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A COMPARATIVE ANALYSIS OF ON-FARM GREENHOUSE GAS EMISSIONS FROM FAMILY FARMS IN LITHUANIA

Vida Dabkienė
Lithuanian Institute of Agrarian Economics
vida@laei.lt

Abstract
The aim of paper is a comparative analysis of on-farm greenhouse gas emissions across family farm types and farm size classes using FADN data in Lithuania. To achieve this, Lithuanian FADN data of 2014 were used for the analysis. The research draws on a sample of 1304 family farms. The methodology is based on an adaptation of the IPCC guidelines using Lithuanian emission factors from Lithuania's National Inventory Report and the activity data of family farms derived from Lithuanian FADN. The GHG emissions were analysed per farm (t CO_{2eq} farm^{-1}) and per hectare (CO_{2eq} ha^{-1} of UAA). The research found out that the major sources of GHG emissions are related to the use of chemical fertilizers on farms comprising 52.6% of the total emissions from family farms. The performed analysis shows that GHG emissions per farm depended on the farm size and ranged from 63.3 t CO_{2eq} farm^{-1} to 479.6 t CO_{2eq} farm^{-1}, on farm size class less than 30 ha UAA and from 500 ha UAA or over, respectively. The GHG emissions on family farms totalled 184.2 t CO_{2eq} farm^{-1} and ranged from 5.8 t CO_{2eq} farm^{-1} to 234.6 t CO_{2eq} farm^{-1}, in the permanent crops farms and in the specialist dairying farms, respectively.
Key words: GHG emissions, FADN, farming type, family farms.

Introduction

At the Paris climate conference in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal (EC, 2017). The agreement aims at holding global warming to well below 2 degrees Celsius and to 'pursue efforts' to limit it to 1.5 degrees Celsius. To accomplish this, countries have submitted Intended Nationally Determined Contributions outlining their post-2020 climate action (Rogelj *et al*., 2016). The European Commission in a Communication 'Roadmap for moving to a competitive low-carbon economy in 2050' has set a target to cut domestic greenhouse gas (further in text – GHG) emissions by at least 80% by 2050 compared to 1990. According to the Intergovernmental Panel on Climate Change (further in text – IPCC) data, Agriculture, Forestry and Other Land Use sector accounts for about a quarter of net anthropogenic GHG emissions (IPCC, 2014). Therefore, it is important emitter of global emissions of GHG as agricultural sector is both a source and a sink of GHGs (Syp *et al*., 2015; Gocht *et al*., 2016). According to European Environmental Agency (further in text – EEA) data of 2014 in the structure of GHG emissions of the European Union (further in the text – EU) agriculture, the dominant sources are CH_4 emissions from enteric fermentation in livestock and N_2O emissions resulting from a number of processes on agricultural soils, 42.9% and 38.0%, respectively. In the period of 2004 – 2014 the emissions from enteric fermentation decreased by 2.4% and from agricultural soils by 1.5% in the EU.

The Common Agricultural Policy (further in text – CAP) plays an important role in achieving environmentally and climate friendly agricultural sector. In the period of 2014 – 2020 greening instruments were added to the first CAP pillar. In addition, agricultural policy encourages to implement such measures as efficient fertiliser use, bio-gasification of organic manure, improved manure management, better fodder, improved livestock productivity, local diversification and commercialisation of production, maximising the benefits of extensive farming, which are expected to reduce GHG emissions by between 42.0% and 49.0% (IEEP, 2011).

As Lynch, Donnellan & Hanrahan (2016) noticed, GHG emissions share that arises from agricultural sector varies greatly by the EU member state. Brizga, Feng, & Hubacek (2014) stated that Lithuania has significantly managed to reduce their total GHG emissions (from all the sectors) since the early 1990s as total GHG emissions decreased by 55.2% in 2004. The same tendency was observed in agricultural sector, the emissions in considered period decreased by 53.7%. Such results are not explained just by the adoption of the United Nations Framework Convention on Climate Change (signed in 1992) and the Kyoto Protocol (signed in 1997), but are more likely related to significant economic and political changes in Lithuania. In 2004, Lithuania became a member of the EU and Lithuanian legislation has to comply with the EU regulations and plans. According to EEA data, in 2014 as compared to 2004, the total emissions of Lithuania decreased by 9.1%, though from agricultural sector it increased by 5.8%. In Lithuania, emissions from agricultural sector comprised 20.1% in 2014. As compared to EU-28 agriculture sector average, it was two times higher. The enteric fermentation is responsible for 42.1% and agricultural soils for 46.4% of agricultural emissions. During the period of 2004 – 2014 the emissions from enteric fermentation decreased by 1.5%. On contrary, the emissions from agricultural soils increased by 18.2% in considered period (EEA, 2016). It should be noticed that during the period of 2004 – 2015 the number of cattle decreased by 8.8% in Lithuania (Central Statistical Office of Lithuania, 2017). Obviously this trend limits the consumption of organic fertilizers and causes higher inputs of chemical fertilizers. Vitunskienė & Vinciūnienė (2014) calculated GHG emissions intensity indicators for the whole economy and agricultural sector in Lithuania. The research results revealed that in the period of 1995–2010 the GHG emissions intensity decreased by 2.6 times in the whole economy, whereas in agriculture, it increased by 1.4 times. Moreover, the GHG emissions intensity in Lithuanian agriculture was greater than the EU-27 average, which showed the higher GHG emissions performed per value added unit.

In line with the increased awareness of the environmental impacts from agricultural sector and the importance of farmers' decision making towards the implementation of environmentally friendly practices on farms, the GHG calculators have been developed (Hillier, 2012; Tuomisto *et al*., 2015). Colomb *et al.* (2012) assessed the developed GHG calculators for agricultural and forestry sector. The authors identified four main types of GHG calculators, those designed to raise awareness, to report, to evaluate projects and to assess products. Accordingly, the end-users of carbon calculators' tools mostly are farmers, projects evaluators and certification organizations. Though the farm-level GHG calculators are usually used at the individual farm level and are not sufficient for larger scale assessment, in order to inform decision-makers (Keller *et al*., 2014) and do not encourage farmers for changes as the consumers are getting more conscious about GHGs (Maraseni *et al*., 2010). GHG emissions assessment on farm is one of indicators measuring farms' environmental sustainability (Reidsma *et al*., 2015; Dillon *et al*., 2016). Regarding the end-user of calculator, each author tries to find the best compromise between output accuracy, data correctness and availability, user-friendliness, compatibility, transparency, and complexity (Colomb *et al*., 2012). Therefore, recently available databases as information sources such as the EU Farm Accountancy Data Network (further in text – FADN) have been employed for farms sustainability assessment (Longhitano *et al*., 2012; Dillon *et al*., 2016) and even calculating GHG emissions (Coderoni & Esposti, 2014). In Lithuanian FADN the collection of information on the quantities of chemical fertilizers applied on farms was launched on 1 January 2014 under the framework of the European Council Regulation (EU) No. 1320/2013. The lack of data limited research and scientific discussion regarding fertilizers consumed and emitted GHGs on farms (Vitunskienė & Dabkienė, 2016). In order to cover this gap, the paper's aim is a comparative analysis of on-farm greenhouse gas emissions across family farm types and farm size classes using FADN data in Lithuania.

Materials and Methods

The methodology proposed for this paper is based on an adaptation of the IPCC methodology (IPCC, 2006) using Lithuanian emission factors from Lithuania's National Inventory Report (further in the text – LNIR) (Lithuania, N. I. R., 2015) and family farms activity data derived from Lithuanian FADN. Considering the main GHG emission sources of agricultural sector and the availability of farms activity data in FADN, the emissions from enteric fermentation of domestic livestock, direct and indirect emissions from manure management and direct and indirect N_2O emissions from managed soils in the study were calculated (Table 1).

The data related to manure management system on farms is not available in Lithuanian FADN. Therefore, the manure management methane emission factors for 'other system' were used for calculation. GHG

Table 1

GHG emission sources accounted in the paper

Emission sources	FADN activity data	Source in IPCC, 2006
N_2O manure management	Animal numbers	Equation 10.25, 10.26, Annex 10A.2, Tables 10A-4 to 10A-8
CH_4 manure management	Animal numbers	Equation 10.22
CH_4 enteric fermentation	Animal numbers	Equation 10.19, 10.20
N_2O agricultural soils		
Direct emissions		
Use of synthetic fertilizers	N fertilizers	Equation 11.11, Table 11.1
Indirect emissions		
Atmospheric deposition	N fertilizers, animal numbers	Equation 11.9, Table 11.3
Leaching and run-off	N fertilizers, animal numbers	Equation 11.10, Table 11.3

emissions at different levels were calculated by summing up CO_2, CH_4 and N_2O emissions based on their equivalence factor in terms of CO_2 (100-year time horizon): 1 for CO_2, 25 for CH_4, and 298 for N_2O.

Lithuanian FADN data of 2014 were obtained for the analysis of GHG emissions on farms. For calculations individual farm records of 1304 family farms were used. This paper focuses on eight groups of farms depending on their production specialisation based on the EU standard classification of 'Type of Farming'. The analysis was carried out for the after-mentioned farming types: specialist cereals, oilseeds and protein crops (further in text – COP), general field cropping and mixed cropping, horticulture, various permanent crops combined, specialist dairying, grazing livestock, specialist granivores and field crops-grazing livestock combined. Alongside, the differences across farm size classes expressed in utilized agricultural area (further in the text – UAA) were estimated. As any sample of size class or farm type has to be large enough (it is advisable to present the results for a group of at least 15 farms) to comply with FADN confidentiality restrictions the number of farm size classes across farm types differs and the analysis by farm size classes for the specialist granivores, horticultural and permanent crops farms was not estimated. ANOVA test was used to measure statistical significance of the difference in the GHG emission values between the farm size classes. The coefficient of variation (further in the text – CV) was calculated to CV: (SD/Mean) x 100. The statistical package for social science (SPSS 21) was employed for processing and analysis of the data.

Results and Discussion

Table 2 reports the structure of GHG emissions across farm size classes expressed in hectare of UAA. The GHG emissions averaged 184.2 t CO_{2eq} $farm^{-1}$ in Lithuanian family farms. The emitted GHG emissions differ significantly at six considered farm size classes. In small-sized farms, the lowest level was estimated, but in the large-sized farms - the highest level of GHG emissions, 63.3 t CO_{2eq} $farm^{-1}$ and 479.6 t CO_{2eq} $farm^{-1}$, respectively. The major sources of GHG emissions are related to the use of chemical fertilizers on farms comprising 52.6% of the total emissions from family farms. The differences across considered farm size classes are significantly higher in relation to chemical fertilizers consumption on farms as compared to CH_4 emissions, as the highest emissions observed were by 11.3 and 3.8 times higher in large-sized farms than in small-sized farms, respectively. It should be noted that even small reduce in chemical fertilizers consumption has positive effect on the total GHG emissions on farms because of the high N_2O global warming potential. The performed analysis shows that GHG emissions per farm depend on the farm size and this finding is in consistence with some other studies (Coderoni & Esposti, 2014).

With regard to small sample of permanent crops, horticultural and specialist granivores farms in FADN, the results of GHG emissions are presented in the average values for the total farms (Table 3). The permanent crop farms have the lowest GHG emissions with emission value of 5.8 t CO_{2eq} $farm^{-1}$. Alongside, the lowest emissions were achieved per farm area unit, i.e. 98.9 kg CO_{2eq} ha^{-1} of UAA. The value of 29.0 t CO_{2eq} $farm^{-1}$ was observed for horticultural farms and this value made 15.7% of the average value of the total farms. In terms of the emissions per area unit, horticultural farms averaged at 843.4 kg CO_{2eq} ha^{-1} of UAA. The specialist granivores GHG emissions per farm comprised 91.6% of total emissions per family farm. The emissions per

Table 2

GHG emissions structure across farm size classes (ha UAA), t CO_{2eq} $farm^{-1}$

The GHG emission sources	Less than 30 ha	From 30 to 50 ha	From 50 to 100 ha	From 100 to 200 ha	From 200 to 500 ha	500 ha or over	Total
CH_4 emissions from enteric fermentation and manure management	30.9	51.4	72.7	123.1	125.4	118.5	87.0
Direct N_2O emissions from manure management systems	0.2	0.1	0.1	0.3	0.2	0.2	0.2
Indirect N_2O emissions from manure management	0.1	0.0	0.1	0.2	0.1	0.1	0.1
Direct and indirect N_2O emissions from managed soils	32.0	33.0	57.6	78.9	150.9	360.8	96.9
Total	63.3	84.5	130.5	202.4	276.7	479.6	184.2

Source: own calculation based on Lithuanian FADN data.

Table 3

GHG emissions of permanent crops, horticulture and specialist granivores farms

Farm type	Number of farms	Average farm size (ha UAA)	t CO_{2eq} $farm^{-1}$	kg CO_{2eq} ha^{-1}
Horticultural farms	39	37.5	29.0	843.4
Permanent crop farms	25	52.0	5.8	98.9
Specialist granivores farms	8	82.5	168.8	5,082.7
Total	1,304	159.8	184.2	1,200.3
Index (total on farms = 100)				
Horticultural farms	3.0	23.5	15.7	70.3
Permanent crop farms	1.9	32.5	3.1	8.2
Specialist granivores farms	0.6	51.6	91.6	423.5

Source: own calculation based on Lithuanian FADN data.

area unit recorded to 5,082.7 kg CO_{2eq} ha^{-1} of UAA, and it is rather obvious as livestock density is high in specialist granivores farms.

Table 4 provides average values of GHG emissions on the COP farms expressed by total emissions on farms (t CO_{2eq} $farm^{-1}$) and by an intensity indicator expressed in kg CO_{2eq} ha^{-1} of UAA. Six size classes were used to examine differences for the COP farms. GHG emissions from the use of synthetic fertilizer contributed 96.4% of the total emissions on farms. The lowest share is observed in small-sized farms whereas the largest share - in large-sized farms, 67.9% and 96.4%, respectively. In addition, it shows the higher diversification of small-sized COP farm activity. The emissions of farms of 500 ha UAA or over amounted to 715.8 t CO_{2eq} $farm^{-1}$. Moreover, the GHG emission gap between the observed farm size classes is large as the lowest level of GHG emissions per farm observed on small-sized farms generated only 7.2 t CO_{2eq} $farm^{-1}$. CV value indicates much higher variation level for the total GHG emissions per farm than measuring differences among intensity values on farms (147.5% and 32.3%, respectively).

Table 5 presents the average values of the GHG emissions of the field cropping farms in identified three size classes. The GHG emissions per farm

Table 4

GHG emissions of COP farms by farm size classes

Farm size classes of UAA	Number of farms	t CO_{2eq} $farm^{-1}$	kg CO_{2eq} ha^{-1}
Less than 30 ha	39	7.2	381.7
From 30 to 50 ha	39	16.4	416.8
From 50 to 100 ha	103	43.8	599.6
From 100 to 200 ha	87	88.5	604.2
From 200 to 500 ha	126	240.8	757.7
500 ha or over	59	715.8	897.8
Total	453	189.2	648.8
$F_{(5,447)}$	-	120.3	9.5
Significance	-	***	***
Coefficient of variation	-	147.5	32.3
	Average farm size (ha UAA)	Index (total GHG on COP farms = 100)	
Less than 30 ha	20.6	3.8	58.8
From 30 to 50 ha	38.5	8.7	64.2
From 50 to 100 ha	72.4	23.1	92.4
From 100 to 200 ha	145.8	46.8	93.1
From 200 to 500 ha	309.6	127.3	116.8
500 ha or over	798.7	378.4	138.4

Note: *** Indicates significance at 1% level, ** at 5% level, * at 10% level.
Source: own calculation based on Lithuanian FADN data.

Table 5

GHG emissions of field cropping farms by farm size classes

Farm size classes of UAA	Number of farms	t CO_{2eq} farm^{-1}	kg CO_{2eq} ha^{-1}
Less than 50 ha	35	12.9	487.6
From 50 to 200 ha	52	80.1	744.9
200 ha or over	38	523.4	1,094.8
Total	125	196.0	779.2
$F_{(2,122)}$	-	49.0	15.5
Significance	-	***	***
Coefficient of variation	-	135.0	39.3
	Average farm size (ha UAA)	Index (total GHG on field cropping farms=100)	
Less than 50 ha	25.7	6.6	62.6
From 50 to 200 ha	101.7	40.9	95.6
200 ha or over	465.1	267.0	140.5

Note: *** Indicates significance at 1% level, ** at 5% level, * at 10% level.
Source: own calculation based on Lithuanian FADN data.

averaged 196.0 t CO_{2eq} farm^{-1} and ranged from 12.9 t CO_{2eq} farm^{-1} to 523.4 t CO_{2eq} farm^{-1}, in small-sized and large sized farms, respectively. The GHG emissions related to soils management comprise 91.0% of the total emissions on farms and ranged from 73.3% in small-sized farms to 91.6% in large-sized farms. The large differences were observed in GHG emissions per farm as index values varied from 6.6% to 267.0%. The same tendency of CV as in the COP farms was assessed, i.e. very large value of the CV in terms of emissions on farms and large in case of measuring GHG intensity per hectare of UAA, 135.0% and 39.3%, respectively.

Five size classes were established for the specialist dairying farms (Table 6). The methane (CH_4) emissions from livestock farming are the dominant source of emissions in dairying and averaged 91.5%. The largest share was for methane in emission structure of small-sized farms and the smallest share was observed on large-sized farms, 95.6% and 90.1%,

Table 6

GHG emissions of specialist dairying farms by farm size classes

Farm size classes of UAA	Number of farms	t CO_{2eq} farm^{-1}	kg CO_{2eq} ha^{-1}
Less than 30 ha	64	32.0	2,386.6
From 30 to 50 ha	57	83.2	2,025.0
From 50 to 100 ha	74	148.4	2,021.3
From 100 to 200 ha	66	313.0	2,293.3
From 200 or over	42	777.6	2,301.4
Total	303	234.6	2,197.2
$F_{(4,298)}$	-	105.7	1.3
Significance	-	***	ns
Coefficient of variation	-	111.7	7.7
	Average farm size (ha UAA)	Index (total GHG on dairying farms=100)	
Less than 30 ha	16.0	13.6	108.6
From 30 to 50 ha	41.2	35.5	92.2
From 50 to 100 ha	72.6	63.3	92.0
From 100 to 200 ha	137.0	133.4	104.4
From 200 or over	337.1	331.5	104.7

Note: *** Indicates significance at 1% level, ** at 5% level, * at 10% level and ns (not significant)
Source: own calculation based on Lithuanian FADN data.

Table 7

GHG emissions of grazing livestock farms by farm size classes

Farm size classes of UAA	Number of farms	t CO_{2eq} $farm^{-1}$	kg CO_{2eq} ha^{-1}
Less than 50 ha	25	51.1	1,763.9
From 50 to 100 ha	34	96.1	1,472.3
100 ha or over	33	256.7	1,447.0
Total	92	141.5	1,542.4
$F_{(2,89)}$	-	35.5	2.0
Significance	-	***	ns
Coefficient of variation	-	80.3	11.3
	Average farm size (ha UAA)	Index (total GHG on grazing livestock farms=100)	
Less than 50 ha	29.9	36.1	114.4
From 50 to 100 ha	66.0	67.9	95.5
100 ha or over	175.6	181.4	93.8

Note: *** Indicates significance at 1% level, ** at 5% level, * at 10% level and ns (not significant)
Source: own calculation based on Lithuanian FADN data.

respectively. Opposite to the results gained from the COP and the field cropping farms, the large-sized dairying farms are more engaged in their activity diversification. The GHG emissions per farm differ considerably across the farm size classes, particularly between small-sized and large-size farms. The highest level of emissions per farm was achieved on farm size class of 200 ha UAA or over and this was 3.3 times more than average emissions on dairy farms whereas the differences across farm size classes in terms of GHG emissions per unit area (expressed as emissions per hectare of UAA) were not significant and minor. This is evidenced by low calculated CV value which equalled to 7.7%.

Table 7 summarizes the results of the GHG emissions on grazing livestock farms in examined three size classes. The methane (CH_4) emissions from livestock farming are the dominant source of emission in grazing livestock farms the same as in dairying farms and averaged 95.4% ranging from 97.0% and 95.4%, in size class less than 50 ha UAA and from 100 ha UAA or over, respectively. The total emissions per farm differ considerably by farm size classes as CV equalled 80.3% whereas the differences of emissions values expressed as intensity indicator kg CO_{2eq} ha^{-1} of UAA were moderate (CV value was 11.3%) and were not statistically significant.

Table 8

GHG emissions of field crops-grazing livestock combined farms by farm size classes

Farm size classes of UAA	Number of farms	t CO_{2eq} $farm^{-1}$	kg CO_{2eq} ha^{-1}
Less than 50 ha	61	26.9	964.8
From 50 to 200 ha	99	130.8	1,186.6
200 ha or over	49	504.3	1,496.3
Total	209	188.1	1,194.5
$F_{(2,206)}$	-	161.4	12.4
Significance	-	***	***
Coefficient of variation	-	113.8	22.0
	Average farm size (ha UAA)	Index (total GHG on field crops-grazing livestock combined farms=100)	
Less than 50 ha	29.6	14.3	80.8
From 50 to 200 ha	104.1	69.5	99.3
200 ha or over	332.4	268.1	125.3

Note: *** Indicates significance at 1% level, ** at 5% level, * at 10% level.
Source: own calculation based on Lithuanian FADN data.

The average GHG emission values per farm and per area unit across three established farm size classes for field crops-grazing livestock combined farms are presented in Table 8. The methane emissions in these farms averaged 72.1%, and the lowest share was established on small-sized farms (less than 50 ha UAA).

Farms of 200 ha UAA or over were the biggest source of GHG emissions both in terms of emissions per farm and per area unit. The gap between farm size class less than 50 ha UAA and from 200 ha UAA or over is large, as the emissions in the largest size farm class were 18.7 times higher than in small-sized farms class. Additionally, the CV value of about 113.8% indicated very large differences regarding emissions per farm. The variation of GHG emissions per unit area (kg CO_{2eq} ha^{-1}) was found significant among different farm size classes with CV value of 22.0%.

Conclusions

1. The assessment of GHG emissions on farms revealed that:
   - major sources of GHG emissions are related to the use of chemical fertilizers on farms comprising 52.6% of the total emissions from family farms. Therefore, chemical fertilizer application planning on farms should be taken into account in achieving environmentally and climate friendly agricultural sector;
   - the GHG emissions on farms averaged 184.2 t CO_{2eq} $farm^{-1}$ and ranged from 5.8 t CO_{2eq} $farm^{-1}$ to 234.6 t CO_{2eq} $farm^{-1}$, on the permanent crop farms and on the specialist dairying farms, respectively;
   - the GHG emissions differ significantly across farm size classes. In small-sized farms, the lowest level was estimated, but in the large-sized farms - the highest level of the GHG emissions, 63.3 t CO_{2eq} $farm^{-1}$ and 479.6 t CO_{2eq} $farm^{-1}$, respectively;
   - the GHG emissions intensity averaged 1,200.3 kg CO_{2eq} ha^{-1} of UAA on family farms and varied from 98.9 kg CO_{2eq} ha^{-1} of UAA to 5,082.7 kg CO_{2eq} ha^{-1} of UAA on the permanent crop farms and on specialist granivores farms, respectively.
2. The GHG assessment across different farming types and farm size classes provides insights for farmers and policy makers about the source and magnitude of GHG emissions in the agricultural sector. Alongside, the indicator related to the GHG emissions on farm can contribute to the continued development of sustainability assessment tool at a farm level.

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