

ASSESSMENT OF LAND USE CHANGE SCENARIO TO INCREASE PRIMARY PRODUCTIVITY FUNCTION AT LOCAL SCALE

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Abstract

The global population has begun to rise exponentially; therefore, the demand for bioresources including food and fibre is increasing. An increasing demand for food and fibre necessitates more sustainable use of natural resources especially for soil-based ecosystem services. In this context, Functional Land Management was developed to optimize agricultural soil-based ecosystem services to meet both agricultural and environmental targets simultaneously. The aim of the research is to evaluate unmanaged agricultural land use change impact on primary productivity function in three parishes in Latvia by using Functional Land Management framework.

Evaluation of primary productivity function was accomplished for both sectors agriculture and forestry by using profit and working hours as a proxy indicators. Production of vegetables and perennial plantations have higher supply of primary productivity function comparing to other land uses.

Land use changes affect all soil functions that we expect from our land, especially primary productivity function. After applying land use changes, an increase in profit is higher in Liezere parish for both areas on mineral soils (7.1%) and areas on organic soils (5.2%); while an increase in working hours is higher in Usma parish: 36.6% in areas on mineral soils and 1.0% increase in areas on organic soils.

Short-term benefits are received from agricultural land, while forest land provides long-term return which increases over time but can only be obtained after reaching the age of felling. Before applying land use changes or changes in management practices we have to consider other soil function and national commitments.

Key words: Functional Land Management, soil functions, agricultural land, forestry land, policy, production.

Introduction

The global population has begun to rise exponentially. In 2017, there were 7.6 billion people. The latest forecast shows that the world population will exceed 8.5 billion people by 2030 and 9.7 billion by 2050 (UN, 2017). This increases the demand for bioresources including food and fibre. This, in turn, necessitates more sustainable use of natural resources especially for soil-based ecosystem services.

Soil basically is non-renewable resource and provides many ecological and social functions (Mueller *et al.*, 2010) and the key soil function 'food and biomass production' must be maintained sustainably (Blum, 1993). Therefore, the EU has established a framework for the protection of soil and the preservation of its capacity to perform environmental, socio-economic and cultural functions, namely biomass production, nutrient and water storage, filtering and transformation, carbon sequestration, the provision of a biodiversity pool, as well as a physical and cultural environment for humans, a source of raw materials and an archive of geological and archaeological heritage (EC, 2006).

In this context, multifunctional soil-based framework, called Functional Land Management (FLM), is developed to quantify the supply and demand of five soil functions, such as primary productivity, carbon sequestration and regulation, water purification and regulation, the provision and

cycling of nutrients, and the provision of habitats for biodiversity (Schulte *et al.*, 2014). Framework aims to optimize agricultural soil-based ecosystem services to meet both agricultural and environmental targets simultaneously. The performance of each soil function depends on land use and soil properties (Coyle *et al.*, 2016). Coyle *et al.*, (2016) expanded FLM framework by developing conceptual models for assessment of supply of each soil function, including the interrelation of land use and dominant soil property. In Ireland, wetness is the dominant soil property. Using results of conceptual models, soil matrix was created. Those soil matrix can be used to show changes in suite of soil functions after implementations of various policy measures. Further framework was used to explore different scenarios for meeting agronomic and environmental objectives simultaneously (Valujeva *et al.*, 2016).

In Latvia, bioresources have a pivotal role to provide economic growth; therefore, Latvian Bioeconomy Strategy until 2030 was developed (LIBRA2030, 2017). One of the main opportunities for development of economy in Latvia is sustainable and efficient use of natural resources. Sustainable development of traditional bioeconomy sectors includes social, economic and environmental dimensions and also requires sustainable soil management. There are three main targets for development of traditional bioeconomy sectors, namely agriculture and forestry:

1. To increase a value added from agriculture and forestry sectors from EUR 2.33 billion in 2016 to EUR 3.8 billion in 2030;
2. To increase a value of bioeconomy production exports from EUR 4.26 billion in 2016 to at least EUR 9 billion in 2030;
3. To provide employment for at least 128,000 inhabitants.

Current research is limited to primary productivity function. The aim of the research is to evaluate unmanaged agricultural land use change impact on primary productivity function in three parishes in Latvia by using Functional Land Management framework. The main tasks of the research are 1) to quantify supply and demand of primary productivity function in three parishes in Latvia; 2) to identify possible pathways how to improve performance of primary productivity function. The object of the study is agricultural and forestry land in Latvia.

Materials and Methods

FLM in Latvia

FLM framework was adapted for Latvia. Data of agricultural land use and farming systems from the State Land Service, the Rural Support Service, Agricultural Data Centre, data of soil type and properties from digitized historical soil maps and land reclamation, and data of forest from the State Forest Service were collected within the project 'Evaluation of the land use optimization opportunities within the Latvian climate policy framework' (Nipers, 2019). Data collected within project was used to create land use and dominant soil property matrix by Valujeva *et al.*, (in preparation). The land use of Latvia was divided into agricultural land and forestry land. Agricultural land had subdivisions, such as grain, oilseed, pulses (GOP), vegetables, perennial plantations, other crops, no crops, grasslands, not cultivated agricultural land and overgrown agricultural land, while forestry land had been divided into managed coniferous forests and managed deciduous forests, and natural coniferous forests and natural deciduous forests. In Latvia, management of organic soils is responsible for 50% of direct N₂O emissions (NIR, 2018); therefore, the carbon content in soil was chosen as the main characteristic for soil properties.

Methodology for quantification of supply of and demand for primary productivity function

Within the project evaluation of socio-economic impact was accomplished for both sectors agriculture and forestry. Proxy-indicator for economic component was profit, but for social component - working hours. Profit for agriculture was a function of sold products, direct payments, and production costs including amortisation, while for forestry appreciation instead of profit was used. Average data of period 2014-

2016 was used for determining profit per hectare. Appreciation per year was a multiplication of stock growth per year and a profit per m³ of wood in the end of production cycle. Workplaces were evaluated as a necessary hourly labour input per hectare per year for both agriculture and forestry. Profit and working hours were set per hectare. Methodology for quantification of profit and working hours were adapted for land use and soil property by Valujeva *et al.*, (in preparation). Tabular index approach developed by Greiner *et al.*, (2018) was used to create indicator from two indexes (profit and working hours) Valujeva *et al.*, (in preparation). Gradient of 5 classes where 1 is low and 10 is high was used for mapping. In the study, quantification of supply of primary productivity function was done in polygon level for three parishes in Latvia.

Demand for primary productivity function is framed by regional and national planning documents, namely Development Programme of Kurzeme Planning Region for 2014-2020; Development Programme of Zemgale Planning Region for 2014-2020; Development Programme of Vidzeme Planning Region for 2014-2020; Latvia Bioeconomy Strategy 2030; National Development Plan of Latvia for 2014-2020; Sustainable Development Strategy of Latvia until 2030. Calculation of demand for each municipality in accordance to targets framed by Bioeconomy Strategy are accomplished by Valujeva *et al.*, (in preparation). Indicator was created from target for value added from agriculture and forestry sectors and unemployment rate (Valujeva *et al.*, in preparation).

Case studies

In the study, the methodology developed by (Nipers, 2019) and expanded by (Valujeva *et al.*, in preparation) was used to quantify the supply and demand in three different parishes of Latvia, namely Usma, Zalienieki, Liezere. Distribution of land uses in relation to soil carbon content for each parish was shown in Table 1. Usma parish is located in North-West part of Latvia in Ventspils municipality; the land area is 219.35 km², population was 527 inhabitants and unemployment rate was 5.7% (SRDA, 2016) in 2018. In Usma parish, 62% of total area is covered by forests, 7% of total area is used for agricultural purposes and 25% of agricultural land in Usma parish is not cultivated or overgrown (Table 1). In Usma, 25% of agricultural and forestry land is located on organic soils. Zalienieki parish is located in Jelgava municipality; the land area is 122.16 km², population was 1,486 inhabitants and unemployment rate was 3.9% (SRDA, 2016) in 2018. The main land use in Zalienieki parish is agricultural land which covers 71% of total area and 0.6% of agricultural land is not cultivated or overgrown, but only 14% of total area

Table 1

Areas of land use in Usma, Zalenieki, Liezere parishes

Land use	Usma parish, ha		Zalenieki parish, ha		Liezere parish, ha	
	Mineral soil	Organic soil	Mineral soil	Organic soil	Mineral soil	Organic soil
GOP	131.0	9.4	7,514.0	0.1	490.0	66.8
Vegetables	6.0	0.0	80.0	0	1.0	0
Perennial plantations	1.0	0	26.0	0	13.0	0
Other crops	172.0	18.0	766.0	0	1,110.0	138.0
No crops	280.7	44.9	209.4	0	659.1	228.2
Grassland	371.0	54.0	54.0	1.0	2,147.0	287.0
Not cultivated agricultural land	242.0	70.0	42.0	0	218.0	49.0
Overgrown agricultural land	42.0	17.0	8.0	0	583.0	84.0
Managed coniferous forest	7,315.0	1,945.5	551.99	33.4	3,666.8	954.38
Managed deciduous forest	1,133.2	1,027.6	901.8	152.9	7,000	1,807.2
Natural coniferous forest	1,187.2	481.1	63.7	0	8.6	0
Natural deciduous forest	258.0	135.0	26.5	0.3	4.0	0
Total	11,139.1	3,802.5	10,243.39	187.7	15,900.5	3,614.58

Source: authors' calculations based on Nipers, (2019).

is covered by forests (Table 1). In Zalenieki, 2% of agricultural and forestry land is located on organic soils. Liezere parish is located in North-East part of Latvia in Madona municipality; the land area is 254.70 km², population was 1,285 inhabitants and unemployment rate was 7.20% (SRDA, 2016) in 2018. 53% of total area in Liezere parish is covered by forests, 24% is agricultural land and 15% of agricultural land is not cultivated or overgrown (Table 1). In Liezere, 19% of agricultural and forestry land is located on organic soils.

Scenarios

In the study, the land use change scenario impact on primary productivity function was explored. The land use changes included the return of not cultivated and overgrown agricultural land to agricultural production depending on soil quality rate: soil quality points less than 25 means that it is more suitable for forestry; soils with a quality rate in the range between 25 and 38 points is suitable for grass production; soil with quality points in the range from 38 to 77 is suitable for crop production. The scenario included the following land use changes: 1) the land use change from not cultivated and overgrown areas on mineral soils with soil quality points less than 25 to managed coniferous forests on mineral soils; 2) the land use changes from not cultivated and overgrown areas on organic soils to managed coniferous forests on organic soils; 3) the land use changes from not cultivated and overgrown areas on mineral soils with soil quality points in the range from 25 to 38 to grassland on mineral soil; 4) not cultivated and overgrown areas with soil quality points in the range from 38 to 77 on mineral soils

were equally distributed between GOP, vegetables, perennial plantations, and other crops on mineral soils.

Results and Discussion

National demand for primary productivity in Latvia is framed by Latvia Bioeconomy Strategy 2030. There is no demand at municipality level, but Valujeva *et al.*, (in preparation) has divided national target into regional targets depending on regional GDP target, share of agriculture, forestry, fisheries and unemployment rate at municipality level. The demand for primary productivity function is higher in Usma and Zalenieki, but lower in Liezere.

Supply of primary productivity function, with proxy-indicators profit and working hours, strongly relates to the land use and soil class. A higher supply of primary productivity function is in Zalenieki parish, while the supply of primary productivity function in Usma and Liezere parishes is distribution between low and high supply (Figure 1). Areas with low supply are not cultivated and overgrown agricultural land, and no crop areas which means that those areas are not used to produce goods for market or there is no available information. Total area with low supply of primary productivity function in Usma is 2,662 ha, in Zalenieki 270 ha, but in Liezere 3,054 ha.

Table 2 shows that GOP and vegetables grown on mineral soils have higher profits in Zalenieki compared to Usma and Liezere. Comparing perennial plantations on mineral soils in all parishes: the profit in Zalenieki is EUR 75,400 per year, which is 50% more than in Liezere and 26 times more than in Usma. Profit from other crops is the highest in Liezere, where it

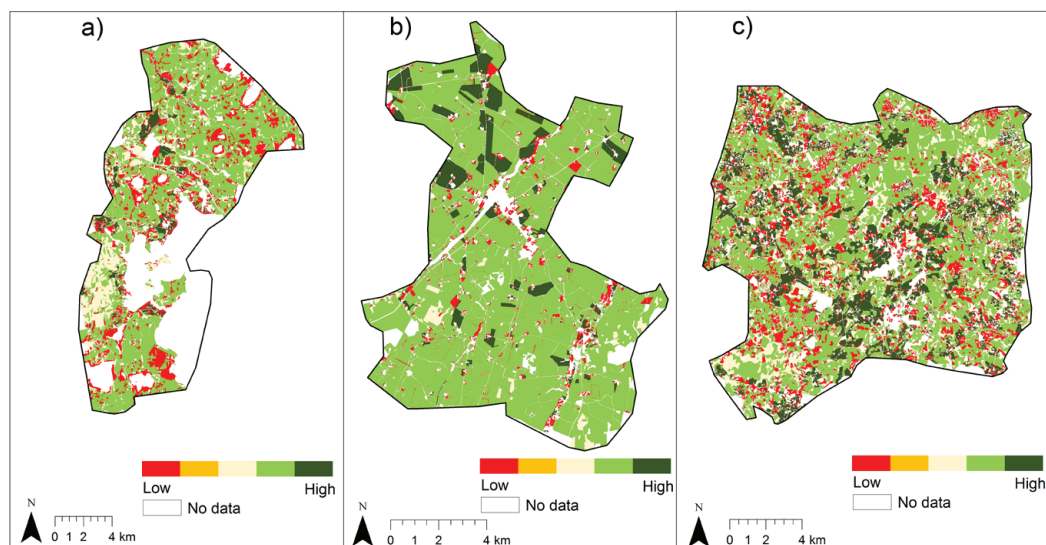


Figure 1. Supply of primary productivity function: a) Usma parish;
b) Zalenieki parish; c) Liezere parish.

Source: authors' construction based on Nipers, (2019) and Valujeva *et al.*, (in preparation).

reaches EUR 333,000 per year, while in Zalenieki the profit is almost EUR 300,000 per year, but in Usma the profit is about 6.4 times smaller than in Liezere.

The highest profit in managed coniferous forests is observed in the parish, where the forest canopy predominates: the profit in Usma is EUR 1,975,050 per year which exceeds the profit in Liezere by almost one million and which is 13 times more than in Zalenieki where the agricultural land predominates. In managed deciduous forest, higher profit is observed

in Liezere (EUR 1,050,000 per year), while in other parishes the profit exceeds EUR 100,000 per year. Natural coniferous forests have the highest profit in Usma: the profit is reaching EUR 160,272 per year. The profit from natural deciduous forests in Usma is EUR 19,350 per year, while in Zalenieki the profit is only EUR 133 per year, but in Liezere there are no natural deciduous forests.

Table 3 shows that GOP, vegetables, and perennial plantations grown on mineral soils have higher

Table 2
Profit in EUR per year for land use and soil class combinations in Usma, Zalenieki and Liezere parishes

Land use	Usma parish		Zalenieki parish		Liezere parish	
	Mineral soil	Organic soil	Mineral soil	Organic soil	Mineral soil	Organic soil
GOP	9,170	141	525,980	2	34,300	1,002
Vegetables	8,700	0	116,000	0	1,450	0
Perennial plantations	2,900	0	75,400	0	37,700	0
Other crops	51,600	3,600	229,800	0	333,000	27,600
No crops	0	0	0	0	0	0
Grassland	37,100	3,780	5,400	70	214,700	20,090
Not cultivated agricultural land	0	0	0	0	0	0
Overgrown agricultural land	0	0	0	0	0	0
Managed coniferous forest	1,975,050	157,586	149,037	2,705	990,036	77,305
Managed deciduous forest	169,980	46,242	135,270	6,881	1,050,000	81,324
Natural coniferous forest	160,272	19,485	8,600	0	1,161	0
Natural deciduous forest	19,350	3,038	133	7	0	0
Total	2,434,122	233,871	1,245,619	9,664	2,662,347	207,321

Source: authors' calculations based on Nipers, (2019) and Valujeva *et al.*, (in preparation).

Table 3

**Working hours EUR per year for land use and soil class combinations in Usma,
Zalienieki and Liezere parishes**

Land use	Usma parish		Zalienieki parish		Liezere parish	
	Mineral soil	Organic soil	Mineral soil	Organic soil	Mineral soil	Organic soil
GOP	3,275	235	187,850	3	12,250	1,670
Vegetables	3,000	0	40,000	0	500	0
Perennial plantations	600	0	15,600	0	7,800	0
Other crops	26,660	2,790	118,730	0	172,050	21,390
No crops	0	0	0	0	0	0
Grassland	11,130	1,620	1,620	30	64,410	8,610
Not cultivated agricultural land	0	0	0	0	0	0
Overgrown agricultural land	0	0	0	0	0	0
Managed coniferous forest	21,945	1,751	1,656	30	11,000	859
Managed deciduous forest	3,400	925	2,705	138	21,000	1,626
Natural coniferous forest	2,374	289	127	0	17	0
Natural deciduous forest	516	81	53	0	8	0
Total	72,900	7,690	368,342	200	289,036	34,155

Source: authors' calculations based on Nipers, (2019) and Valujeva *et al.*, (in preparation).

working hours in Zalienieki compared to Usma and Liezere. A managed coniferous forest, natural coniferous forest, and natural deciduous forest on mineral soils provide higher working hours in Usma parish, while other crops, grassland and managed deciduous forest provide higher working hours in Liezere. Higher working hours from areas on organic soils are observed in Liezere parish (EUR 34,155 per year): compared to Usma (EUR 7,690 per year) and Zalienieki (EUR 200 per year) (Table 3).

Improvements in supply of primary productivity

Firstly, not cultivated and overgrown agricultural land on mineral soils with soil quality points less than 25 on mineral soils are transferred to managed coniferous forests on mineral soils, because biomass production in intensively managed forests is on average 26% higher than in unmanaged forests (Karttunen *et al.*, 2018) and higher potential for biomass production is shown by coniferous stands (Nord-Larsen and Pretzsch, 2017). Secondly, not cultivated and overgrown agricultural land on organic soils is transferred to managed coniferous forests on organic soils, because afforestation of well-drained organic soils increases biomass production (Weslien *et al.*, 2009), also this measure increases carbon sequestration in the soil, which is another soil function which we expect from our soils although we are not investigating that in this study. Thirdly, not cultivated and overgrown agricultural land on mineral soils with soil quality points in the range from 25 to 38 are transferred to grassland. Fourthly, not cultivated and overgrown agricultural land with soil quality points in

the range from 38 to 77 on mineral soils is equally distributed between GOP, vegetables, perennial plantations, and other crops on mineral soils.

After applying land use changes to areas on mineral soils, the increase in profit is 5.6%. A higher increase in profit is observed in Liezere parish (7.1%), while lower increase in profit is in Zalienieki parish (2.2%), but the increase in Usma parish is 5.6% (Figure 2). An increase in the supply of primary productivity function on organic soils is on average 4.0%. A higher increase is observed in Liezere (5.2%), but a lower increase is observed in Usma (3.0%). In Zalienieki, there are no not cultivated or overgrown agricultural land on organic soils. A higher increase in working hours after land use changes on mineral soils is in Usma (36.6%) and Liezere (7.6%), but in Zalienieki the increase is only 2.0% (Figure 2). An increase in working hours after land use changes on organic soils from not cultivated and overgrown to managed forests is in the range from 0.4% in Liezere to 1.0% in Usma.

Food and fibre is not the only social demand for our land that we expect. We also expect carbon storage and regulation, nutrient cycling, water purification and provision of habitat for biodiversity (Schulte *et al.*, 2014). Therefore, before applying land use changes or changes in management practices we have to consider other soil function and national commitments. Climate-smart land management is a key to achieve socio-economic and environmental targets; therefore, further research is necessary to explore how these land use changes affect other soil functions, namely climate function and biodiversity.

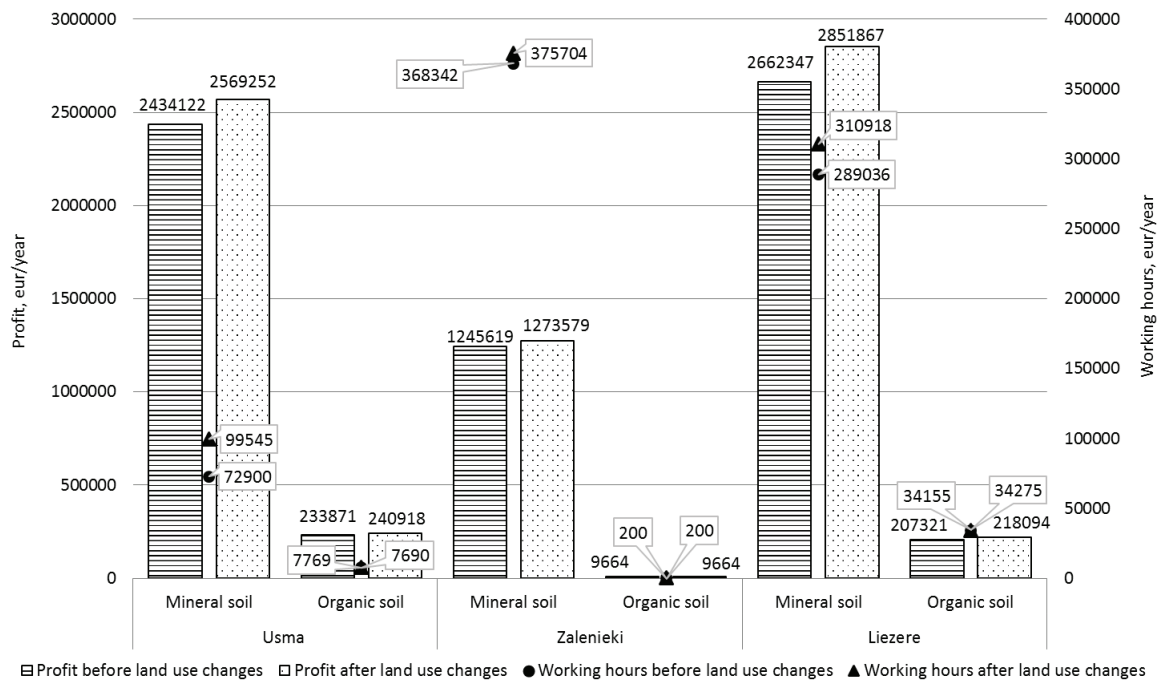


Figure 2. Profit and working hours before and after applying land use changes in Usma, Zalenieki and Liezere parishes.

Source: authors' construction.

Conclusions

Soil is non-renewable resource and provides food and biomass production for society. Also, it provides many other ecological and social functions like water purification, habitat for biodiversity, nutrient cycling, and carbon sequestration and regulation. Therefore, protection of soils and the preservation of its capacity to perform socio-economic and ecological functions is necessary.

Land use changes affect all soil functions that we expect from our land, especially primary productivity function. Higher profit and working hours are observed

from areas on mineral soils. Short-term benefits are received from agricultural land, while forest land provides a long-term return which increases over time but can only be obtained after a reaching the age of felling. Before applying land use changes or changes in management practices we have to consider other soil function and national commitments.

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