of the company, number of employees, the number of participants at the meeting and the possibilities of summarising the meeting results.
Key words: meeting management, online meeting, add-in tool, meeting quality assessment.

Introduction

Communication between company's employees is one of the most important aspects in every organization. Data show that managers of large companies spend more than 75% of their time preparing, attending and managing meetings (Allen *et al*., 2014). Since meeting is a place where information is exchanged, ideas are generated and gathered and decisions are made, it is very important that meetings are organized as efficiently as possible.

In order to make different stages of the meetings more efficient, both company managers and researchers are looking for about improving the efficiency of meeting organization. Theoretical framework of effective meeting organisation consists of three stages: preparation, implementation and summarising of results. Preparation is required before organising meeting-setting goals, selecting and informing participants, time planning, drawing up and sending out the programme. During the implementation of the meeting it is necessary to start and finish on time, to stick to the agenda, assign a recorder and time keeper, discuss next steps and allocate responsibilities. After the meeting it is necessary to send a summary to the participants with decisions made and next steps to be taken, list of responsible persons for the implementation and implementation deadlines (Koshy *et al*., 2017). Various of the previously mentioned organisational stages can be made more efficient by using digital meeting management tools. Some studies show that a lot of meeting organizers do not use basic meeting planning methods which is the reason why most of the meetings are considered a waste of time (Geimer *et al*., 2015). Researchers who develop recommendations for improvement of meeting quality, identify several design characteristics related to meetings (Leach *et al*., 2009; Cohen *et al*., 2011). Design characteristics include using agenda, keeping meeting minutes, meeting punctuality etc. One of the characteristics that could increase meeting efficiency is the improvement of preparation of meeting minutes which usually takes a lot of time (Vermaelen & Kovach, 2021). The question on the impact of meetings on employee well-being was considered in some studies (Luong & Rogelberg, 2005). The authors found a significant positive correlation between meeting attendance and daily fatigue.

Time is the most important resource for the company and its management (Rovelli, 2020). In order to use this resource effectively, it is necessary to act strategically and need to pay close attention to the schedule. This is especially important for large companies, whose management model is a complex set of different processes and circumstances, where the organization, conduct, and planning of meetings and decision-making process plays a major role in its management. Thus, one of the main principles of efficient use of time resources is a well-thought-out and cleverly organized meeting.

In today's digital age, Information and communications technologies have played an important role in both work and daily life. In Latvia, by the year of 2021 the use of Information and communications technologies (ICT) was ensured in absolutely all enterprises (Official statistics portal, 2021). COVID-19 pandemic stimulated the ICT field more than ever and it was the biggest experiment of 'work from home' (Banjo *et al*., 2020). During the

COVID-19 pandemic people became more active online because the pandemic changed their habits and replaced presence meetings, conferences, meetings with friends and communication at work with different telecommunication online tools. The above mentioned improvements and innovations have increased the productivity, cooperation and significantly reduced the amount of waste resources (Attaran, M., Attaran, S., & Kirkland, 2019). In comparison with the time before the COVID-19 pandemic, the number of online meetings has doubled. This COVID-19 pandemic-driven online activity highlights the potential of Information and communications technologies (Mouratidis & Peters, 2022).

The aim of this study is to analyse previous meeting quality dependence from other factors (e.g. sector, number of employees, time spent in meetings, use of digital tools, etc) and meeting organisers' readiness to pay for the digital meeting management tool depending on other factors. To mitigate the use of wasteful resources this paper focuses on a comparison of organising planned meetings with or without digital-based assets.

Materials and Methods

In the middle of 2020 a company WeAreDots developed the tool Meetinch- meeting management solution which helps to plan, manage and follow on meetings and its results. In the autumn 2020, the company WeAreDots in cooperation with Latvia University of Life Sciences and Technologies organised study in order to find out efficiency, usability of the tool, and possibility to improve functional requirements, economical usefulness and efficiency. In order to achieve these goals, a customer identification survey was developed. At the end of 2021 in total 889 users were registered in the Meetinch database.

In total, 15 questions were included in the survey to identify the initial situation of customers. The survey was conducted in the summer of 2021. Survey was conducted for a specific focus group selected by the customer (WeAreDots) who provided information on their company and experience with meetings.

Survey questions were divided into several groups. First three questions described company- field and sector in which it operates, and company's size in terms of employee number in the company. The aim of the next seven questions was to ascertain previous company's experience in organizing meetings. The average time spent in meetings, whether they start and end in time, the average time spent planning meetings, summarizing results and sending them to the meeting participants was ascertained. The last five questions were intended to ascertain information on previous experience of respondents of using digital tools for meetings.

The obtained data were analysed using quantitative methods. The Chi-square Independence Test was used to determine if there is a significant relationship between the two categorical variables. Principal component analysis was used to reduce the dimension of the data set by transforming a larger set of variables into a smaller one.

Results and Discussion

Survey results showed that respondents represent five sectors: sector of financial services, non-governmental sector, research and educational sector, state's administration sector and entrepreneurship, which were represented most (Figure 1). In order to identify specific target groups more precisely,

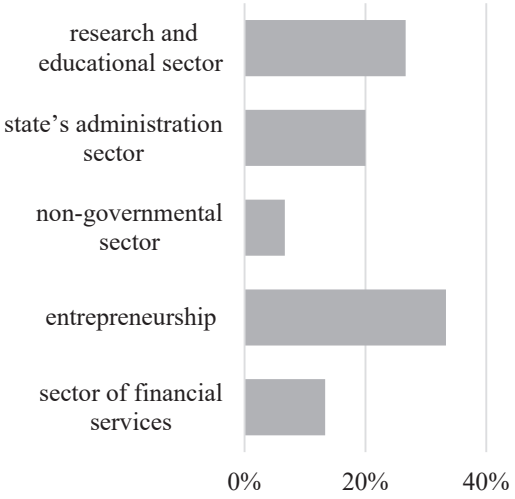

Figure 1. Sectors represented by the survey respondents.

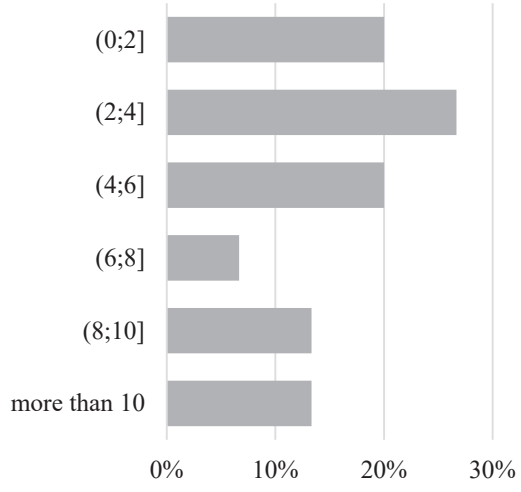

Figure 2. Average time (in hours) which is spent in meetings during the week.

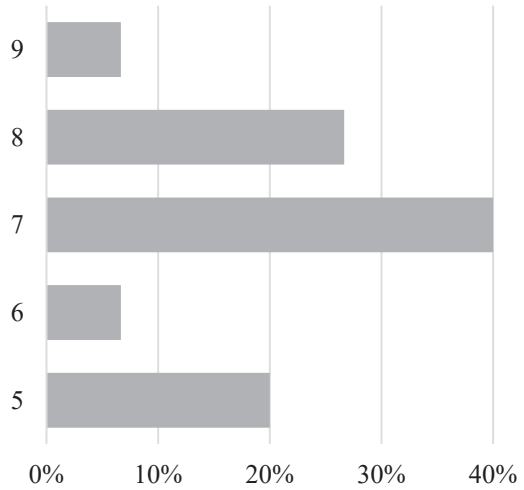

Figure 3. Evaluation of meeting quality in a ten-point grading scale.

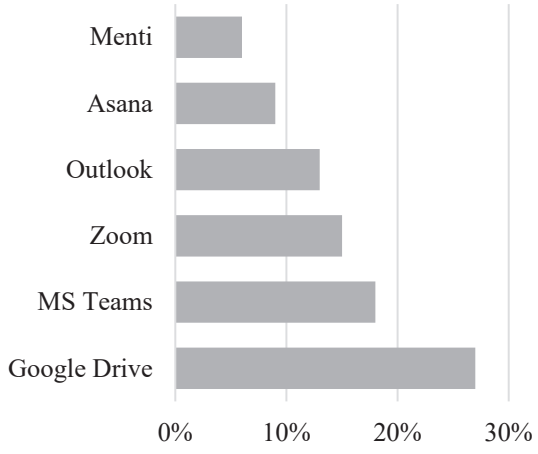

Figure 4. Digital tools using for online meetings.

sectors of represented companies were analysed and it was ascertained that most companies were from the financial sector and from the sector of research and education, the percentage of other sectors was lower. Survey respondents most often represent companies which employ more than 50 employees (63%), the less represented companies were those which employ up to 10 employees (17%).

After the analysis of the company's previous experience in organizing meetings, an issue regarding the average time spent in meetings during one week was examined. Most of the respondents (20%) indicated an approximate time of 5 hours, only 6% of respondents indicated 1 hour, whereas 14% of respondents indicated that they spend about 15 hours at meetings during the week (Figure 2). After the survey a conclusion was drawn that respondents from the non-governmental sector is the part who spend most of the time in meetings. In research organizations an unanimous decision was not reached in this matter; however it can be concluded that time spent in meetings in general correlates with the number of employees in the research organization.

Analysing the quality of previous meetings, respondents were asked to evaluate meetings from 1 to 10 (where 10 is the highest grade). None of the respondents evaluated it with 10, only 7% of all respondents evaluated with 9 but also none of the respondents evaluated lower than with 5 (Figure 3). Quality of the meeting with the highest rate was evaluated by the people who work at the state's administration, while those who work in the business sector and non-governmental sector often rated their meetings as satisfactory- representatives of these sectors were those who gave the lowest rate.

The practice shows that only part of the employees participates in the meetings; therefore a question regarding the number of participants in organized meetings was included in the survey. A survey data show that most of the meetings are organized for 5-10 participants (67%), less common are small meetings for up to 5 participants (20%) and large meetings for more than 10 participants (13%). Looking at the correlation between the average number of meeting participants and the sector in which companies operate, a conclusion can be made that large meetings are more common at the entrepreneurship and financial service sector, while smaller- at all sectors. Significantly, that companies from non-governmental sectors organize smaller meetings with less participants; therefore, it is necessary to investigate why representatives of this sector evaluated the quality of the meetings as low.

In order to develop software, the issue regarding meeting time in accordance with the planned time was very vital. To be more precise, it was examined how often meetings begin and end on time. Survey results demonstrated that only 12.5% of the meetings always start on time, whereas there were no respondents who ascertained that meetings always end at the scheduled time.

Analysing the average time spent summarizing and sending the results of the meeting, it was concluded that 33% of all respondents spend more than 30 minutes for this job and most of them are employed in companies with more than 50 employees.

To examine market trends, it was ascertained what tools potential clients use to make meetings more qualitative and productive. The most commonly used tool was Google Drive with spreadsheets which was not designed as a meeting management tool but was often indicated by the respondents as a tool for organizing meetings (27%). The most popular online meeting management tools

are MS Teams (18%) and Zoom (15%), Outlook calendar with notification option was mentioned in 13% of cases. Add-ins of Meetinch tool were adjusted to MS Team user needs. Quite often the tool Asana (9%) which is project management tool and Mentimeter (6%) which are online voting and online brainstorming tools were mentioned (Figure 4). Also, such tools as Slack, ToDoList, SharePoint, miro, Doodle.com, Qtime were mentioned. None of the respondents mentioned tool Meetinch, so it can be concluded that the product was not so well- known in the market at that time.

The survey was prepared in order to examine the desire of the potential customers for Meetinch add-in tool, to explore what respondents expect from a meeting management tool. After the analysis of this qualitative indicator it was concluded that the most essential functions and features of meeting tool that users expect are: (1) convenient and clear interface; (2) meeting planning function, which allows you to enter the agenda of the planned meeting in the tool, schedule the time for each question and list of participants; (3) function to keep the minutes of decisions taken and tasks set with option to add transcript to the meeting minutes of the issues discussed and possibility to add presented material with all notes; (4) function to control the implementation of tasks set with the possibility to set the execution deadline, and with possibility to add document of implemented tasks; (5) creating archive of meetings which allows to see issues discussed, meeting minutes, progress of the implementation of set tasks. According to the survey data, it can be concluded that the weakest points in the organization of meetings in companies are the preparation of the meeting plan and preparation of the meeting minutes as well as control of decisions made and tasks set. Therefore, from the point of view of the authors it would be necessary to focus on the development of these functions in the meeting management tool.

To evaluate survey respondents' previous meeting quality evaluation dependence from other factors Chi-Square Test of Independence was carried out. Let's define the null hypothesis H0: quality evaluation of previous meetings (X) does not depend on the factor (Y) and such an alternative hypothesis H1: quality evaluation of previous meetings (X) depends on the factor (Y). Results achieved are summarized in Table 1. Examination of hypothesis was carried out at the significance level $\alpha=0.05$. Since value $p=0.032<0.05$ it can be concluded that meeting quality significantly depends on the company's sector but does not depend on other factors because in all other cases value p is greater than 0.05.

To evaluate survey respondents' readiness to pay for the meeting management tool depending on other factors, the following null hypothesis was considered H0: respondents' readiness to pay for the meeting management tool (X) depends on factor (Y) and such an alternative hypothesis H1: respondents' readiness to pay for the meeting management tool (X) does not depend on factor (Y). Results achieved are summarized in Table 2. Examining the results, it can be concluded that the readiness to pay for the meeting management tool depends on the end time of the meeting ($p=0.017<0.05$). Respondent readiness to pay for the meeting management tool does not significantly depend on other factors.

The conclusions were drawn after the analysis of data from Table 1 and Table 2 motivated to continue study and to carry out so-called Principal Component Analysis (PCA) for further data analysis. The PCA

Table 1

The results of Chi-Square Test of Independence on the quality of meetings depending on other factors

Factor (Y)	Pearson Chi-Square value	Asymptotic Significance (2-sided), p-value
Entrepreneurship	27.958	0.032
Number of employees at company	12.833	0.118
Time spent in meetings	31.250	0.306
Start of meetings at the scheduled time	24.250	0.835
End of meetings at the scheduled time	17.750	0.604
Average amount of meeting participants	8.250	0.409
Time spent for planning of the meeting	5.625	0.229
Time spent to process meeting data	5.469	0.706
Usage of digital tools for meetings	4.773	0.311
Usage of Microsoft 365 or Google G Suite productivity solutions	0.938	0.919

Table 2

The results of Chi-Square Test of Independence on readiness to pay for the meeting management tool

Factor (Y)	Pearson Chi-Square value	Asymptotic Significance (2-sided), p-value
Entrepreneurship	7.894	0.444
Number of employees at company	2.727	0.604
Time spent in meetings	14.394	0.421
Start of meetings at the scheduled time	9.182	0.906
End of meetings at the scheduled time	21.727	0.017
Average amount of meeting participants	1.394	0.845
Time spent for planning of the meeting	0.545	0.761
Time spent to process meeting data	3.614	0.461
Usage of digital tools for meetings	3.223	0.200
Usage of Microsoft 365 or Google G Suite productivity solutions	3.843	0.146

Table 3

Rotation Component Matrix (coefficients with an absolute value of less than 0.5 were excluded)

	Components			
	PC1	PC2	PC3	PC4
Entrepreneurship	0.850			
Number of employees at company	0.801			
Time spent in meetings	-0.795			
End of meetings at the scheduled time		-0.844		
Usage of digital tools for meetings		0.807		
Start of meetings at the scheduled time		-0.651		
Time spent to process meeting data			0.937	
Average amount of meeting participants			0.689	
Time spent for planning of the meeting				0.774
Usage of Microsoft 365 or Google G Suite productivity solutions				-0.745

was performed using the Varimax rotation method, as a result instead of the original 10 covariates, a data set of four realized principal components (PC) was estimated. PCA selects linear combinations of covariates with maximum variance, called principal components (PC). The first and second PCs correlate with the three original variables each, with an absolute value of the correlation coefficient of more than 0.6 in both cases. The third and fourth PCs correlate with two initial variables each, with an absolute value of the correlation coefficient greater than 0.6 and 0.7, respectively (Table 3).

The first principal component PC1 includes company's sector, number of employees and time of the meeting, so this component can be viewed as a measure of the Company. The second principal component PC2 contains beginning and end time of the meeting, usage of digital tools, the PC2 can be viewed as a measure of the Meeting Implementation. The third principal component PC3 includes obtaining of meeting results and number of respondents, so it can be viewed as a measure of the Meeting Results. The last component PC4 contains the use of necessary time for meeting and productivity solutions, the PC4 can be viewed as a measure of Meeting Planning. The component scores to different meeting evaluations are given in Table 4. Assuming that qualitative are those meetings evaluated with grade 8 and above

Table 4

Report on meeting quality indicator coherence

Evaluation of meeting quality (10 grade scale)	PC1	PC2	PC3	PC4
5	0.8176383	-0.1670270	0.4140102	-0.5571515
6	-2.2957528	-1.1142941	-0.9876959	0.5477468
7	0.2673273	0.2254453	-0.2493188	0.0561672
8	-0.5136799	0.0756683	0.4966761	-0.0090893
9	0.2935941	-0.0399699	-0.7451265	0.8230618

Table 5

Report on readiness to pay for meeting management tool

Fee for meeting management tool (for one user per month)	PC1	PC2	PC3	PC4
Up to 5 EUR	-.1435239	.0951008	-.0542897	.1334475
From 5 to 10 EUR	.1380697	.1524529	-.1193510	-.5622416
More than 10 EUR	1.1645539	-1.5034680	.9552398	.2188022

the most essential value indication 0.8230618 is for Meeting Results component (PC4) when evaluated with grade 9. The result of 0.49666761 which shows Meeting Implementation component (PC3) impact on meeting quality. Therefore, a conclusion can be drawn that qualitative meetings need planning and simplified summarization of the results, whereas, allocation with lower grades points out greater allocation differentiation (e.g. grade 5 and Company component PC1).

The component scores, depending on the amounts that the meeting organiser would be ready to pay for the meeting management tool for one meeting participant are given in Table 5. Software developer is interested in finding out the criteria on which customer would be ready to pay a higher fee for the product. After the analysis it was concluded that when there is a readiness to pay more than 10 EUR per month the most essential value indication of 1.1645539 has the company factor (PC1) and for value indication of 0.9552398 has the result factor (PC3). Thus, it can be concluded that the company sector and number of employees, as well as the ability to summarise results and the number of meeting participants have a significant impact on the readiness of companies to pay more for the meeting management tool.

It was concluded that the meeting quality depends on the planning of the meeting and simplified summarization of meeting results. Analysis showed that Meetinch developers have correctly chosen to include these stages into their product offering to automatize meeting planning (development of schedule and time management, notifications), as well as process of summarising results (recording, saving meeting minutes and sending them to the participants), indication of responsible persons of set tasks and control of task accomplishment. Since the result factor was more essential than readiness to pay for the product higher price, further improvements should focus mainly on the development and improvement of the features of this tool.

Conclusions

1. Weakest points in the process of meeting organisation are preparation of the meeting plan and preparation of the meeting minutes, as well as control of decisions taken and tasks set; therefore it is essential to focus on the development of these functions in the meeting management tool.
2. Evaluation of meeting quality significantly depends on the sector of the company but readiness of meeting organisers to pay for a meeting management tool depends on the end time of the meeting.
3. In order to organise a qualitative meeting, planning of the meeting and summarization of results is very essential.
4. Readiness of companies to pay for a meeting management tool mostly depends on the sector of the company, number of employees, the number of participants at the meeting, as well as the possibilities of summarising the meeting results.

References

Allen, J.A., Beck, T., Scott, C.G., & Rogelberg, S.G. (2014). Understanding workplace meetings: A qualitative taxonomy of meeting purposes. Management Research Review. 37(9), 791–814. DOI: 10.1108/MRR-03-2013-0067.

Koshy, K., Liu, A., Whitehurst, K., Gundogan, B., & Al Omran, Y. (2017). How to hold an effective meeting. *International Journal of Surgery: Oncology*. 2(5): e22. DOI: 10.1097/IJ9.0000000000000022.

Geimer, J.L., Leach, D.J., DeSimone, J.A., Rogelberg, S.G., & Warr, P.B. (2015). Meetings at work: Perceived effectiveness and recommended improvements. *Journal of Business Research*. Vol. 68, 2015–2026. DOI: 10.1016/j.jbusres.2015.02.015.

Leach, D.J., Rogelberg, S.G., Warr, P.B., & Burnfield, J.L. (2009). Perceived Meeting Effectiveness: The Role of Design Characteristics. *Journal of Business and Psychology*. 24, 65–76. DOI: 10.1007/s10869-009-9092-6.

Cohen, M.A., Rogelberg, S.G., Allen, J.A., & Luong, A. (2011). Meeting design characteristics and attendee perceptions of staff/team meeting quality. Group Dynamics: Theory, Research, and Practice, 15(1), 90–104. DOI: 10.1037/a0021549.

Vermaelen, N., & Kovach, J. (2021). Driving meeting effectiveness through organizational process improvement-A Lean Six Sigma case study. Organizational Dynamics. 100827. DOI: 10.1016/j.orgdyn.2021.100827.

Luong, A., & Rogelberg, S.G. (2005). Meetings and More Meetings: The Relationship Between Meeting Load and the Daily Well-Being of Employees. Group Dynamics: Theory, Research, and Practice, 9(1), 58–67. DOI: 10.1037/1089-2699.9.1.58.

Rovelli, P. (2020). 'I am stuck in meetings': Understanding the relation of CEO time management with TMT size and gender diversity. *European Management Journal*, 38(5), 777–790. DOI: 10.1016/j.emj.2020.02.010.

Official statistics portal. (2021, October). *Information and communication technologies in enterprises*. Retrieved February 2, 2022, from https://stat.gov.lv/en/statistics-themes/information-technologies/computers-and-internet/5679-information-and.

Banjo, S., Yap, L., Colum, L., & Vinicy, C. (2020). The coronavirus outbreak has become the world's largest work-from-home experiment. Retrieved February 21, 2022, from https://time.com/5776660/coronavirus-work-from-home.

Attaran, M., Attaran, S., & Kirkland, D. (2019). The need for digital workplace: Increasing workforce productivity in the information age. *International Journal of Enterprise Information Systems*, 15, 1–23. DOI: 10.4018/IJEIS.2019010101.

Mouratidis, K., & Peters, S. (2022). COVID-19 impact on teleactivities: Role of built environment and implications for mobility. Transportation Research Part A: Policy and Practice, 158, 251–270. DOI: 10.1016/j.tra.2022.03.007.

 DOI: 10.22616/rrd.28.2022.045

THEORETICAL SUBSTANTIATION OF YOUTH EDUCATION IN THE FIELD OF NATIONAL DEFENCE BASED ON ECOLOGICAL APPROACH

***Sandra Kreija-Gaikste**, **Irena Katane**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: sandra.kreija_gaikste@inbox.lv

Abstract
The ability of the society of the future to develop itself, to ensure the sovereignty of its country, to strengthen the economy, to raise the level of prosperity, to preserve and enrich its culture is being shaped and developed in today's schools and universities as the future generations study / and learn there. Therefore, innovations in the content of general secondary education are needed in Latvia by introducing a new subject National Defence Studies in schools. Model programs for general secondary education and the Youth Guard have been developed. The theoretical basis of the performed research is formed by scientific publications that represent several research directions in human ecology, incl. educational ecology. The aim of the study was to substantiate the diversity of ecological approaches in the education of young people in the field of national defence. The results of the research show that an ecological approach is visible in the development of the national defence content and the provision. One of the manifestations of the ecological approach in education is ´environmental education´ (education about the environment; education in the environment; education for the environment). Studies show that the content of national defence training has several dimensions: civil, military, informative and psychological, which many authors also call environmental contexts. Latvia's youth for national defense is being formed, which consists of two inseparable or closely related structural parts: 1) psychological readiness (I want) and 2) competence-based readiness (I am able).
Key words: ecological approach, national defence training, national sustainable development, youth education environment.

Introduction

The current geopolitical situation in the world, and especially in Europe, highlights the sustainability of each society and country in the present dimension and sustainable development in the future. The ability of the society of the future to develop itself, to provide for the sovereignty of its country, to strengthen its economy, to raise its level of prosperity, to preserve and enrich its culture, without prejudice to the interests and needs of other peoples and countries for self-determination, is shaped and developed in today's schools and universities as the next generations are learning and studying there. They will be managing the country in the future, taking care of sustainable development of the society, the economy of their country, its security and defence, being at the heart of our country's future society.

Therefore, innovations in the content of general secondary education in Latvia are needed by introducing a new subject of 'National Defence Training' in schools. At present, everything is being done to implement 'National Defence Training' as a compulsory subject in secondary education institutions from the 2024/2025 school year (Valdība apstiprina ziņojumu ..., 2021).

A legal basis has been developed for the introduction of the new subject, as evidenced by several normative documents (Par Nacionālās identitātes ..., 2018; Par Valsts aizsardzības koncepcijas ..., 2020; Par valsts aizsardzības mācības ieviešanu ..., 2018; Valsts aizsardzības mācības …, 2020; Valsts aizsardzības koncepcija, 2020). One of these documents is the 'National Defence Concept', which was developed and approved in 2020. The 'National Defence Concept' is a policy planning document that defines the strategic goals and basic principles of national defence. Comprehensive protection is both one of the goals of the concept and the best tool for building a sustainable society. In the overall context of defence, both formal and non-formal education for young people in the field of national defence is important.

Sample curricula have already been developed for both formal general secondary education in schools and non-formal education of the 'Youth Guard' (Bērziņa *et al.*, 2020; Kukuļinskis, 2021).

In global forums as well as in scientific publications since the end of the 20th century, the ecological paradigm has been substantiated as a transdisciplinary paradigm, but the ecological approach in human thinking, in promoting the development of children and youth, in all kinds of activities (including education) has been substantiated as an imperative (Bronfenbrenner, 1996; Bruntland, 1987; Naess, 1973), which has become more and more relevant in the 21st century (Bonnedahl, Heikkueinen, & Paavola, 2022; Katane, 2007; Messerli & Murniningtyas, 2019; Palmer & Neal, 2004). Therefore, the aim of the research was: to substantiate the diversity of ecological approach manifestations in the education of young people in the field of national defence.

Materials and Methods

The aim of the theoretical research also led to the research question: What are the manifestations of the ecological approach in the education of young people in the field of national defence?

The theoretical basis of the performed research is formed by scientific publications that represent several research directions in human ecology, incl. educational ecology: 1) sustainability and sustainable development; 2) education for sustainable development; 3) basic principles and guidelines of environmental education; 4) ecologically multidimensional approach in developing and substantiating classifications of environmental dimensions/contexts; 5) ecological systemic approach in developing and substantiating multi-level environmental system models; 6) principles of human-environment interaction in *human development ecology* and *ecosophy* (*deep ecology*), incl. the principle of ego – and eco – balance.

Research methods: 1) study, analysis, and evaluation of scientific literature (method of theoretical research); 2) reflection of the authors' experience (empirical research method).

Results and Discussion

Substantiation of the country's sustainable development from the point of view of human ecology

Sustainability and sustainable development are among the key concepts of human ecology, including educational ecology (Katane, 2007).

The origins of the concept of sustainable development and the concept itself can be traced back to the end of the 20th century, with the formulation of the ecological paradigm and ecological approach as an imperative for human thinking and responsible action. Initially, the ideas of sustainable development came about in an effort to change the way humanity thinks about our planet and resulted in the publication of a book in 1987, 'Our Common Future' (Bruntland, 1987). Definitions of sustainable development emerged, revealing the diversity of interpretations of sustainable development. The most popular of these are (Hajlan & Kashani, 2021): 1) balanced development of society, economy and natural environment; 2) the preservation and increase of the various resources at our disposal, especially natural resources, so that modern generations do not live at the expense of future generations for the sake of their well-being, but, on the contrary, pass on their material and spiritual values to future generations. Among the greatest values of the nation is independence and one's own country, for which the defenders of our homeland have given their lives. Thus, one of the basic ideas of the concept of sustainable development is also applicable to the sustainable development of our country, so that future generations can be born, grow, develop and live in their own country.

Key findings on national sustainable development can be found in the UNESCO Education for Sustainable Development (Education for Sustainable Development, 2012): 1) all activities at the international level should be in line with the interests and needs of each country; 2) any kind of war is destructive in nature and therefore runs counter to sustainable development and actions aimed at sustainability; while peace, development, and environmental protection are interrelated and inseparable concepts.

Thus, today the concept of sustainable development is constantly evolving and expanding, as a result of which the concepts of sustainability and sustainable development are obtaining new interpretation and new challenges (Messerli & Murniningtyas, 2019; Sustainable Development in ..., 2021).

New dimensions of the concept of sustainable development are emerging that are directly related to the protection of the country/countries and its/their sustainable development. Here are some examples of the new dimensions of sustainable development:

- sustainable development on our Earth and the sustainability of space (Prasad, 2019);
- responsible action as a guarantor of sustainability (Bonnedahl, Heikkueinen, & Paavola, 2022);
- sustainable development of information environment and cyber security, cyber protection (Galinec, Možnik, & Guberina, 2017) etc.

One of the cornerstones of sustainable development is ecosophy, or deep ecology, in which life and its protection are the core values of an ecologically minded, responsible society (Katane, 2007). It is important to note that among the key findings of ecosophy are insights that are especially relevant today (Naess, 1973; Sessions, 1995): 1) every life has a value in itself; 2) human thinking needs to change, because ecological, technological, and war crises are caused by a crisis in people's thinking; 3) therefore, political and technological structures must change, and the thinking of politicians, of each person, must change.

Ecological approach in the substantiation of the Latvian national defence education content and learning environment

Education plays a very important role in the process of developing world beliefs, values and attitudes, and competencies of new generations. Today, the concept of Education for Sustainable Development (ESD) is becoming more and more important, which is gaining further development, where teachers' thinking, attitudes and competencies in the field of sustainable development also play an important role, as evidenced by several publications (Education for Sustainable Development, 2012; Sinakou, Boeve-de Pauw, & Van Petegem, 2019).

In order to develop new thinking, value-based attitudes and actions, it is very important to respect the ecological approach in the design of school

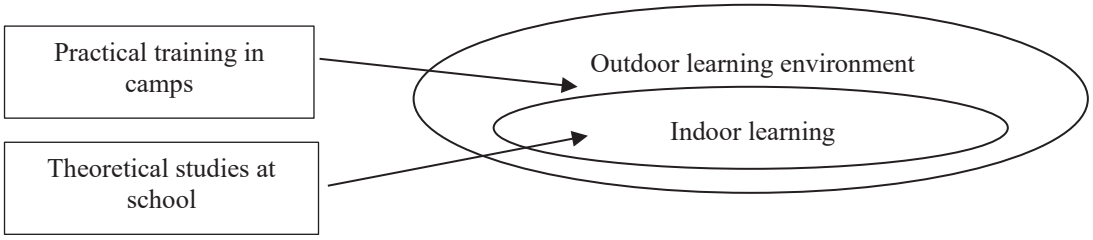

Figure 1. National defence learning environment (created by the authors).

youth curricula and in the maintenance and further development of the educational environment. This also applies to the subject National Defence Training, which represents the formal education of schoolchildren, as well as the content of the Youth Guard training, which is non-formal in nature.

One of the manifestations of the ecological approach in education is environmental education (Sterling, 1992), which is the didactic basis for education for sustainable development.

There are three basic principles of environmental education, which are also called guidelines (Katane, 2007): education about the environment; education in the environment; education for the environment.

All three basic principles of environmental education are also integrated into the *National Defence Training* of schoolchildren (Bērziņa *et al.*, 2020) and the content of the *Youth Guard* training (Kukuļinskis, 2021).

Education about the environment

In order to promote the readiness of school youth for national defence, the history of Latvia occupies an important place in the content of the National Defence Training. The content of National Defence Training also concerns the study of the surroundings, the specific territory in both theoretical and practical studies and its reflection in topographic maps (military topography and orientation) (Bērziņa *et al.*, 2020; Kukuļinskis, 2021). The psychological resilience and ICT competence of young people is also important, especially in the context of hybrid warfare in the information environment/space, so young people need to be well informed about the processes in the global and national information and technology environment/space (Mattis & Hoffman, 2005).

Education in the environment

The acquisition of the content of the National Defence Training for School Youth (secondary school students) and also the 3-level curricula of the Youth Guard is planned in both indoor lessons (theoretical studies) and outdoor lessons (practical training), thus the indoor and outdoor education environment can be updated (Figure 1).

There is also a theoretical basis for the division of the indoor education/learning environment and outdoor education/learning environment (Figure 2),

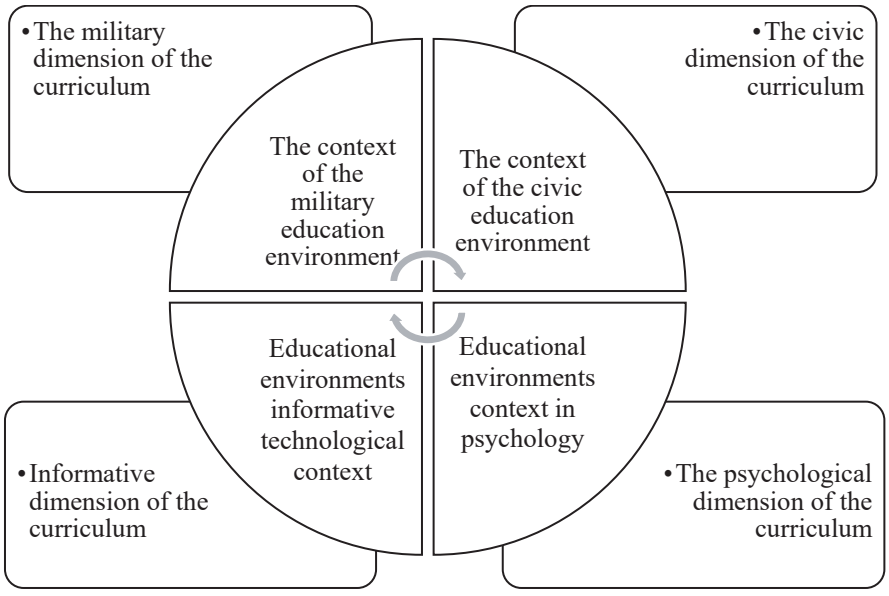

Figure 2. Environmental dimensions of national defence education (created by the authors).

which can be found in several publications (Barnes & Sharp, 2004; Margeviča-Grinberga & Šūmane, 2020).

Based on the ecological approach, the learning environment has several explanations, incl. the learning environment is (Katane, 2007): 1) a learning process as an interaction system, where learning subjects interact: teacher and learner/learners, as well as object: learning content; 2) a field of semantics, thus it can be concluded that the specifics of the national defence learning environment are largely determined by the content of learning in the field of national defence.

Studies show (Berzina, 2020; Kreija-Gaikste & Katane, 2021) that the content of National Defence Training has several dimensions: civil, military, informative and psychological.

In turn, in human ecology, incl. the ecology of education, based on an ecologically multidimensional approach, several environmental dimensions are distinguished, which many authors also call environmental components and also environmental contexts (Hiemstra, 1991; Īriste, 2018; Katane, 2007; Katane & Katans, 2014).

Based on the above, the authors have singled out four dimensions or contexts of the school youth's national defence education environment (Figure 2): 1) the environmental dimension of military education; 2) the environmental dimension of civic education; 3) the informative technological dimension of the educational environment; 4) the psychological environment of the educational environment.

In Latvia, based on the justification of lifelong learning (Katane & Kalniņa, 2010), when formal education is supplemented with non-formal education and the diversity of the education offered allows creation and development of a very wide range of competencies, national defence education will soon be offered in all Latvian schools as formal education within the compulsory subject National Defence Training and also as non-formal education (Youth Guard Training).

It also identifies overlapping types of national defence environmental segments (Figure 3): 1) National defence learning environment at school (formal learning environment); 2) National defence learning environment in Youth Guard (non-formal learning environment), which together form the school youth education environment in the field of national defence, because: 1) many high school students are also youth guards; 2) in many schools, Youth Guard training is offered as non-formal or interest education, and in general it forms the educational environment for young people in the field of national defence.

Education for the environment

The main finding arising from the goal of ecological upbringing is the promotion of the new generation's environmentally friendly attitudes and responsible actions, understanding the term 'environment' as the diverse environment of human life, incl. social environment, cultural environment, natural environment, economic environment, information environment and other types of environmental dimensions. Therefore, it is still relevant in the educational sciences that the content of education is an important pedagogical means of educating the new generation and that the result of education is a system of attitudes based on values (Špona, 2004). Responsible attitude towards the state and its security is a precondition for Latvia's existence as a state (Nacionālās drošības koncepcija, 2019), as well as an important task for the new generation of national defence education.

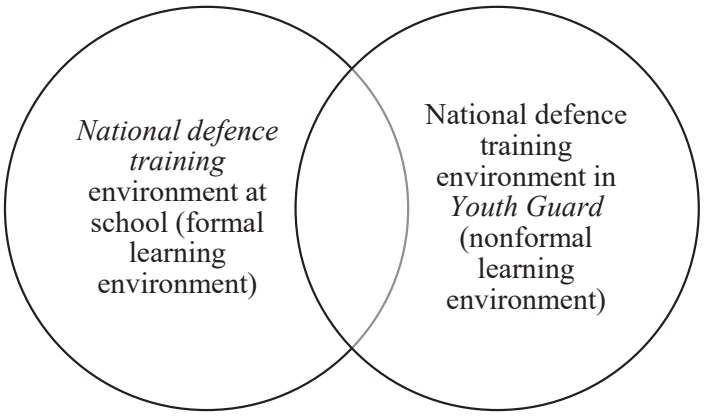

Figure 3. Youth education environment in the field of national defence (created by the authors).

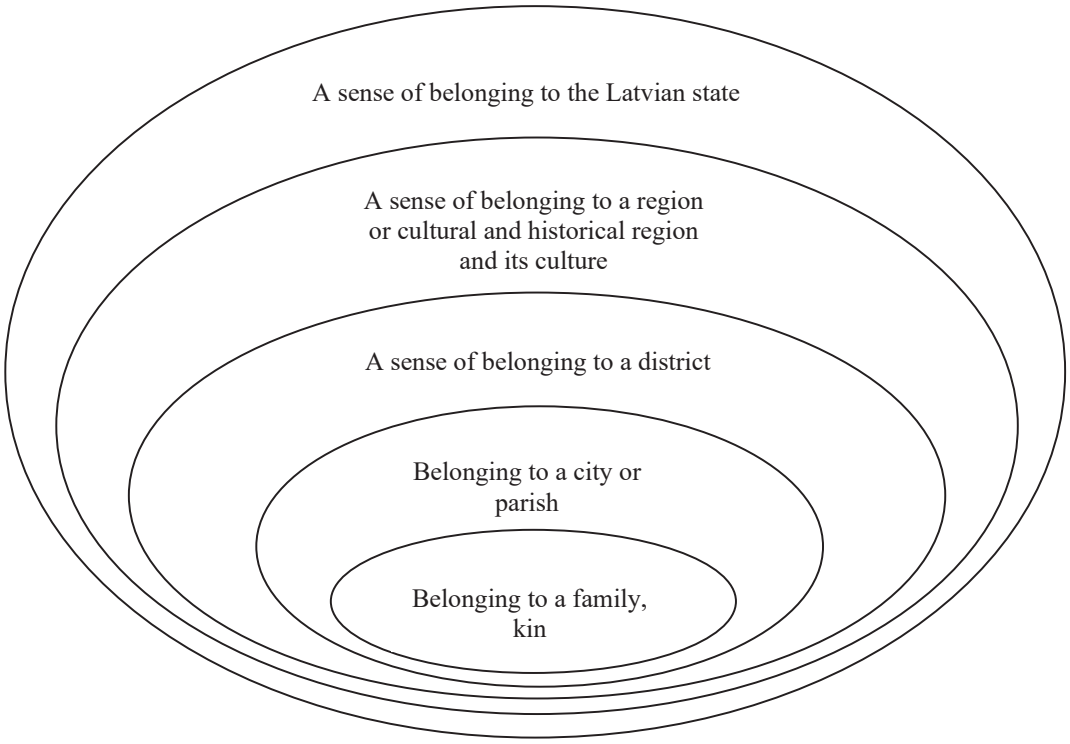

Figure 4. Model of a person's belonging to their multilevel living environment (Created by the authors).

The concept of comprehensive national defence (Par Valsts aizsardzības ..., 2020) points to the great importance of the desire and ability of the whole society and each of its individuals, incl. young people, to protect their country, as the guarantor of national sustainability is national security.

A large part of the content of national defence curricula for young people (secondary school students, some of whom are also youth guards) has a patriotic upbringing function. Responsibility for the security and sustainability of one's country is not the only goal of patriotic upbringing. Equally important is the patriotism of young people, which is largely based on their love for their Fatherland (homeland) and a sense of belonging to their family and kin, their city or parish, administrative district, region or cultural-historical region: Kurzeme, Zemgale, Sēlija, Vidzeme and Latgale and its culture, Latvia as a whole (Figure 4). Young people's belonging to at least one of these levels of the environment is very important in the process of forming a national identity. The Cabinet of Ministers Order No. 345 issued in 2019 also reports on the policy of national identity, civil society and integration in Latvia (Par Nacionālās identitātes ..., 2018).

The authors' created 'Model of a person's belonging to their multilevel living environment' (Figure 4) is based on an ecological systemic approach in human developmental ecology, which makes it possible to show the environment as a supersystem (ecosystem) with several environmental subsystems (environmental levels). The ecological systemic approach has been used by several authors to justify the human living environment and/or the educational environment (Bronfenbrenner, 1996; Huitt, 2012; Katane, 2007).

Thus, it can be concluded that the goal of patriotic upbringing in the framework of National Defence Training is the formation of young people's attitudes and perseverance towards their country, where the focus is on patriotism, the integral components of which are responsibility for national security and sustainability, love for one's homeland, and a sense of belonging, starting with one's family and kin, the place where the young person lives (city or rural parish) and belonging to the entire state of Latvia.

Based on scientific publications (Bronfenbrenner, 1996; Reņģe, 2002; Špona, 2004), it can be concluded that attitudes can be considered as personal connections with the surrounding world, it is a whole system of attitudes that develops during life in relation to various objects and subjects that are formed in the process of interaction with the human environment. Although the structure of attitudes has several components: emotions, knowledge, habits, research shows that initially the main component of attitudes is emotional experiences, which also determine liking or disliking, loving or not loving, respecting or not respecting, feeling belonging or feeling excluded etc., and which become the main

indicators for evaluating events, relationships and values. Any narrative, whether it is about the history of the country, or about the experiences of family members during their lives, in the context of the historical events of our country, is emotionally experienced, perceived and interiorized in the form of reflections of the external environment, in the internal environment or in the human psyche, where notions, imaginative images of what is heard and learned are formed. Events find their reflection not only in the form of new ideas and knowledge, but also emotions, values, attitudes, personally experiencing everything and 'living' in the imagination. As a result, these narratives become personally relevant to young people. Also, attitudes are either positive or negative or ambivalent (contradictory: both), but attitudes can't be neutral, because in that case there is no such attitude at all, which is possible if there is no necessary information, knowledge, if something is not assessed cognitively or emotionally, simply – a person has no experience and opinion on a particular issue. Therefore, in order for young people to have as a diverse experience as possible in the field of national security and defence, to develop attitudes based on emotional experiences and values, not only the content of the study, the diversity of the learning process and the student-centred approach, but also the pedagogue's own attitudes in the learning process, examples of his experience in the form of narratives, his methodological competence, and creativity in organizing various types of activities in the field of national defence are very important.

Thanks to the acquired knowledge, skills and competencies, as well as attitudes and motivation to participate in the comprehensive national defence system, the readiness of young people for national defence is being formed. As a result of theoretical research (Baltušīte, 2012), the authors concluded that the readiness of young people for national defence consists of two integral or closely related structural parts: 1) psychological readiness (I want) and 2) competence-based readiness (I able).

Conclusions

1. Since the end of the 20th century, the concept of sustainable development has further developed, expanded, and the basic ideas are reflected in the concepts of sustainable development of society, economy, culture, and others in the form of transfers. Based on one of the interpretations of the concept of sustainable development, it can be concluded that it is necessary to ensure and promote the sustainable development of our country so that future generations can be born, grow up, develop and live in their sovereign and secure country.
2. There is the diversity of ecological approach manifestations in the education of young people in the field of national defence. The content of national defence education and the learning process itself is and will continue to be based on the three basic principles of environmental education: education about the environment; education in the environment; education for the environment.
3. The basic principle of education in the environment allows to explain the national defence educational environment from various aspects and manifestations of the ecological approach: 1) the ecological systemic approach makes it possible to distinguish between the internal and external environment of national defence education and substantiate belonging to the multilevel human living environment; 2) the ecologically multidimensional approach makes it possible to distinguish several contexts of the national defence education environment, the specifics of which are determined by various dimensions of national defence education content.
4. Thanks to the acquired knowledge, skills and competencies, as well as attitudes and motivation to participate in the comprehensive national defence system, the readiness of Latvian youth for national defence is formed, which consists of two integral or closely interrelated structural parts: 1) psychological readiness (I want) and 2) competence-based readiness (I able).

References

Baltušīte, R. (2012). *Pedagoģijas studentu gatavība profesionālai darbībai skolas vidē* (Preparedness of pedagogy students for professional activity in the school environment). Promocijas darbs. Jelgava: LLU. (in Latvian).

Barnes, P., & Sharp, B. (Red.). (2004). *Outdoor Education.* Lyme Regis: Russel House Publishing Ltd.

Berzina, I. (2020). From 'total' to 'comprehensive' national defence: the development of the concept in Europe. *Journal on Baltic Security, 6*(2), 7–15. DOI: 10.2478/jobs-2020-0006.

Bērziņa, I., Kuzmins, V., Falka, S., Gūtmane, U., & Damberga, J. (2020). *Valsts aizsardzības mācība: Specializētā kursa programmas paraugs vispārējai vidējai izglītībai* (National Defence Training: Sample specialized course program for general secondary education). Rīga: Jaunsardzes centrs, VISC, AM. (in Latvian).

Bonnedahl, K., Heikkueinen, P., & Paavola, J. (2022). Strongly sustainable development goals: Overcoming distances constraining responsible action. *Environmental Science & Policy, 129*, 150–158. DOI: 10.1016/j.envsci.2022.01.004.

Bronfenbrenner, U. (1996). *The ecology of human development: Experiments by nature and design.* Cambridge: Harvard University Press.

Bruntland, G. (1987). *Our Common Future: Report of the World Commission on Environment and Development.* Oxford: Oxford Universitu Press. Retrieved May 17, 2021, from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf.

Education for Sustainable Development. (2012). Paris: UNESCO. Retrieved October 15, 2021, from https://sustainabledevelopment.un.org/content/documents/926unesco9.pdf.

Galinec, D., Možnik, D., & Guberina, B. (2017). Cybersecurity and cyber defence: national level strategic approach. *Automatika: Journal for Control, Measurement, Electronics, Computing and Communications, 58* (3), 273–286. DOI: 10.1080/00051144.2017.1407022.

Hajlan, M., & Kashani, S. (2021). Evolution of the concept of sustainability. From Brundtland Report to sustainable development goals. *Sustainable Resource Management: Modern Approaches and Contexts*, 1–24. DOI: 10.1016/B978-0-12-824342-8.00018-3.

Hiemstra, R. (Ed.). (1991). *Creating Environments for Effective Adult Learning.* San Francisco: Jossey-Bass.

Huitt, W. (2012). *A systems approach to the study of human behavior: Educational Psychology Interactive.* Valdosta: Valdosta State University. Retrieved July 30, 2021, from http://www.edpsycinteractive.org/materials/sysmdlo.html.

Īriste, S. (2018). *Prospective managers'of Hospitality Business Competitiveness Evaluation and Development Promotion in the Dual Study Environment of Higher Education Institution.* Doctoral Thesis. Jelgava: LLU.

Katane, I. (2007). *No ekoloģiskās paradigmas līdz vides modelim izglītības pētniecībā* (From the ecological paradigm to the environmental model in educational research). Sērija 'Izglītības ekoloģija'. Jelgava: LLU. (in Latvian).

Katane, I., & Kalniņa, I. (2010). *Skolēnu personības konkurētspējas attīstība neformālās komercizglītības vidē* (Development of Students' Personality Competitiveness in the Environment of Non-Formal Commercial Education). Jelgava: LLU. (in Latvian).

Katane, I., & Katans, E. (2014). Multidimensional Model of Distance Learning Environment. In V. Ļubkina, & G. Marzano (Ed.), *Society. Integration. Education. 2*, pp. 106–115. Rezekne: RA. DOI: 10.17770/sie2014vol2.667.

Kreija-Gaikste, S., & Katane, I. (2021). Multidimensional and Multifunctional Content of National Defence Training in Latvian Schools. *Research for Rural Development. 36*, pp. 337–343. Jelgava: Latvija University of Life Sciences and Technology. DOI: 10.22616/rrd.27.2021.048.

Kukuļinskis, G. (Red.). (2021). *Valsts aizsardzības mācība: Specializētā kursa programmas paraugs* (National Defence Training: Sample specialized course program). Rīga, VISC, AM (in Latvian).

LR Aizsardzības ministrija. (2021). *Valdība apstiprina ziņojumu par valsts aizsardzības mācības ieviešanas rezultātiem un uzlabojumiem Jaunsardzē* (The government approves a report on the results of the implementation of national defence training and improvements in the Youth Guard). (2021). Retrieved July 30, 2021, from https://www.mod.gov.lv/lv/zinas/valdiba-apstiprina-zinojumu-par-valsts-aizsardzibas-macibas-ieviesanas-rezultatiem-un (in Latvian).

LR Ministru kabinets. (2018). *Par Nacionālās identitātes, pilsoniskās sabiedrības un integrācijas politikas īstenošanas plānu 2019.-2020. gadam* (On the National Identity, Civil Society and Integration Policy Implementation Plan for 2019-2020). Retrieved July 30, 2021, from https://likumi.lv/ta/id/300483. (in Latvian).

LR Ministru kabinets. (2018). *Par valsts aizsardzības mācības ieviešanu un Jaunsardzes attīstību 2019.–2027: Informatīvais ziņojums* (On the Introduction of National Defence Training and the Development of the Youth Guard in 2019–2027: Information statement). Retrieved July 30, 2021, from http://tap.mk.gov.lv/mk/tap/?pid=40467754. (in Latvian).

LR Saeima. (2019). *Nacionālās drošības koncepcija* (The concept of national security). Retrieved July 30, 2021, from https://likumi.lv/ta/id/309647-par-nacionalas-drosibas-koncepcijas-apstiprinasanu. (in Latvian).

LR Saeima. (2020). *Valsts aizsardzības mācības un Jaunsardzes likums* (Law on the National Defence Training and the Youth Guard). Retrieved July 30, 2021, from https://likumi.lv/ta/id/319794-valsts-aizsardzibas-macibas-un-jaunsardzes-likums. (in Latvian).

LR Saeima. (2020). *Par Valsts aizsardzības koncepcijas apstiprināšanu: Saeimas paziņojums* (On approval of the National Defence Concept: Statement of the Saeima). Retrieved July 29, 2021, from https://likumi.lv/ta/id/317591-par-valsts-aizsardzibas-koncepcijas-apstiprinasanu. (in Latvian).

Margeviča-Grinberga, I., & Šūmane, I. (2020). *Mūsdienu mācību vide skolēnu aktīvai iesaistīšanai mācību procesā* (Modern learning environment for active involvement of students in the learning process). Rīga: LU. (in Latvian).

Mattis, J., & Hoffman, F. (2005). Future Warfare: The Rise of Hybrid Wars. *Proceedings of the U.S. Naval Institute* Retrieved September 20, 2021, from https://www.usni.org/magazines/proceedings/2005/november/future-warfare-rise-hybrid-wars.

Messerli, P., & Murniningtyas, E. (Eds.). (2019). *The Future is Now: Science for Achieving Sustainable Development: Global Sustainable Development Report.* New York: United Nations: Department of Economic and Social Affairs.

Naess, A. (1973). The shallow and deep, long-range ecology movement: A summary. *In quiry, 16*, 95–100.

Palmer, J., & Neal, P. (2004). *The handbook of Environmental Education.* New York: Routledge.

Prasad, M. (2019). Relevance of the Sustainable Development Concept for International Space Law: An Analysis. *Space Policy, 47*, 166–174.

Reņģe, V. (2002). *Sociālā psiholoģija* (Social psychology). Rīga: Zvaigzne ABC. (in Latvian).

Sessions, G. (1995). *Deep Ecology for the 21st Century.* Boston: Shambhala Publications.

Sinakou, E., Boeve-de Pauw, J., & Van Petegem, P. (2019). Exploring the concept of sustainable development within education for sustainable development: implications for ESD research and practice. *Environment Development and Sustainability, 21*(3), 1–10. DOI: 10.1007/s10668-017-0032-8.

Sterling, S. (1992). *Coming of Age: a short history of environmental education (to 1989).* Walsall: National Association for Environmental Education.

Sustainable Development in European Union. (2021). Brussels: European Commission. Retrieved March 11, 2022, from https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_21_3006.

Špona, A. (2004). *Audzināšanas process teorijā un praksē* (Upbringing process in theory and practice). Rīga: RaKa. (in Latvian).

 DOI: 10.22616/rrd.28.2022.046

EVALUATION OF LISTENING AS TEACHERS COMMUNICATIVE ABILITY IN THE CONTEXT OF MEDIATION

***Lolita Tereze Nicmane**, **Regina Baltusite**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: lolita.tereze@inbox.lv

Abstract
In recent years, the interest in mediation has increased significantly in school environment. Study groups are organized for both teachers and students. Teachers and agemates can participate in resolving conflicts. To become a mediator, students and teachers need certain competencies, skills and knowledge. The core competence which helps in this process is the communicative competence. The communicative competence is also one of professional competences of a teacher. Listening skills, which ensure the receipt and processing of information and decision-making, plays an important role in the communicative competence. The aim of the article is to evaluate the level of teachers' listening ability and to improve the mediation training program based on the results of the research. Eighty nine respondents participated in the survey. The data were obtained using the methodology developed by Burley-Allen with 30 statements about listening as an element of the communication process, which was based on the respondents' self-assessment. The topicality of the article is determined by the fact that listening as a communicative ability is considered within the context of mediation rather than the acquisition of foreign languages. The empiric study analyses the replies given by the respondents, describing the way they listen to a conversation and skills they use to understand the conversation partner better. The study draws a conclusion that teachers must pay attention to listening, when they are not interested in the speaker's words, as well as to selectivity of attention.
Key words: communicative competence, mediation, listening, teacher.

Introduction

The origins of mediation can be traced back to the 20th century, but historically its roots go back to the Ancient World. In a broad sense, mediation can be described as a social institution promoting constructive development of society (Chupris, 2018). In a narrower sense, mediation, one form of alternative dispute resolution, is a process in which a third party helps other party manage their conflict (McCorkle & Reese, 2019). The interest in mediation in the school environment has increased significantly in recent years. Both teachers and students are gradually integrated into the mediation process, as this is a more democratic way of resolving conflicts. Communicative competence is one of the most important professional competences of a teacher. Listening skills can be called a core competence in communicative competence. Croatian researchers concluded that teachers do not associate burnout with communication, but they have insufficient skills in conflict solving, and communication barriers are influenced by stereotypes (Bakic-Tomic, Dvorski, & Kirinic, 2015). A number of authors (Humphreys, 2019; Doran & Winkeler, 2017; Leonov, 2019; Vikulina, 2014) emphasize the role of listening skills in personal development, interpersonal communication and mediation because, as one Eastern wisdom says, the truth is in the listener's ears and not in the speaker's words (Panfilova, 2006). Active listening involves several techniques – paraphrasing, summarizing, reflecting on feelings, etc. It plays the key role in mediation, as it is important for the mediator to listen and to hear both parties of a dispute in order to solve the conflict.

The aim of the article is to evaluate the level of teachers' listening skills to improve the training mediation program for teachers based on the results of the research.

Materials and Methods

Eighty nine respondents – teachers from different regions of Latvia (Vidzeme, Latgale, Kurzeme and Zemgale) participated in the study. The questionnaire survey was held during the mediation course red in various regions of Latvia by the author of the article L.T. Nicmane. The research was made in 2021.The following methods were used in the study: analysis and synthesis of theoretical findings and methodology for determining listening characteristics. The author of the methodology is M. Burley-Allen (Burley-Allen, 1995; Cheliotes & Reilly, 2010). The methodology includes 30 statements on listening characteristics in the process of communication. All the characteristics are linked with the listening skills. The respondents evaluated the characteristics of the communication process as most of the time, frequently, occasionally, almost never. The methodology is based on the self-assessment of the respondents. The data were processed based on the key (Table 1).

The answers given for statements 1, 3, 8-10, 13, 22-23 were assessed from 1 to 4 points. In turn, the answers given for statements 2, 4-7, 11-12, 14-21, 24-30 were assessed from 4 to 1 point. The responses most of the time and frequently, as well as the responses occasionally and almost never are counted together.

Based on the data acquired, the level of the listening skills was defined for each teacher. The

Table 1

Methodology key (data processing)

Statement numbers	Points			
	Most of the time	Frequently	Occasionally	Almost never
1, 3, 8, 9, 10, 13, 22, 23	1	2	3	4
2, 4-7, 11, 12, 14-21, 24-30	4	3	2	1

levels of communication efficiency are evaluated as follows: superior – 110-120; 99-109 – above average; 88-98 – average; 77-87 – fair.

Results and Discussion

The process of mediation cannot be imagined without communication. Consequently, the mediator must have communicative competence, conflict identification competence and other competences. There is no single definition of the communicative competence. The following definitions can be mentioned: communicative competence is the ability to interact well with others (Spitzberg, 1988 in Communicative competence defined. Dr.Lane's perspective, 2020); competence as a situational ability to set realistic and appropriate goals and to maximize their achievement by using knowledge of self, other, context and communication theory to generate adaptive communication performances (Friedrich, 1994 in Communicative competence defined. Dr.Lane's perspective, 2020); communicative competence is the degree to which the communicator's goals are achieved through effective and appropriate interaction (Communicative competence defined. Dr. Lane's perspective, 2020); communicative competence is the ability to achieve communicative goals in a socially appropriate manner (Kiessling & Fabry, 2021). Therefore, communicative competence is the ability, which ensures constructive interaction with others and the achievement of communication goals. One of the characteristics of communicative competence is the ability to listen. Listening skills play significant role in mediation. S.Ater names five reasons why one must listen to mediation:1) listen to unravel deep seated issues that may not be explicit; 2) listen to engage; 3) listen to reframe; 4) listen to empathize; 5) listen because it's a dialogue (Ater, 2021). One of the main competences of a mediator is identification of conflict. In the process of conversation, it is necessary to listen to your partner attentively. If something remained unclear, ask a direct question: 'What do you mean by…?', or by rephrasing the phrase: 'Have I got you right?'. The conversation involves the activity of both parties and represents a dialogue of equal participants *(*Doran & Winkeler, 2015; Leonov, 2019). Thus, listening is a basic ability that influences the quality of relationships in communication, successful interaction and understanding (Panfilova, 2006; Vikulina, 2014). Other authors (Abramenko *et al.*, 2014; Gulam, 2010) also define listening as the ability to: 1) listening is the ability to accurately receive and interpret messages in the communication process; 2) listening is the key to all effective communication, without the ability to listen effectively messages are easily misunderstood.

The research concludes that listening to a conversation partner takes about 42-53% of time in communication. Therefore, the listening skills are required more than writing and reading. Listening efficiency is also evaluated in the research at a 25% level, while the respondents evaluate it even higher (up to 50-60%) (Panfilova, 2006). This reveals the necessity to develop this ability, as inefficient listening causes misunderstanding and inaccurate interpretation of what is heard. To prevent this, it is necessary to find out what is engaged, active listening. In communication, it must be understood what is hearing and what is listening. Hearing is a physical process that requires less intellectual effort, but listening is a process of perceiving, understanding, comprehending, structuring and memorizing information that involves many aspects of personality. The basis of the listening process is focusing on specific stimuli that reach our sensory organs (Leonov, 2019; Panfilova, 2006; Vikulina, 2014).

The authors define the following types of listening. The most frequent is non-reflexive and reflexive listening (Leonov, 2019; Vikulina 2014). Non-reflexive listening involves minimal interference in a partner's speech and focusing on giving answers to his questions and understanding the aim of the conversation. It is necessary to show understanding, support and kindness while staying silent. There are also passive and active listening techniques – verbal (asking, paraphrasing, etc.) and non-verbal (posture, gestures, gaze). Passive listening is an attentive, quiet perception of the other person's information, but the speaker can sometimes get the impression that he is not being listened to. Non-reflexive listening can be used: 1) the partner in conversation has negative emotions and wants to talk to someone about his concerns; 2) the partner in conversation feels confused, uncertain and has difficulties in the conversation; 3) it is difficult to express in words what he wants to say;

4) it is necessary to obtain more information about the partner in conversation (Panfilova, 2006; Vikulina, 2014). In the cases mentioned above, non-reflexive listening elements may be used in mediation.

In turn, active listening includes certain signs that illustrate listening (nodding, asking, repeating of what has been told, etc.). Reflexive listening provides for active feedback in the conversation. The focus is on the logic in the dialogue. It is important to make sure that the partner in the conversation has understood the question. To hear the response and to make sure that we have understood the partner right. The techniques of reflexive listening include clarification, reflection, summarizing, paraphrasing of feelings (Figure 1). If necessary, the words, logics of the partner is used when the partners in the conversation have different level of communication skills or vocabulary. There can also be empathic listening – communication focused on emotions and the inner state of a person, the aim of which is to understand the inner state, to form a dialogue on the level of feelings (Humphreys, 2019; Leonov, 2019; Panfilova, 2006; Vikulina, 2014). The concept of empathic listening was introduced by K. Rogers (Lyutova-Roberts, 2007). The level of empathic listening is also mentioned by M. Burley-Allen (1995) and R. Salem (2003). M. Burley-Allen distinguishes three levels of listening (Burley-Allen, 1995): empathetic listening; 2) hearing words, but not really listening; 3) listening in spurts. Reflexive and emphatic listening is the most important in the process of mediation.

The efficiency of listening depends on several factors: 1) switching from speaker's to listener's role – if instead of listening, the partner in conversation plans a response and waits for the opportunity to say something, the efficiency of listening decreases rapidly; changing roles requires effort and attention; 2) listening before reacting – the listener stops listening before the speaker finishes, as everyone thinks that he knows what the partner will be talking about; experience shows that this is our assumption, so it is important to allow the speaker express himself and to form a habit of active listening; 3) objective listening – the words of the partner in the conversation and his behaviour patterns deviate from careful listening, many of which may create a 'semantic noise' that makes people react emotionally or negatively and disturbs the emotional balance; therefore, it is important to understand the meaning of the response before answering (Panfilova, 2006). The factors mentioned influence the understanding in communication, determine accurate deciphering of a statement, thus conferring the correct meaning to it. Understanding in communication is limited by: a) differences in life and professional experience; b) differences in the vocabulary. Understanding is affected by unknown words and fast talking, a large amount of facts and figures or vaguely worded ideas (Panfilova, 2006).

The study conducted by the authors also focused on teachers' reactions being in the role of a listener. As it has been already mentioned, people's behaviour while listening may be very different. The empiric study analyses the replies given by the respondents, describing the way they listen to a conversation partner if his opinion differs, if he is thinking of preparing a reply during listening, if he simulates listening, hovers around his mind or hears only what he wants to hear (Figure 2). When answering to the statement 'I switch off when I listen to people with whom I disagree or whom I do not want to hear', 36% of respondents answered by affirmation, while 64% do it rarely or almost never. Thus, the quality of listening is affected by the coincidence or disagreement of the conversation partners. The listener stops listening to the speaker if he knows what he wants to say, to be more exact, he thinks he knows. It disturbs 21% of teachers, while 79% of respondents continue listening to the conversation partner. Another factor affecting the process of listening is preparing of objections during listening, which is typical for 48 % of respondents. Listening to another person involves simulating of listening, even if the person is not listening (29% of teachers). Another significant barrier to listening is selective listening (39% of respondents). Listening is also influenced by the so-called hovering around in mind. Respondents used to

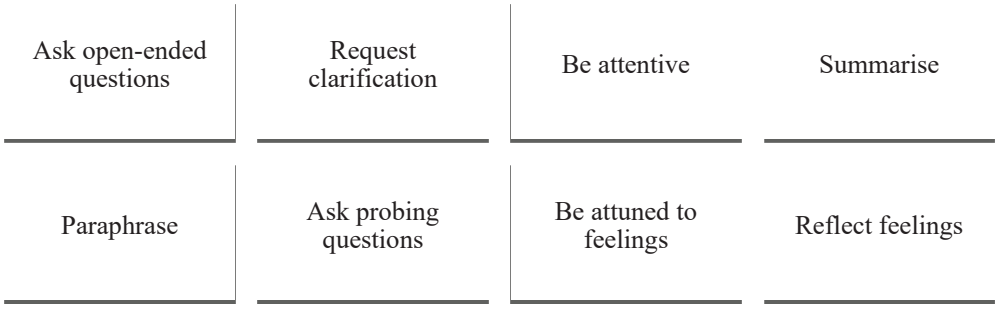

Figure 1. The techniques of active listening
(drawn by the authors according to Doyle, 2021; Panfilova, 2006).

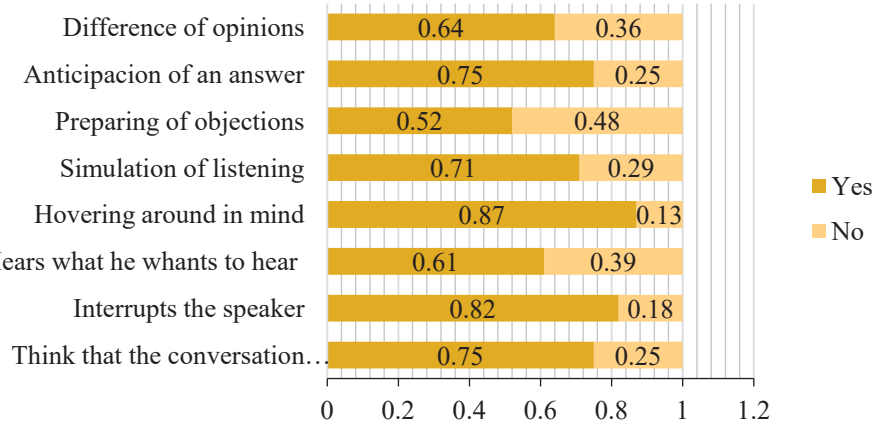

Figure 2. Listener's behaviour in different situations, %.

Table 2

Listen to the speaker even if it is not interesting

Perception	Frequency (n)	Percent (%)
Most of the time	19	21
Frequently	29	32
Occasionally	32	37
Almost never	9	10
Total	89	100

hover around in mind when someone is speaking to them (13%). Experience plays an important role in mutual communication, as the level of communication ability of various people is different. A situation arises where one of the conversation partners thinks that the other partner knows it (22% of respondents), but in reality it is not true. This creates confusion and misunderstanding during the conversation. Therefore, it is important to ask if you have understood the idea correctly (Figure 2).

Active listening occurs, when a person is focusing on what the speaker is saying even when it is not interesting (53% of respondents), but 47% of respondents need to learn doing it (Table 2).

In order to better hear and understand the speaker, it is important to repeat in your own words what you think the speaker feels (Figure 3) (35% of respondents reflect the partner's feelings, 65% of teachers do not). There are many details to follow in a conversation, that is why 56% of teachers capture the key ideas during the conversation. However, 44% of respondents do not consider it necessary. Teachers take into account who they are talking to (anxious, aggressive, disinterested, hurried, shy, stubborn, impatient person, etc.) – 95% of respondents. When speaking, respondents also think about how the partner will react to what they say (76%). Problems in communication are affected by word comprehension; consequently, it is necessary to ask the speaker, what a particular word means. Teachers – 56% of respondents – ask to repeat foreign words that they do not understand and to explain their meaning. Communication is productive when we listen to a different opinion of our partner (93% of respondents) and listen when it is not interesting for them (53% of teachers). Twenty seven percent of teachers use paraphrasing in communication. The most common listening errors are: a) deviation from the topic of conversation; b) focus only on the facts (research shows that a person can remember 5 facts); c) painful moments (certain words causing the listener's reaction) (Burley-Allen, 1995; Panfilova, 2006). Teachers believe that when communicating with others, they take something from each conversation partner, even though sometimes it can be something insignificant (67%). When listening, respondents perceive what is being said in general: verbally and non-verbally – 89% and understand that the same words mean different things to different people – 80%. Visual contact is important almost for all respondents, as 95% look at the speaker. Respondents focus more on what is said than on the appearance of the speaker – 83%. In the communication process, teachers understand which words or statements cause more emotional reaction of the communication partner – 77%. Respondents

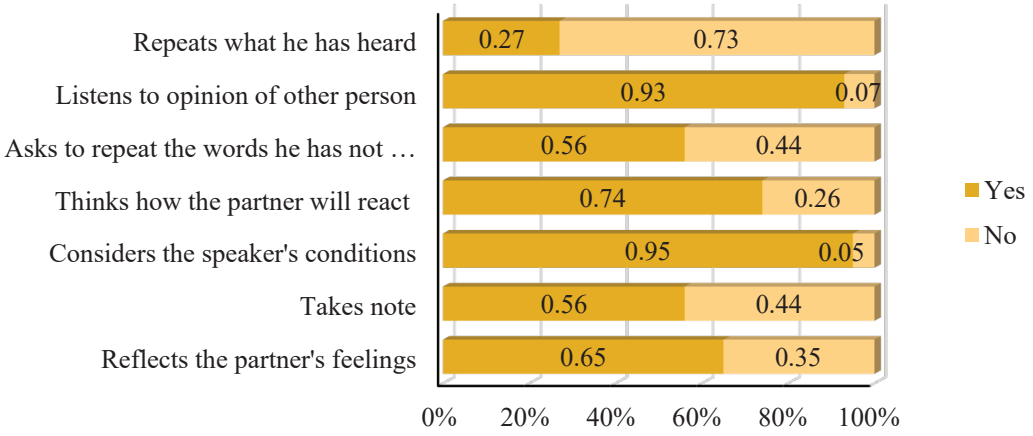

Figure 3. Listener's behaviour in communication for better understanding of a partner, %.

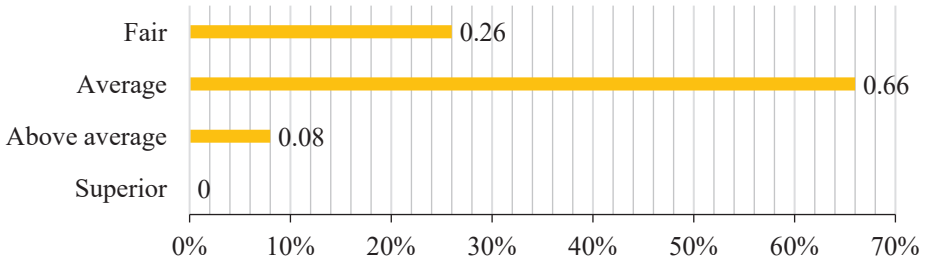

Figure 4. Teachers listening level, %.

thinking previously of the goal they desire to achieve in a particular communication – 78%. Respondents who plan at which moment it would be better to express their thoughts – 66%. Teachers also evaluate how to communicate better: in writing, verbally, by phone, on a notice-board, with a note – 81%.

Respondents allow the speaker to express their negative attitude without taking a position of defence – 25% and 62% of teachers listen to speakers without judging or criticizing them. Respondents are disturbed by ambient noise in communication – 40%. Therefore, the environment in which the conversation takes place must be considered. Respondents repeat the instructions received and statements made to make sure they understand them – 57%.

When evaluating the respondents' answers to the methodological statements, the levels of listening ability of teachers were determined (Figure 4). It should be noted that no respondents have a superior level. In turn, 8% of respondents have above average level, 66% of respondents have average level and 26% of teachers has fair level. This shows that all respondents still have something to strive for as a listener in order to fully participate in the mediation process, in which listening plays an important part. Of course, for teachers, the ability to listen is useful not only in mediation, but also in their everyday pedagogical activities.

Thus, the ability to listen plays an important role in the communicative competence of teachers in general and in the role of mediator in particular. Therefore, changes need to be made in the mediation study curriculum (program A – 36 hours) based on the findings of the study (overcoming selectivity of attention; how to focus on listening when it is not interesting; how to listen without judging the conversation partner and reflect the feelings).

Conclusions

1. Listening is an essential skill in the communication process, and it is a part of teachers' communicative competence. The ability to listen is used in mediation, which is a promoting, non-confrontational process of dispute resolution, which focuses directly on the priorities and needs of the parties of a dispute. To reach an agreement in the mediation process, the parties of a dispute must be able to listen to the parties involved in the dispute. Listening is affected by concentration, emotional culture of a person and by the motivation to listen in general.
2. In the process of communication, mutual beneficiation of partners takes place. This is the opinion of 67% of respondents. Respondents think that they can gain experience from each conversation partner to a greater or lesser extent.

3. The following strong points in the communication process (listening) can be underlined for teachers: creating visual contact (95%); continues to listen to the partner even if he thinks he knows what the partner will say (79%); focuses on what is said (83%); 77% of respondents are aware of their emotional reaction to certain words; in spite of different situations, 88% of teachers try to maintain their listening focus in communication.
4. It is necessary to improve the ability to listen in relation to the selectivity of information perception in cases of disagreement, to allow the speaker to complete his thoughts in any listening situation. Only 28% of respondents contribute their time to improving their listening ability. Consequently, the mediation program for teachers will include exercises and theory on these aspects of listening.

References

Abramenko, J.V., Dulina, N.V., Fedotova, L.A., & Jashchhenko, R.V. (2014). *Slushanije v mezhlichnostnom obshcheniji: metod. Ukazanija dla studentov bakalavriata (Listening in Interpersonal Communication: Guidelines for Undergraduate Students).* Volgograd: VolgGTU, 20 s. Retrieved January 5, 2022, from https://studopedia.ru/19_184722_vopros--slushanie-v-mezhlichnostnom-obshchenii.html. (in Russian).

Ater, S. (2020). *Five reasons why you must listen at mediation*. Retrieved January 5, 2022, from https://www.mediate.com/articles/ater-five-mediation.cfm.

Bakic-Tomic, L., Dvorski, J., & Kirinic, A. (2015). Elements of teacher communication competence: An examination of skills and knowledge to communicate. *International Journal of Research in Education and Science (IJRES),* 1(2), 157–166. DOI: 10.21890/ijres.54372.

Burley-Allen, M. (1995). *Listening the forgotten skill.* Second Edition. New York: John Wiley & Sons.

Cheliotes, L., & Reilly, M. (2010). *Coaching Conversations: Transforming Your School One Conversation at a Time.* California: Corwin.

Chupris, A.S. (2018). *Formirovanije gotovnosti к mediaciji bakalavrov gumanitarnih napravlenij podgotovki (Formation of readiness for mediation of bachelors of social sciences).* Dissertation in candidacy for a scientific degree. Kaliningrad: Kaliningrad University (in Russian).

Communicative competence defined. Dr.Lane's perspective (2020). Retrieved January 5, 2022, from http://www.uky.edu/~drlane/capstone/commcomp.htm.

Doran, C., & Winkeler, M. (2017). How to listen like a mediator. Retrieved January 13, 2022, from https://www.mwi.org/how-to-listen-like-a-mediator/.

Doyle, A. (2021). *Types of listening skills with examples*. Retrieved January 5, 2022, from https://www.thebalancecareers.com/types-of-listening-skills-with-examples-2063759.

Humphreys, B. (2019). *Effective listening skills*. Retrieved February 11, 2022, from https://careers-in-sport.co.uk/career-advice/developing-effective-listening-skills/.

Gulam, K. (2010). *Business Communication: Basic concepts and skills.* Retrieved January 8, 2022, from https://www.uj.edu.sa/Files/1001210/Subjects/Chapter%205%20Listening%20Skills%20%20.pdf.

Kiessling, C., & Fabry, G. (2021). What is communicative competence and how can it be acquired? *GMS Journal for medical education,* Volume 38(3): doc. 49. DOI: 10.3205/zma001445.

Leonov, N.I. (2019*). Konfliktologija: obshchaja i prikladnaja: uchebnik i praktikum dla bakalavriata, specialiteta I magistraturi (Conflictology: General and Applied: Textbook and Workshop for Bachelor's, Specialist's and Master's Degrees).* Moscow: Jurait, 395 s. (in Russian).

Ljutova-Roberts, J.K. (2007). *Trening nachinajushchego konsultanta: vedenije doveritelnoj besedi (Training for young consultants: holding a confident conversation*. SPb.: Rech, 307 s. (in Russian).

McCorkle, S., & Reese, M.J. (2019). *Mediation theory and practice.* Thousand Oaks, CA: SAGE Publications.

Panfilova, A.P. (2006). *Trening pedagogicheskogo obshchhenija (Training for pedagogical communication).* Retrieved January 5, 2022, from https://obuchalka.org/2016110991708/trening-pedagogicheskogo-obscheniya-panfilova-a-p-2006.html. (in Russian).

Salem, R. (2003). *Empathic Listening*. Beyond Intractability. Eds. Guy Burgess and Heidi Burgess. Conflict Information Consortium, University of Colorado, Boulder. Retrieved January 5, 2022, from http://www.beyondintractability.org/essay/empathic-listening.

Vikulina, O.V. (2014). *Teorija i praktika psihologiji upravlenija. Naviki aktivnogo slushanija (Theory and Practice of the Management Psychology. Active Listening Skills).* Retrieved January 5, 2022, from https://psyera.ru/6504/navyki-aktivnogo-slushaniya. (in Russian).

 DOI: 10.22616/rrd.28.2022.047

ROLE OF EDUCATION IN REDUCTION OF INCOME INEQUALITIES IN LATVIA

***Biruta Sloka**, **Ginta Tora**, **Ilze Buligina**, **Juris Dzelme**
University of Latvia, Latvia
*Corresponding author's email: Biruta.Sloka@lu.lv

Abstract
Recent years have been challenging in finding solutions to address inequalities, especially in relation to certain branches of national economy. The purpose of the study: suggest a range of educational activities in lifelong learning to increase the employability for certain groups at risk – young people, people before retirement age and in retirement age. The analysis is based on data of the Labour Force Survey, databases of Official Statistics Portal. Methods used – statistical data analysis using time series analysis. The results indicate that lifelong participation has been gaining force in recent years, and a higher share of the population is improving their digital skills. Still, there is a significant part of inhabitants who are excluded from significant mainstream processes, and this tends to prevent them from having appropriate standard of living. This part of the population is typically characterized by low income, low level of information on possible participation in life-long learning activities, lack of access to information technologies (IT) tools and the internet, low level of digital literacy. Innovative solutions of social marketing and the application of positive cases publications are important tools for increasing social inclusion. Virtual contacts and social networking could be added to cultural and business activities. Life-long learning could be more initiated by municipalities and non-governmental organisations in Latvia as other countries have shown wonderful results. Combining complementary digital tools and platforms for the virtual interaction and networking of people from different age groups needs to be used alongside with an appropriate combination of face-to-face contacts.
Key words: social inclusion, digital skills, adult education, life-long learning, region.

Introduction

Implementation of life-long education is considered as one of the most effective tools for social inclusion and active involvement in employment, for communication with other members of the society and the authorities where it is important to have certain skills as well as access to the internet. In scientific publications, these important aspects are discussed as there are several ways to motivate persons for life-long education/learning as better educated people could be better employed and could be more socially active. International organisations have indicated that Latvia has to do a lot more to involve different parts of society in life-long learning as well as Latvia was criticized on low level of internet access in households. For this reason, also academic researchers pay considerable attention to different aspects related to life-long learning which is an important tool for increase of person's competitiveness and self-confidence and well-being. The current research paper is devoted to evaluation of various developments that foster the involvement of the population of Latvia in life-long education – by gender, by age group, by education level. The aim of the paper: to suggest several educational activities in lifelong learning to increase employability for several groups: at risk- young people, people before retirement age and in retirement age based on situation analysis and development in Latvia including access to internet as the internet is becoming one of very important tools in realization of life-long education. The tasks: 1) to analyse previously conducted scientific research results; 2) investigate participation and tendencies of participation in life-long education programs different population groups in Latvia, 3) analyse trends in relation to access to the internet.

Materials and Methods

Academic researchers have investigated in detail various relevant aspects of the role of life-long education with regards to strengthening social inclusion in multicultural societies through information literacy (Oğuz & Kurbanoğlu, 2013). Researchers have analysed various assumptions regarding the life-long learning opportunities of older people using social care services (Hafford-Letchfield, 2010) with practical suggestions for improved social inclusion. Various aspects for the future of the workforce in the context of labour market in Italy and learning outddors by creating global competitive economies with innovative approach have been discovered by researchers (Barbabella *et al*., 2022; Aylward & Mitten, 2022) with developed practical recommendations for innovative applications. In recent years the internet and digital skills are becoming increasingly important using also online e-learning to address cognitive disabilities (Cinquin, Guitton, & Sauzéon, 2019) where researchers have developed a systematic review. Different innovative projects are developed for social inclusion, like Emilia project for accessing lifelong learning and reducing the social exclusion (Greacen & Jouet, 2008). Other aspects of innovative approaches in Grundtvig project partnership case study 2009-2011 on life-long learning application for active citizenship and capacity building in the realised education project 'Lifelong Learning for

Active Citizenship and Capacity Building' (LLLab) which was created to make the knowledge triangle (education, research and innovation) accessible to employed people – to promote the concept for wider audiences. This project was created to build capacity of the employed persons in order for those employed persons better respond to the new challenges of the EU standards in a developing intercultural knowledge-based society (Grabowska, 2010). Approaches in 'nothing to lose and everything to gain' as a moto for neighbourhood houses and later life learners (Ollis *et al*., 2018) could be applied also in other countries. Student living labs as innovation arenas for sustainable tourism (Jernsand, 2019; Sergejeva & Aboltins, 2020; Sergejeva, Aboltins, & Atslega, 2021) are suggested for application for life-long learning. Income and quality of life influence on citizens' participations in activities of local governments in Latvia (Savrina & Seimuskane, 2018; Seimuskane, Vilka, & Brekis, 2017), importance of financial aspects (Romanova *et al*., 2018) as well as ergonomic aspects (Kalkis, Andza, & Roja, 2020; Kalkis, Graveris, & Roja, 2021) and effective marketing (Batraga *et al*., 2018) are also prominent trends. Digitalization in the Baltic States (B. Rivza & P. Rivza, 2020) is a meaningful aspect for social inclusion. Life-long learning activities for social inclusion is supported in several policy recommendations by several international organisations and especially by OECD (OECD, 2022; 2016; OECD/EU, 2016). Researchers have stressed the role of arts in life-long learning and social inclusion as well (Reiss & Pringle, 2003), also stressing the special role and influence of arts.

The methods used – statistical data analysis using time series analysis. The analysis is based on the data of Labour Force Survey, databases of Official Statistics Portal of the Republic of Latvia reflecting also Census 2021 data. For empirical research, the methods applied in this paper consist of the analysis on Labour Force Survey Population data aged 25-64 in education or training (number of hours spent on all taught learning activities within the last four weeks – COURLEN) as a share of the total population of the same age group (European Commission, Eurostat, 2022). Starting from 2016 *Eurostat* has changed calculation methodology of this indicator. It includes also persons who were on holidays during the last 4 weeks (Official Statistics portal, 2022; European Commission, Eurostat, 2022). Data collection methods used in the Labour Force Survey: 1995-2005 – face-to-face interviews using paper questionnaires (Paper-and-Pencil Interviewing – PAPI); starting from 2006 – face-to-face interviews using portable computers (computer-assisted personal interviewing – CAPI); starting from 2007 – CAPI and telephone interviews (computer-assisted telephone interviewing – CATI); starting from 2018 – CAPI, CATI and online surveys (computer-assisted web interviewing – CAWI); as of 13 March 2020, with the aim to limit spread of Covid-19 – CATI interviews and online surveys (CAWI). The survey covers all persons living in the surveyed household, and questions on activity status asked to persons aged 15-89 (prior to 2001, to persons aged 15 and over, but from 2002 until 2020 (including) – persons aged 15-74). The questionnaires contain relevant questions characterising the activity of the population; these questionnaires were prepared in accordance with the internationally approved methodology of the International Labour Organisation (ILO) specifically in the area of labour force surveys that ensures comparability of information with other countries. The LFS provides information on the number of population including the active population (employed and unemployed) broken down by various characteristics (sex, age, education qualification, place of residence, employment status, etc.) (Official Statistics portal, 2022; European Commission, Eurostat, 2022). That creates confidence that data are representative and could be used for research. Data obtained are analysed with trend analysis to determine developments regarding the share of population involved in additional education.

Data on access to internet in households was based obtained material from conducted survey on the use of information and communication technologies (ICT) in households and by individuals. The source of the data is the questionnaire No. ICT-persons 'Use of computers and the internet in households'. The sample of the survey is of a mixed design: 1) The CAPI (face-to-face interviews) part of the sample consists of two stages, with counting areas being selected in the first stage by using the principles of stratified systemic sample creation. The counting areas are divided into 16 strata, which have been formed by combining groups of territorial divisions; In turn, the second stage of the sample selects respondents according to the simple random sampling method. 2) The CATI (telephone interviews) part of the sample applies the stratified simple random sample for selecting respondents. Respondents are divided into 36 strata, which are formed as a combination of age groups (16-24, 25-34, 35-44, 45-54, 55-64, 65-74) and statistical regions (Riga, Pierīga, Vidzeme, Latgale, Kurzeme and Zemgale), in 2019 8500 households/persons were included in the sample, response was 5219 persons (Official Statistics portal, 2022).

Results and Discussion

As indicated by scientific publications and research results as well as policy document studies – life-long learning is relevant for social inclusion,

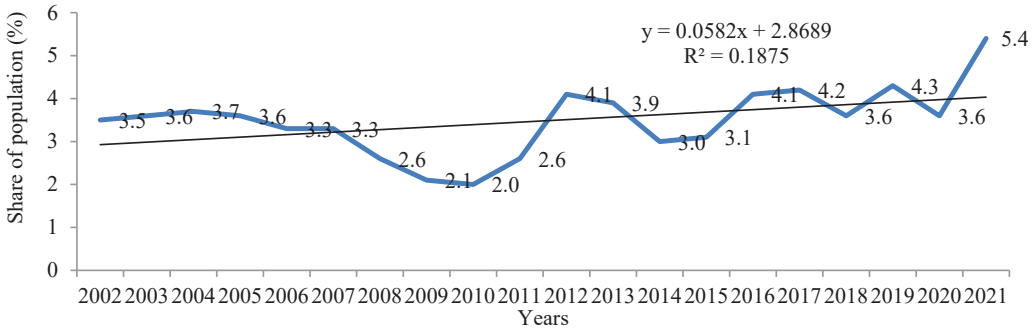

Figure 1. Share of population (in percent) aged 15-74 years by additional education in Latvia in 2002-2021.
Source: Author's construction and calculations based on Official Statistics database IZ1030.

Table 1

Share of adult learning participants by age group and sex in Latvia in 2012-2021 (in percent)

Gender	Age groups	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	25–64	7.2	6.8	5.7	5.7	7.3	7.5	6.7	7.4	6.6	8.6
	25–34	12.8	12.3	10.4	9.9	12.6	11.8	11.8	13.0	11.8	13.4
	35–54	5.9	5.5	4.9	5.1	6.2	7.3	6.0	6.7	6.1	8.5
	55–64	4.2	3.4	2.2	2.6	4.0	3.5	3.0	34	2.7	4.5
Males	25–64	6.2	5.1	4.9	4.1	6.1	6.0	4.8	5.4	4.6	5.5
	25–34	12.5	9.7	8.7	7.7	11.3	10.5	9.3	10.9	9.4	9.7
	35–54	4.5	3.8	4.1	3.3	4.6	5.0	3.8	4.2	3.9	5.2
	55–64	2.7	2.7	2.1	1.4	3.1	2.8	1.8	2.0	…	2.0
Females	25–64	8.1	8.2	6.3	7.2	8.5	8.8	8.4	9.3	8.4	11.5
	25–34	13.2	15.1	12.1	12.1	14.0	13.2	14.3	15.2	14.4	17.4
	35–54	7.2	7.2	5.6	6.7	7.8	9.4	8.0	9.1	8.2	11.7
	55–64	5.3	3.9	2.4	3.6	4.7	4.0	4.0	4.6	…	6.5

Source: Author's construction based on Official Statistics database IZ1030.

for increase of self-confidence of people. Life-long learning is becoming more and more important and therefore a lot of attention paid by different stakeholders – policy makers, non-government organisations as well as by academic researchers to investigate best possible solutions in practical application of life-long learning. In recent years, data on share of population involved in additional education in 2002-2021 in the Republic of Latvia are included in Figure 1.

Data indicate that the share of population involved in life-long education is increasing but still has a high degree of fluctuations in different years; also, there is a different situation by age groups and gender, see Table 1.

Data indicate that females are involved in life-long learning more than males; more active participants in life-long learning are persons in the age group 25-34 years old. Tendencies of developments for inhabitants in Latvia regarding involvement in life-long learning are reflected in Figure 2.

Involvement of people in life-long learning by education level is different, but the share is increasing for the last year for all types of groups in relation to previously acquired education levels, as it is reflected in Figures 2–6.

Data in Figure 3 indicate that share of population aged 25-64 years (%) by additional education in Latvia with higher education by gender in analysed years remains approximately the same for the whole population and males are involved in additional education traditionally less than females.

It is worth noting that there are increasing numbers of people in Latvia involved in life-long education, also for people with no formal education, as it is reflected in Figure 6.

Data included in Figure 6 and tendency analysis indicate that the share of population by additional

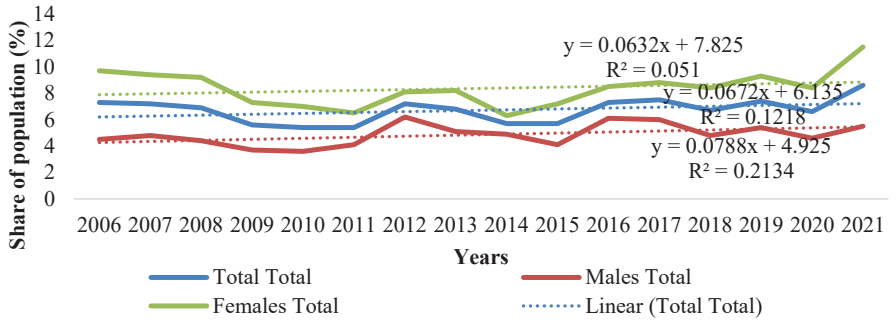

Figure 2. Share of population aged 25-64 years (%) by additional education in Latvia by gender in 2006-2021.

Source: Author's construction and calculations based on Official Statistics database IZ1030.

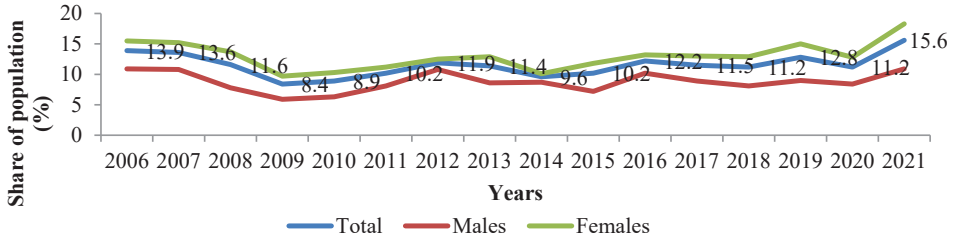

Figure 3. Share of population aged 25-64 years (%) by additional education in Latvia with higher education (ISCED levels 5 to 8) by gender in 2006-2021.

Source: Author's construction and calculations based on Official Statistics database IZ1030.

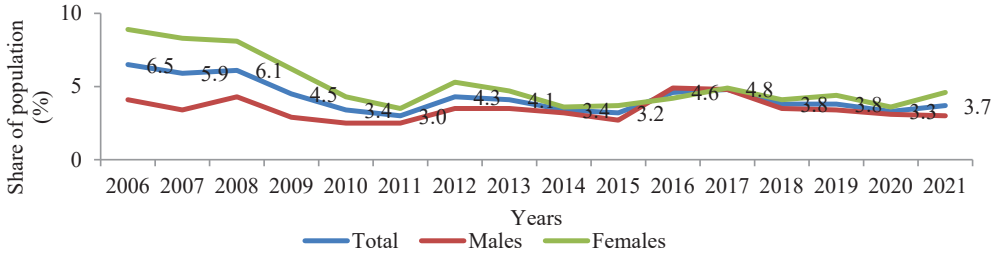

Figure 4. Share of population aged 25-64 years by additional education in Latvia with vocational education or professional secondary education (ISCED levels 3 and 4) by gender in 2006-2021.

Source: Author's construction and calculations based on Official Statistics database IZ1030.

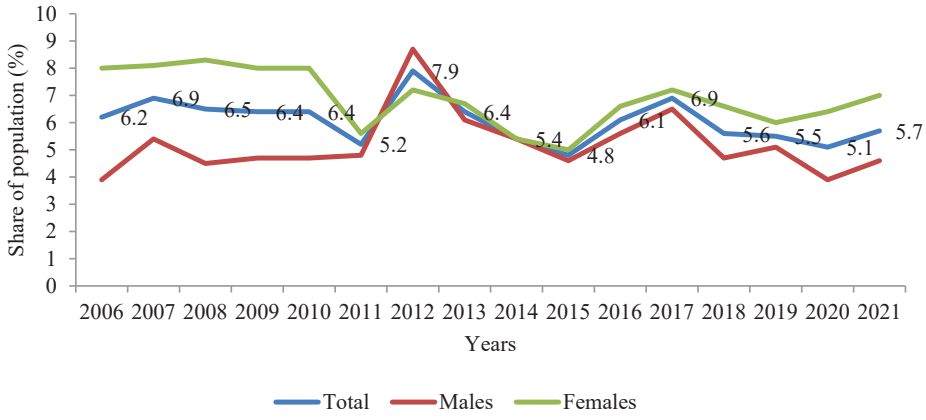

Figure 5. Share of population aged 25-64 years by additional education in Latvia with general secondary education (ISCED level 3) by gender in 2006-2021.

Source: Author's construction and calculations based on Official Statistics database IZ1030.

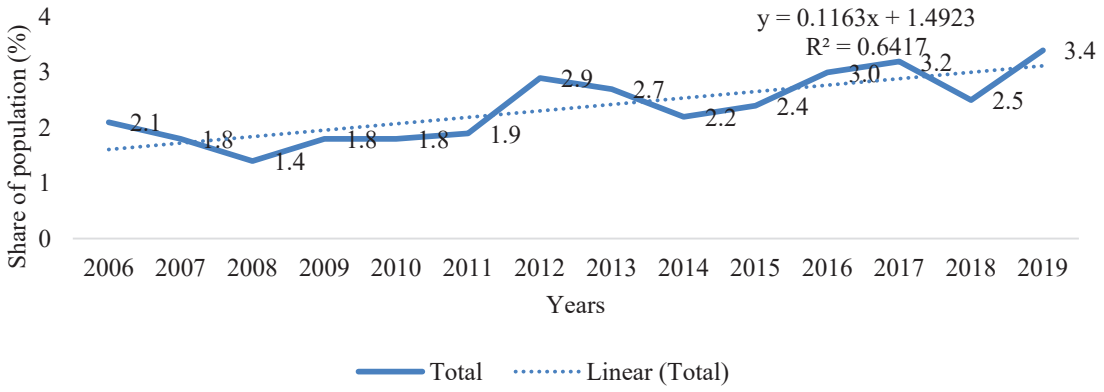

Figure 6. Share of population aged 25-64 years by additional education in Latvia with no formal education, less than primary education, basic or primary education (ISCED levels 0 to 2) in 2006-2019.

Source: Author's construction and calculations based on Official Statistics database IZ1030.

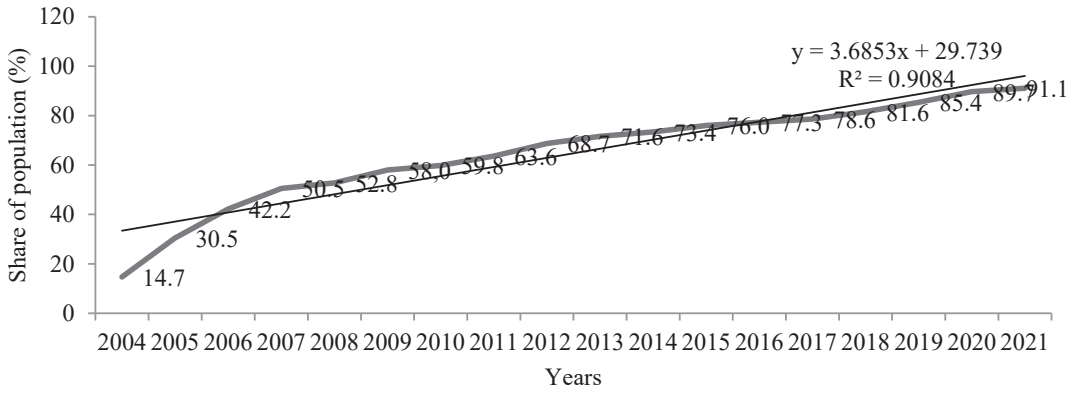

Figure 7. Share of households (%) by access to internet in Latvia in 2004-2021.

Source: Author's construction and calculations based on Official Statistics database DLM060.

education in Latvia with no formal education increases annually on average by 0.12% points and coefficient of determination 0.6417 indicating that this tendency is significant. In recent years, the role of access to the internet is increasing as the internet is becoming a substantial requirement for life-long learning, for being socially active also during unusual conditions with restricted face-to-face contacts. Data on tendency of share of households in Latvia with access to the internet are included in Figure 7. Tendency indicates that access to the internet in Latvia is increasing annually on average by 3.7% points, the tendency is statistically significant as the coefficient of determination is very high (0.9084).

Results of analysis indicate that share of households by access to the internet in Latvia in 2004-2021 is increasing on average by 3.7 percent points with every year. This is important aspect for involvement of different age inhabitants in Latvia in life-long learning. The average increase of the participation in life-long learning is less than an increase of the access to the internet. The information technologies and access to the internet itself is not enough. More social and informational efforts are necessary to help people and motivate them to join the life-long learning. The results indicate that participation in lifelong learning is gaining force in recent years and a higher share of the population is improving their digital skills, too. Still, there is a significant part of inhabitants who are excluded from significant processes allowing for more appropriate standard of living. These target groups tend to have low income, low level of information on possible participation in life-long learning activities, limited availability of information technology tools and internet access, as well as a low level of digital literacy.

Conclusions

Life-long learning is key for social inclusion, for increase of self-confidence.

The share of population involved in life-long education is increasing but has a high degree of fluctuations in different years; also, there are different situations in different age groups and gender.

Involvement of people in life-long learning regarding education level is different, but the share for the last year is increasing for representatives of all previously acquired education levels.

It is being observed that there are increasing numbers of people in Latvia involved in life-long education without prior formal education.

In recent years, the role of access to the internet is increasing, as the internet is becoming a substantial requirement for life-long learning.

Innovative solutions of social marketing and application of positive cases publications (promotion) are important tools to increase social inclusion. Virtual contacts and social networking could be added to cultural and business activities, and life-long learning initiated by local governments and non-governmental organisations could be increased, both using face-to face and virtual forms of communication and interaction. Complementary tools for the interaction and networking of people from different age groups are relevant, as these tend to be mutually enriching.

Acknowledgement

This research is supported by National Research Programme proj. INTERFRAME-LV, No. VPP-IZM-2018/1-0005.

References

Aylward, T., & Mitten, D. (2022). Celebrating Diversity and Inclusion in the Outdoors. *Journal of Outdoor and Environmental Education,* 25(1), 1–10. DOI: 10.1007/s42322-022-00104-2.

Barbabella, F., Cela, E., Socci, M., Lucantoni, D., Zannella, M., & Principi, A. (2022). Active Ageing in Italy: A Systematic Review of National and Regional Policies. *International Journal of Environmental Research and Public Health*, 19(1), 600. DOI: 10.3390/ijerph19010600.

Batraga, A., Salkovska, J., Braslina, L., Legzdina, A., & Kalkis, H. (2019). New innovation identification approach development matrix**.** *Advances in Intelligent Systems and Computing*, 783, 261–273. DOI: 10.1007/978-3-319-94709-9_26.

Cinquin, P.-A., Guitton, P., & Sauzéon, H. (2019). Online e-learning and cognitive disabilities: A systematic review. *Computers and Education*, 130, 152–167. DOI: 10.1016/j.compedu.2018.12.004.

European Commission, Eurostat. (2022). *Quality report of the European Union Labour Force Survey 2020, 2022 edition*. Luxembourg: Publications Office of the European Union. DOI: 10.2785/88166.

Grabowska, A. (2010). Grundtvig partnership case study 2009-2011 Lifelong Learning for active citizenship and capacity building LLLab. *IFIP Advances in Information and Communication Technology,* 324, 136–143. DOI: 10.1007/978-3-642-15378-5_13.

Greacen, T., & Jouet, E. (2008). Emilia project: Accessing lifelong learning and reducing the social exclusion. *Information Psychiatrique*, 84(10), 923–929. DOI: https://doi.org/10.1684/ipe.2008.0412.

Hafford-Letchfield, T. (2010). The age of opportunity? revisiting assumptions about the life-long learning opportunities of older people using social care services. *British Journal of Social Work*, 10(2), 496–512. DOI: 10.1093/bjsw/bcp004.

Jernsand, E.M. (2019). Student living labs as innovation arenas for sustainable tourism. *Tourism Recreation Research,* 44(3), 337–347. DOI: 10.1080/02508281.2019.1613299.

Kalkis, H., Andza, K., & Roja, Z. (2020). Physical Load and Preventive Measures in Metal Manufacturing Industry. *Advances in Intelligent Systems and Computing*, 1215, 48–55. DOI: 10.1007/978-3-030-51549-2_7.

Kalkis, H., Graveris, I., & Roja, Z. (2021). Ergonomic Indicators and Physical Workload Risks in Food Production and Possibilities for Risk Prevention. *Lecture Notes in Networks and Systems*, 273, 47–53. DOI: 10.1007/978-3-030-80713-9_7.

OECD. (2022). *Future-Proofing Adult Learning in Berlin, Germany, OECD Reviews on Local Job Creation.* Paris: OECD Publishing. DOI: 10.1787/fdf38f60-en.

OECD/EU. (2016). *Inclusive Business Creation: Good Practice Compendium.* Paris: OECD Publishing. DOI: 10.1787/9789264251496-en.

OECD. (2016). *Weaving Together Policies for Social Inclusion in Ireland.* Paris: OECD Publishing. DOI: 10.1787/9789264252677-en.

Official Statistics database of Republic of Latvia. (2022). Retrieved March 2, 2022, from https://stat.gov.lv/en/metadata/4285-employment-and-unemployment.

Ollis, T., Ryan, C., Starr, K., & Harrison, U. (2018). 'Nothing to lose and everything to gain': Neighbourhood Houses and later life learners. *Studies in the Education of Adults*. 50(1), 19–38. DOI: 10.1080/02660830.2018.1520539.

Oğuz, E.S., & Kurbanoğlu, S. (2013). Strengthening social inclusion in multicultural societies through information literacy. *Bilgi Dunyasi*, 14(2), 270–290.

Reiss, V., & Pringle, E. (2003). The role of artists in sites for learning. *International Journal of Art and Design Education*, 22(2), 215–221. DOI: 10.1111/1468-5949.00356.

Rivza, B., & Rivza, P. (2020). Digitalization in the Baltic States. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2020, 2020-August (2.1), pp. 135–144. DOI: 10.5593/sgem2020/2.1/s07.018.

Romanova, I., Grima, S., Spiteri, J., & Kudinska, M. (2018). The payment services Directive II and competitiveness: The perspective of European fintech companies. *European Research Studies Journal*, 21(2), 3–22. DOI: 10.35808/ersj/981.

Savrina, B., & Seimuskane, L. (2018). Income and Quality of Life Influence on Citizens' Participations in Activities of Local Governments in Latvia. CBU International Conference Proceedings 2018: Innovations in Science and Education, 6, 424–432. DOI: 10.12955/cbup.v6.1193.

Seimuskane, L., Vilka, I., & Brekis, E. (2017). Assessment of Socio-Economic Status Relevance for Latvian Electoral Participation, Local Government and Urban Governance in Europe, 209–232. DOI: 10.1007/978-3-319-43979-2_11.

Sergejeva, N., & Aboltins, A. (2020). Knowledge of mathematics and physics as basis for studies in engineering sciences. *Engineering for Rural Development*, 19, 1302–1307. DOI: 10.22616/ERDev.2020.19.TF325.

Sergejeva, N., Aboltins, A., & Atslega, S. (2021). Problems and solutions of acquiring mathematical knowledge at university during COVID-19 crisis. *Engineering for Rural Development*, 20, 1266–1271. DOI: 10.22616/ERDev.2021.20.TF276.

 DOI: 10.22616/rrd.28.2022.048

ECOLOGICAL APPROACH AS A BASIS FOR A HIGHER EDUCATION ENVIRONMENT

***Marina Troshkova**, **Irena Katane**
Latvia University of Life Sciences and Technologies, Latvia
*Corresponding author's email: marina.troshkova@gmail.com

Abstract
Continuous interaction between the student and the higher education environment is becoming increasingly important today. It is now important to use the ecological (environment) approach in education to create learning environment that is inclusive and friendly to students, identifying environment's multiple and diverse dimensions/contexts. The purpose of this study is to offer a theoretical basis for the university environment, given various education trends and dimensions of that environment, based on the ecological approach to education ecology. The following research methods were used: study, analysis and evaluation of scientific literature. The theoretical research highlighted one of the manifestations of the ecological approach: the multidimensional/ multicontextual approach, discussed an appropriate learning environment as a key component to encourage students' professional growth and readiness for professional activities and emphasised continuous interaction between the student and the higher education environment.
Key words: ecological approach to education, higher education environment, multidimensional environment, student-centred approach in universities, sustainability.

Introduction

The pandemic highlighted the problem of providing learning environment (including that of higher education) that supports and encourages students to independently learn and re-train, direct them towards the job market and lifelong education, and help them achieve success in life. Such learning environment integrates learning and work, is fair and inclusive, and focuses on the student's individual learning and competences. It also includes the latest technologies used to improve effectiveness and access (OECD, 2019).

In the context of the spread of the pandemic and the relevance of the problems it caused in education and the economy, the public now expects universities to provide professional training to students with a view to the future, ensuring long-term success and ability to live and work in an ever-changing job market. Higher education has undergone changes because of this, meaning that education becomes certain, accredited and supportive. The main attention is focused on uniting and integrating the job market and universities, making sure that the students can apply what they learn academically in actual professional environment. A few universities have updated their strategies to improve access for working students and underrepresented social groups, at the same time ensuring that all students can be successful. New accreditation forms have sprouted up, including short-term, competence-based and stackable (Klein-Collins & Travers, 2020). A critical role is assigned to creating, maintaining and developing the university environment that promotes self-managed learning by students. This is why the ecological approach to education is currently relevant.

The ecological approach has been present in social sciences, including education sciences, since the 20th century, and is one of the critical components of creating and developing the education environment (Briede & Pēks, 2011; Bronfenbrenner, 1979; Katane & Pēks; 2006; Katane, 2007; Manuĭlov, 1997; Novikova, 2003; Panov, 2004; Peckover, 2012; Popa *et al*., 2020; Yang & Sanborn, 2021).

The ecological approach is relevant at all levels of education, including higher education (Baltušīte, 2012; Īriste, 2018; Katane, 2007; Ruiz-Mallén & Heras, 2020). In higher education, the ecological approach helps enable the student's general and professional development (Baltušite, 2012). Students interact with a diverse study environment that is friendly to them which results in a positive study and professional experience that promotes the development of competitiveness in the students (Īriste, 2018).

The aim of this study is to offer a theoretical basis for the university environment, given various education trends and dimensions of that environment, based on the ecological approach to education ecology.

Materials and Methods

The relevance of the ecological approach was pointed out by the 21st century's main trend in education: providing education for sustainable development which is based on the diversity of education including higher education. The diversity of universities is important not only for ensuring the sustainability of higher education, but also in achieving excellence in studies and research (Briede & Pēks, 2011).

The ecological approach to education helps predict changes in environmental context, promoting ecological thinking in individuals and society as a whole, fostering environmentally friendly attitudes and actions, preventing the consequences of reckless actions committed by people, and creating friendly environment, focusing on the development of personalities. In achieving sustainability in

education, it is important to ensure that it is open and accessible, and respects special features of the cultural environment (Katane, 2007).

According to the ecological approach, a critical objective of education is to create a balance between sustainability and continuously rising contradictory and competitive differences, and the flow of information, which often results in imbalance, conflict and stress (Īriste & Katane, 2021).

Green thinking and making the environment green is the predominant global context for sustainability, linking people, the planet and profits. Two additional contexts are minor and regional: 'resilience' and 'alternative'. All of this encourages changes in the organisational culture of higher education, adding sustainability values in strategic planning, and in academic and management activities. A profound and critical representation of the world's views, contradictions and tensions on a global and regional scale is necessary to find common paths towards sustainability (Ruiz-Mallén & Heras, 2020).

The ecological approach to education studies what happens in education using the dimensions of time and space; the development of individuals, society, and education/environment systems interacting with a changing and heterogeneous environment (Yasvin, 2020).

In understanding the ecological approach to higher education, one must start with the definition of environment. The environment of an individual is defined by the interaction of natural and artificial circumstances in which the individual achieves personal development as a natural and social being. These parts are mutually related. A shared space that is directly or indirectly accessible by the individual is a component of the natural environment. The context of the social environment is created by society and social relations that enable the individual to achieve personal fulfilment as a social being (Markovich, 1991).

The theoretical investigation highlighted the multidimensional/multicontextual approach as a basis for the educational environment and research which is one of the manifestations of the ecological approach. Every researcher offers their own vision of the dimension/context of the environment as a basis of diversity (Īriste, 2018; Kalniņa, 2010; Katane, 2005).

The research methods of the current study are as follows: reviewing, analysing and evaluating scientific literature.

Results and Discussion

The theoretical research carried out revealed different views pertaining to the dimensions/contexts of the environment. Researchers often propose their own classifications of the dimensions, contexts or components of the learning environment, associated with the topics of their research and the specific features of the problem they researched. Furthermore, there is no uniformity in the use of terminology: in explaining the ecological approach, the terms 'dimension, context, component, element of the environment' are used as synonyms. This indicates a lack of a generally accepted definition of a higher education environment, and classification of the dimensions/contexts of that environment.

For example, Yasvin (Yasvin, 2020) believes that the structure of the environment consists of a physical, a psychological, and a sociocultural component which describes the conditions and resources for the development of a personality. The structural information model includes the living environment of the individual, consisting of the way the physical and home environment are organised, and relationships among the people with whom the individual grows up and develops physically and mentally. The supportive environment (peers, cultural, ethnic, ideological, information, geographic, economic environments) is analysed. The development environment of an individual includes their psychoemotional, sociocultural, hygienic technical, socioeconomic and demographic environments. A review of family and school environment is carried out. Space is viewed as a physical environment. The personal development environment is based on a tendency to comply with the effective organisation of a specific environment and social components. The social component includes mutual understanding and client relations, dominating positive mood, authority of managers, involvement in the management of the education process, cohesion and awareness, and collaboration in achieving productivity as part of the education process. The component of a specific environment includes the complexity and heterogeneity of the environment, the junctures between the functional zones of the environment, the flexibility and manageability of the environment, the provision of opportunities, and the customisation and the authenticity of the environment. A quality environment that develops personality has high values in the following quantitative system parameters: space, intensity, awareness, generalisation, emotionality, dominant focus, interaction, social activities, structure, mobility, safety and stability.

Other researchers (Artyuhina, 2007; Entwistle, 1991; Īriste & Katane, 2021) emphasise the idea of the higher education environment including professional development of students, as well as their socialisation as future specialists, because the university environment has multiple dimensions/contexts-social environment, cultural environment, ICT environment, professional environment, etc.-interactions with which result in the creation and development of various competences, accumulation of new experience which has an effect

on life and professional situations and becomes the basis of the new thinking, professional activities and general career success of the future specialist. Studies of trends in the development of universities show that the ecological approach is a priority in the activities of universities, as it activates the creative potential, competence and competitiveness of students.

R. Hiemstra (Hiemstra, 1991) defines the university study environment as an environment that consists of physical surroundings, psychological and emotional circumstances, and social and cultural factors, all of which affect the development of an adult. Other researchers (Closs, Mahat, & Imms, 2021) define it slightly differently, believing that it consists of social, physical, psychosocial and teaching components. The study environment is where learning takes place; it affects the attitude and achievements of the students and makes it possible to organically feel the learning experience for students in higher education.

Meanwhile, Australian researchers (Radcliffe, 2008) highlight the physical, teaching and technological components that constantly interact with each other. In the context of the physical component, they mention the spaces that promote collaboration in teaching and learning processes (Collaborative Teaching and Learning Spaces) which include both internal and external features using videoconferencing and accessing network spaces. The design of such spaces is considered to be such that provides the opportunities for teaching and learning not provided by traditional learning spaces and classrooms. The advanced concept teaching space represents the state-of-the-art in which the teaching and learning space, the use of information technologies and the design of the study environment play the central role in teaching. Providing informal study spaces in a university has a positive effect on the student learning process because these spaces enable students to learn independently or in groups, to take breaks or simply spend their time at university with their peers or communicate with their instructors. Fourth-generation libraries also play an important role in creating the university environment, because they currently provide various kinds of services, from printed and digital sources of information to study spaces for individuals and groups.

In terms of the physical environment (Acton, 2018), four design principles are highlighted: student focus, compatibility, flexibility and accessibility.

Generation Z prefers open spaces that promote active learning, as these spaces open up room for students and staff members to move about, creating a shared social space and uniting them.

The teaching environment component includes the activities, tools, resources, methods, strategies and structures that facilitate the teaching of students. The psychological and social components are closely associated with each other, characterised by personalisation, inclusion, student cohesion, satisfaction, task orientation, innovation, individualisation, investigation, cooperation, student capital and support by instructors (Dorman, 2014).

The learning environment and the individual learning process cannot be separated, as they continuously interact, complementing each other. Between the teaching and learning, there is the student's perception of the teaching and assessment processes (Shum *et al.*, 2021; Vermetten, Vermunt, & Lodewijks, 2002). The perception of the learning environment affects the learning performance of the student.

Universities face various challenges, which highlights the need for improving the study environment (Valtonen *et al.*, 2021). Some of the challenges have to do with the use of a new teaching model, transitioning from the instruction paradigm to the learning paradigm, with the rapid development of education technologies, with the diversity of non-traditional groups of students that need flexible courses, and with rising hopes associated with the skills necessary in current and future professional life. New hopes associated with learning goals arise as well. In addition to the traditional content of education, students are expected to learn twenty-first-century skills or skills for their current or future professional environment. Twenty-first-century skills include creative and critical thinking, cooperation and communication skills, social and/or cultural competences, problem-solving skills, and skills using information and communication technologies (ICT). In order to integrate the learning of these skills into curricula, one must create an environment, in which the students actively learn using ICT, and learn as experts.

Another significant change in higher education involves the use of ICT, which is the core element of twenty-first-century skills, and the main means for supporting modern learning and teaching practice. ICT plays an important role, including such elements as blended learning, massive open online courses, and flipped classroom strategies with online video materials which make higher education more flexible and broadly accessible (Valtonen *et al.*, 2021). This is why it is important to single out the ICT environment dimension/context as part of the higher education environment.

According to the 'Universities Without Walls Vision for 2030' report (European University Association, 2021), future universities will be hybrid in nature and structure. Universities will accommodate equally important physical and virtual environments at the same time. In the future, the physical and digital

learning environment and research environment will be united in a holistic way, to meet diverse social needs and to enable the development of flexible and mixed approaches. The physical environment will continue to have a decisive role in social interaction and dialogue: a place for holding meetings that challenges and at the same time inspires, but also offers quiet spaces for focused learning and research. The virtual environment will make universities omnipresent. It will be created to improve every person's access to research and learning, to improve cooperation, to research new, innovative methods, and to pursue the missions of universities.

This makes it possible to define the university study environment as a multicontextual environment, in which a special role is played by its ICT component.

In order to promote the professional growth of the student and their preparedness for professional activities, the student must have an appropriate study environment (Baltušīte, 2012). The study environment of a university consists of two key components: 1) the environment of the university; 2) the places where its students complete their internships, i.e., professional environments, which when put together constitute the dual nature of the study environment. The dual study environment of a university includes an interdisciplinary cooperation system (between the university and the company providing the internship) and an interpersonal cooperation system (on a level between individuals) (Īriste, 2018).

The value of the study environment of universities, in what pertains to personal growth, is created whenever there is a connection established with the student's personal experience and life (Artyuhina, 2007). A.I. Artjuhina emphasises the influence of a diverse environment on the development of personality and personal growth, the necessity to integrate environmental factors, the diversity of the environment that enables the personal and professional development of the individual, as something that must be taken into account in planning a university study environment geared towards the professional and personal growth of the students. It is important for different types of components of the environment to mutually interact, so that a uniform internal organisation is created that is harmonised, enabling the joining of the educational and professional environments.

Another proposed university environment model for modern conditions (Ng, 2021) distinguishes three components of the virtual environment: the student's individual study environment (which consists of the student's learning activities and devices), the physical environment (at home, in the library, the cafe) where the student is located, and the virtual online environment. In the context of online studies, the learning process is affected not only by the virtual environment, but also by the current physical environment of the student, and its physical and social aspects. The physical aspects can include the indoor air, the room, the ergonomics of the furniture, and the physical infrastructure. The social aspects can include people, events, and rules.

Learning takes place by interaction with the learning content, the experience associated with it, as well as ideas, findings and events during learning (Briede & Pēks, 2011). Thus, the content of studies largely defines the special features of a higher education environment.

A student-centred study environment and student-centred activities within it improve learning, help students gain specialised knowledge, and promote the general development of skills and competences. Participation and involvement can be beneficial to the study process. However, at the same time it puts much responsibility on the students who are expected to manage their learning process on their own, achieving certain study results. The learning process cannot be strictly defined, and one should rather create an environment and provide tools that encourage learning, make learning possible, support, manage and present content and introduce activities that help with the learning process. The study environment creates possibilities for learning. Therefore, in the opinion of the authors, the emphasis should rather be placed on creating a student-centred environment in which the student can use what is available, such as activities, exercises, resources, tools, instructions, etc. (Damsa & de Lange, 2019).

Conclusions

1. The ecological approach has been present in social sciences including education sciences since the 20th century.
2. The ecological approach is one of the critical components of creating and developing the learning environment.
3. The ecological approach is relevant at all levels of education including higher education.
4. The theoretical investigation carried out revealed different views pertaining to the dimensions/ contexts of the environment. Researchers often propose their own classifications of the dimensions, contexts or components of the learning environment, associated with the topics of their research and the specific features of the problem they researched. Furthermore, there is no uniformity in the use of terminology: in explaining the ecological approach, the terms 'dimension, context, component, element of the environment' are used as synonyms. This indicates a lack of a generally accepted definition of a higher education environment, and classification of the dimensions/

contexts of that environment. This makes it possible to define the university study environment as a multicontextual environment, in which a special role is played by its ICT component.

5. In order to promote the professional growth of the student and their preparedness for professional activities, the student must have an appropriate study environment. The study environment of a university consists of two key components: 1) the academic environment of the university; 2) the places where its students complete their internships, i.e., professional environments, which when put together constitute the dual nature of the study environment.
6. A student-centred study environment and student-centred activities within it improve learning, help students gain specialised knowledge, and promote the general development of skills and competences.

References

Acton, R. (2018). Innovating lecturing: spatial change and staff-student pedagogical relationships for learning. *Journal of Learning Spaces*, *7*(1), 1–15.

Artyuhina, A.I. (2007). Obrazovatel'naya sreda medicinskogo vuza kak faktor lichnostno-professional'nogo razvitija specialista (Learning environment of medical university as a personal and professional development factor). Disertacija. *Izvestija Volgogradskogo gosudarstvennogo pedagogicheskogo universiteta*, 1, 73–78. (in Russian).

Baltušīte, R. (2012). *Pedagoģijas studentu gatavība profesionālai darbībai skolas vidē* (The pedagogy students' readiness for professional activities in the school environment). Promocijas darbs. Jelgava: LLU. (in Latvian).

Briede, B., & Pēks, L. (2011). *Ekoloģiskā pieeja izglītībā.* (Ecological approach in education). Sērija 'Izglītības ekoloģija' Jelgava: LLU. (in Latvian).

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Cambridge: Harvard University Press.

Closs, L., Mahat, M., & Imms, W. (2021). Learning environments' influence on students' learning experience in an Australian Faculty of Business and Economics. *Learn Environment*. DOI: 10.1007/s10984-021-09361-2.

Damsa, C., & de Lange, T. (2019). Student-centred learning environments in higher education – From conceptualization to design. *Uniped*, 42, 9–26. DOI: 10.18261/issn.1893-8981-2019-01-02.

Dorman, J.P. (2014). Classroom psychosocial environment and course experiences in pre-service teacher education courses at an Australian university. *Studies in Higher Education*, *39*(1), 34–47. DOI: 10.1080/03075079.2012.674936.

Entwistle, N. (1991). Approaches to learning and perceptions of the learning environment - Introduction to the Special Issue. *Higher Education* 22, 201–204. DOI: 10.1007/BF00132287.

European University Association. (2021). *Universities Without Walls. Vision for 2030.* Brussels: EUA.

Hiemstra, R. (1991). *Creating Environments for Effective Adult Learning*. San Francisco: Jossey-Bass Inc.

Īriste, S. (2018). *Prospective Managers' of Hospitality Business Competitiveness Evaluation and Development promotion in the Dual Study Environment of Higher Education Institution.* Summary of the Doctoral Thesis. Jelgava: LLU.

Īriste, S., & Katane, I. (2021). Digital Competence of Hospitality Students within the Context of Information and Communication Technology Environment. In Rural Environment, Education, Personality, May 7-8, 2021, (74–82). Jelgava: LLU. DOI: 10.22616/REEP.2021.14.008.

Kalniņa, I. (2010). *Vidusskolēnu konkurētspējas attīstības veicināšana un izvērtējums neformālās komercizglītības vidē.* (Promotion and evaluation of the development of secondary school pupils' competitiveness within the environment of non-formal commercial education). Promocijas darbs. Jelgava: LLU, IMI. (in Latvian).

Katane, I. (2005). *Lauku skolas kā izglītības vides izvērtēšanas modelis*. (Rural schools as a model for assessing the educational environment). Promocijas darbs. Daugavpils: Daugavpils Universitāte. (in Latvian).

Katane, I. (2007). *No ekoloģiskās paradigmas līdz vides modelim izglītības pētniecībā.* (From the ecological paradigm to the environmental model in educational research). Jelgava: LLU. (in Latvian).

Katane, I., & Pēks, L. (2006). *Izglītības ekoloģija: starpdisciplinārs virziens mūsdienu izglītības pētniecībā*. (Ecology of education: an interdisciplinary direction in modern educational research). Sērija 'Izglītības ekoloģija'. Jelgava, LLU. (in Latvian).

Klein-Collins, R., & Travers, N. (2020). *Learning Recognition and the Future of Higher Education-A Vision for A Post-Pandemic Learning Ecosystem. Recognition of Prior Learning in the 21st Century.* Boulder: Western Interstate Commission for Higher Education.

Manuĭlov, J.S. (1997). *Sredovoy podhod v vospitanii.* (Environmental approach in education). Tema dissertacii i avtoreferata. Moskva: Rosiyskaya akademiya obrazovaniya. (in Russian).

Markovich, D.Zh. (1991). *Socialnaja ekologija: Kniga dlja uchitelya.* (Social Ecology: A book for teachers). Moskva: Prosveshhenie. (in Russian).

Ng, C.F. (2021). The Physical Learning Environment of Online Distance Learners in Higher Education – A Conceptual Model. *Frontiers in Psychology*, *12,* 635117. DOI: 10.3389/fpsyg.2021.635117.

Novikova, O.N. (2003). Social'noe myshlenie i obrazovatel'naja paradigma. (Social thinking and the educational paradigm). Perm': Permskiy gosudarstvenniy universitet. (in Russian).

OECD. (2019). *Future of Education and Skills 2030. OECD Learning Compass 2030.* A Series of Concept Notes. Retrieved March 2, 2022, from https://www.oecd.org/education/2030-project/teaching-and-learning/learning/learning-compass-2030/OECD_Learning_Compass_2030_concept_note.pdf.

Panov, V.I. (2004). *Ekologicheskaya psihologiya: Opyt postroeniya metodologii.* (Ecological psychology: Experience of creating methodologies). Moskva: Nauka. (in Russian).

Peckover, C. (2012). Realizing the Natural Self: Rousseau and the Current System of Education. *Philosophical Studies in Education,* 43, 84–94.

Popa, C., Rus, A., Lee, W., Parris, S., Webster, R., Lobo, A., & Stativa, E. (2020). Bronfenbrenner's ecological system theory and the experience of institutionalization of Romanian children. *New approaches in behavioral sciences,* 237–251. Retrieved March 3, 2022, from https://bettercarenetwork.org/sites/default/files/2021-03/2020PopaLeeRuseds._Rusetal_Bronfrenbrenner.pdf.

Radcliffe, D. (2008). A pedagogy-space-technology (PST) framework for designing and evaluating learning places. Learning spaces in higher education: Positive outcomes by design. Brisbane, Qld: The University of Queensland and the Australian Learning and Teaching Council. Retrieved March 11, 2022, from http://www.uq.edu.au/nextgenerationlearningspace/proceedings.

Ruiz-Mallén, I., & Heras, M. (2020). What Sustainability? Higher Education Institutions' Pathways to Reach the Agenda 2030 Goals. *Sustainability, 12*(4), 1290. DOI: 10.3390/su12041290.

Shum, A., Fryer, L., Cano, F., Pichardo-Martínez, M.C., & Berbén, A.B. (2021). Nature vs nurture: learning conceptions and environment as precursors to learning strategy patterns and their outcome, *Higher Education Research & Development.* Retrieved March 10, 2022, from https://www.tandfonline.com/doi/abs/10.1080/07294360.2021.1985088.

Valtonen, T., Leppänen, U., Hyypiä, M., Kokko, A.K., Manninen, J., Vartiainen, H., Sointu, E., & Hirsto, L. (2021). Learning environments preferred by university students: a shift toward informal and flexible learning environments. *Learning Environments Research, 24*. DOI: 10.1007/s10984-020-09339-6.

Vermetten, Y.J., Vermunt, J.D., & Lodewijks, H.G. (2002). Powerful learning environments? How university students differ in their response to instructional measures. *Learning and Instruction,* 12, 263–284.

Yang, E., & Sanborn, B. (2021). *Ecological Systems Theory from: A Handbook of Theories on Designing Alignment between People and the Office Environment*. Routledge. Retrieved March 12, 2022, from https://www.routledgehandbooks.com/doi/10.1201/9781003128830-9.

Yasvin, V.A. (2020). Tehnologiya sredovogo proektirovaniya v obrazovanii. *Social'no-politicheskie issledovanija.* (Technology of environmental design in education. Socio-political research). *1,* 6. Retrieved March 1, 2022, from https://cyberleninka.ru/article/n/tehnologiya-sredovogo-proektirovaniya-v-obrazovanii. (in Russian).

Annual 28th International
Scientific Conference

Research for Rural Development

2022

Volume 37

ONLINE ISSN 2255-923X
ISSN 1691-4031