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Benchmarking the GHG emissions intensities of crop and livestock–derived agricultural commodities produced in Latvia

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Abstract. With the production of grain and livestock–derived agricultural commodities increasing, the agricultural sector has become one of the main sources of greenhouse gas emissions (GHG) in Latvia. In 2016, the agricultural sector contributed to 23.6% of the total GHG emissions originated in Latvia (266.4 kt CO_2eq), and therefore the mitigation of the emissions is important. Considering the new indicative target, Latvia must reduce its GHG emissions in the non-ETS sectors by 2030 (Regulation 2018/842) so that the emissions do not exceed the 2005 level. The research aims to estimate the emissions intensities (EI) of grain and livestock-derived commodities produced in Latvia and benchmark the EI against those for other countries. The GHG EI were analysed per kilogram of product (kg CO_2eq kg^{-1}) and per hectare currently in use agricultural land (kg CO_2eq ha^{-1}). The main part of the GHG emissions of crop production originated from fertilizer application (direct N_2O emissions) and soil liming (direct CO_2 emissions). The main part of the GHG emissions of livestock–derived production originated from livestock enteric fermentation (direct CH_4 emissions) and from manure management systems (direct CH_4 and N_2O emissions). The EI per hectare of industrial crops and grain were 550.5 and 438.4 kg CO_2eq ha^{-1}, respectively. The yield and fertilizer application had a strong impact on the EI per kilogram of product. Pulses had a lower EI (0.003 kg CO_2eq kg^{-1}), while industrial crops (0.17 kg CO_2eq kg^{-1}) and grain (0.09 kg CO_2eq kg^{-1}) had the highest EI. A comparison of the GHG EI of crop and livestock–derived agricultural commodities per kilogram of product between Latvia and other EU Member States showed: Latvia had the lowest grain EI (0.09 kg CO_2eq kg^{-1}), but one of the highest cattle meat EI (25.18 kg CO_2eq kg^{-1}) and milk EI (0.64 kg CO_2eq kg^{-1}).

Key words: GHG, emissions intensity, commodities, benchmarking.

INTRODUCTION

In 2016, agricultural GHG emissions made up 23.6% of the total GHG emissions originated in Latvia (NIR, 2018), and the emissions are viewed as an important factor affecting the sustainability of agriculture (Lenerts et al., 2017). An increase in the emissions makes a negative impact on the value of natural capital. The accumulated information on agricultural GHG emissions is a basis for decision-making regarding how to mitigate the negative environmental impact. At the same time, agriculture has to meet the growing demand for food under available resource constraints (FAO, 2017). A priority for the nearest future for agriculture is to find a solution to how to produce more food without decreasing the value of natural capital. One of the solutions is to estimate and account for the environmental impact of agricultural holdings (Lenerts et al., 2017). This implies establishing an economic system that considers a decrease in the value of natural capital to be external costs related to GHG emissions produced by economic activity. One of the indicators for estimating an impact at the micro-level is agricultural GHG emissions intensity (EI). In the EU, research on GHG EI focuses on both livestock production (Leip et al., 2010) and grain production (Carlson et al., 2017). Such a metric/indicator could contribute to adapting the management system to a low emission cycle, which could be an opportunity for economic growth as well as sustainability in the future. Based on this metric, it is possible to assess an economic process on agricultural holdings and identify whether the economic growth pattern of the agricultural holdings is extensive or intensive. The economic growth pattern makes a significant effect on the EI of agriculture (Bonesmo et al., 2013 and Bonesmo et al., 2012).

The research **aim** is to assess the emissions intensity of agriculture in Latvia and benchmark it against those in other EU Member States. To achieve the aim, the following specific **research tasks** were set: to examine a methodology for calculating and assessing agricultural GHG emissions intensity; to perform an assessment of the GHG emissions intensity of agriculture in Latvia; to benchmark the agricultural GHG emissions metrics among the EU Member States.

The research used the Central Statistical Bureau of Latvia (CSB), Eurostat and FAO databases. To process the data, the following economic **research methods** were employed: data grouping for statistical indicator calculation; time series, correlation and regression analysis.

MATERIALS AND METHODS

GHG emissions from agriculture are quantified by using the IPCC guidelines and methodology (IPCC 2018). The calculated indicators show the intensity of economic activity in a particular territory (country), yet they do not reveal emissions intensity for the production process as well as products produced. The characteristics and distribution of GHG emission sources and categories are presented in Table 1.

Table 1. Distribution of agricultural GHG emissions accounted for by group of sources and by category

Characteristics of groups of GHG emission sources	GHG emission category
Change in carbon (C) stocks (GHG emissions produced or C absorbed) in agricultural land for the entire utilised agricultural area	CO_2
Natural soil emissions for the entire utilised agricultural area	N_2O
Emissions from soil liming for the entire utilised agricultural area	CO_2
Emissions from fertiliser application for the entire utilised agricultural area	N_2O
Emissions from organics soils for the utilised agricultural area	N_2O
Emissions from livestock enteric fermentation	CH_4
Emissions from manure management systems	CH_4; N_2O

For the purpose of simple comparison and interpretation of data, emission inventory reports use a calculated CO_2 equivalent (eq) value, depending on the potential of anthropogenic greenhouse gases for making impacts on climate change (CH_4; N_2O and CO_2). Were used 25 CH_4 and 298 for N_2O global warming potential values to determine the effect of CH_4 and N_2O on climate change. Generalised emission factor values are used based on the IPCC Tier 1 methodology. The groups of emission sources determined in reality pertain to various technological processes and production systems, yet the mentioned methodology does not allow detailing the processes and systems and calculating an accurate emission factor for a particular country. The Tier 2 methodology employs emission factors for individual countries that have been proved by research investigations. Calculations are constrained by the extent of detail provided for technological processes and systems. The Tier 3 methodology allows for an individual approach to GHG emission calculations by each country. The current GHG emission inventory data are considerably constrained (MacLeod., 2018) because: agricultural GHG emissions are determined for individual processes instead of integrated ones; GHG emission calculations do not take into account the factors of technological processes and production systems (crop rotation, soil tillage etc.); the calculations determine total emissions instead of EI (per some unit of measure).

The data might be misleading, as changes in emissions could occur owing to changes in agricultural activity as a whole rather than changes in EI. That is why it is necessary to complement quantitative agricultural GHG emission indicators by EI metrics. The recommended EI metrics are summarised in Table 2.

Table 2. Agricultural GHG emission intensity indicators

Emissions intensity metric	Attributable to	Description
kg CO_2eq/country/territory	Country, territory	It is used in current national GHG emission inventories; does not show the amounts of GHG emissions produced by various industries and production efficiency
kg CO_2eq/kg product^{-1}	Food produced	It allows analysing the emissions intensity of the same product produced in various territories and production systems. It is not possible to compare products of different energy values.
kg CO_2eq/kg CP kg DM^{-1}	Value of crude protein (CP)	It allows comparing emissions intensity of products measured per unit of weight, nutritional value and energy value.
kg CO_2eq/MJ kg DM^{-1}	Energy value produced (MJ)	
kg CO_2eq/EUR^{-1}	Economic value of production	It allows assessing economic growth. It is difficult to interpret the role of the metric in practice. Changes in emissions intensity might be related to changes in: 1) production efficiency; 2) increase in value; 3) both.

Emissions intensity indicates the production efficiency of agricultural commodities, which depends on the accumulated disposable energy and nutrients of the commodities. Agricultural commodities that should be produced might be identified depending on needs and future market demand, thereby contributing to a low GHG-emissions-intensity production system (Audsley & Wilkinson, 2014). GHG emissions from the production of key agricultural commodities and the accumulated disposable energy and nutrients are presented in Table 3.

Table 3. Yield, composition and GHG emissions of key crops

Production indicator / Product	Average yield, t ha^{-1}	Dry matter (DM) content g kg^{-1}	Metabolisable energy (ME) MJ kg DM^{-1}	Crude protein (CP) content g kg DM^{-1}	GHG emissions, kg CO_2eq per unit of measure:		
					kg^{-1}	GJ ME^{-1}	kg CP^{-1}
Winter wheat for food	7.7	860	13.6	130	0.51	0.044	4.56
Winter wheat for feed	8.1	860	13.6	116	0.46	0.039	4.61
Barley	5.7	860	13.2	116	0.38	0.033	3.81
Winter rapeseed	3.2	930	23.1	212	1.05	0.049	5.33
Sugar beet	63	220	13.2	68	0.04	0.015	2.87
Potato	48	200	13.3	93	0.1	0.038	5.38
Field beans	3.4	860	13.3	298	0.03	0.056	1.99
Maize (green forage)	11.2	280	11	101	0.3	0.027	2.97

The research results (Audsley & Wilkinson, 2014) revealed that the most emissions-intensive crops were potato – if measured per unit of accumulated crude protein content – and field beans – if measured per unit of accumulated energy. In the context of GHG emission change/reduction, a prudent and purposely-shaped cropping pattern and technologies and production systems used become increasingly important.

Crop and livestock production requires a certain amount of production resources. Upon starting agricultural business, an agricultural holding can decide what to produce and how to do it by employing all the disposable resources. The production process could be expressed as a function of the factors of production.

$$P=f(x_1, x_2, x_3, \ldots, x_n) \tag{1}$$

where P – output; $x_1, x_2, x_3, \ldots, x_n$ – GHG-intensive factors of production used.

The function shows how and how fast resources are turned into a final product and how many units of (for example) nitrogen (N) fertiliser or soil liming material have to be applied to acquire the crop yield planned. A linear increase in use of the factors of production logically increases the amount of GHG emissions and decreases the use efficiency of resources. Research studies have proved that GHG emission intensity decreases if production inputs are accurately accounted for and compared with output. An increase in the area sown with emission-intensive crops inevitably increases the total amount of emissions produced. According to the research studies examined, EI is lower if papilionaceous crops are included in crop rotation (Brock et al., 2012; Gan et al., 2014 and Alhajj Ali et al., 2015) and the crop rotation is observed (Kustermann et al., 2013). EI increases if growing monocrops (Barber et al., 2011; Roos et al., 2011; Ma et al., 2013; Wojcik-Gront & Bloch-Michalik, 2016). The research studies examined indicate the need to determine GHG emission factors tailored to the conditions in Latvia. It is recommended employing the Tier 2 methodology where appropriate and enhancing the Tier 3 methodology, as a dispersion analysis of emission factor values (552–8,360 kg CO_2eq ha^{-1}) allows concluding that the emission factors are significantly affected by the technologies and production systems used by each agricultural holding.

Fig. 1 shows GHG emissions intensity values (kg CO_2eq ha[-1]) for various soil tillage technologies and different kinds of crop rotation.

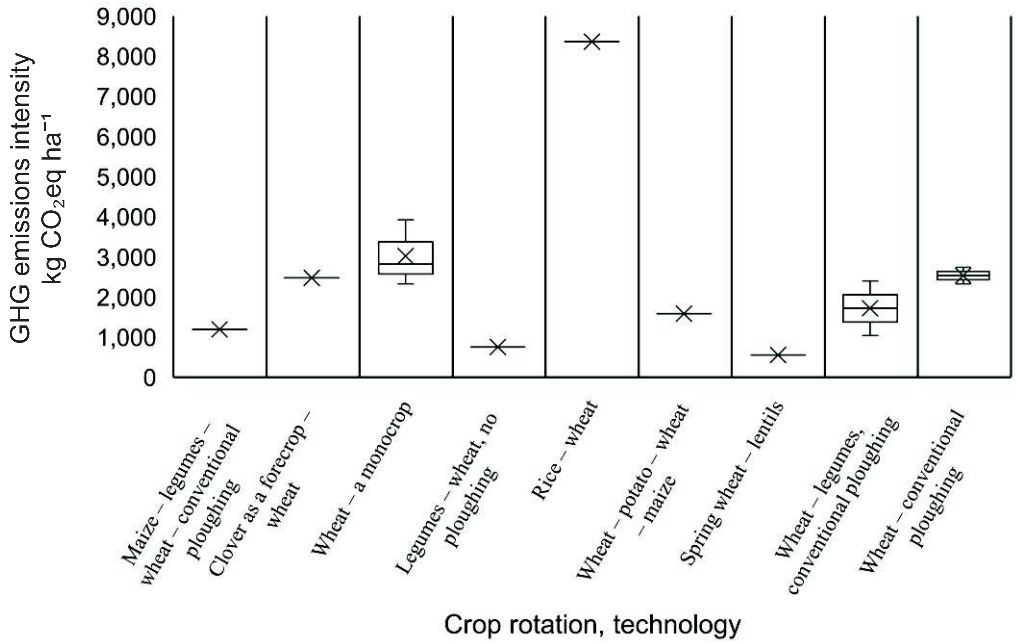

Figure 1. GHG emissions intensity values for wheat production (kg CO_2eq ha^{-1}) by kind of agricultural practice.

In Latvia, GHG emissions intensities can vary across regions and agricultural holdings. The production of one tonne of wheat results in GHG emissions of up to 500 kg CO_2eq. An increase in N fertiliser application efficiency and N_2O emissions is directly affected by the type of soil, meteorological conditions and soil quality characteristics. Depending on the type of soil, the performance of an amelioration system and soil temperature, for example, N_2O emissions from N fertilisers applied vary in the range from 0.84% for loamy soils to 4.67% for wet clay soils (Brentrup & Pallière, 2008).

Two approaches are employed to calculate GHG EI values (MacLeod et al., 2016). Depending on the purpose, emissions are categorised:

- direct GHG emissions from agricultural production;
- direct and indirect emissions from agricultural production (Life Cycle Analysis, LCA).

The research determines direct GHG emissions from agricultural production for the purpose of calculation of GHG EI.

RESULTS AND DISCUSSION

In 2016 in Latvia, the key sources of agricultural GHG emissions were as follows: nitrous oxide (N_2O) emissions from agricultural soils, accounting for most (59.5%) of the total emissions, and methane (CH_4) emissions from livestock enteric fermentation, which was the second largest emission source, comprising 32.3% of the total. Methane CH_4 and nitrous oxide (N_2O) emissions from manure management comprised 7.1%, while CO_2 emissions from soil liming and urea application totally made up 1.1% of the total agricultural emissions in 2016 (NIR 2018).

In 2015, 1,884.8 thou. ha of land was utilised in Latvia. Of this area, 1,229.8 thou. ha was arable land. The key crops grown in arable land were as follows: grains 672,4 thou. ha; industrial crops 91 thou. ha; maize for silage and green forage 25,5 thou. ha; potato 24,8 thou. ha; legumes 31,6 thou. ha and open field vegetables 8,1 thou. ha. In 2015 compared with 2005, the utilised agricultural area rose by 8.7%. However, the arable land area increased by 12.6%.

An analysis of EI values measured per unit of agricultural area revealed that industrial crops had the highest EI value (550.4714 kg CO_2eq ha^{-1}). Grains demonstrated a 20% lower emissions intensity (438.43 kg CO_2eq ha^{-1}), whereas legumes had the lowest EI value (9.3 kg CO_2eq ha^{-1}).

GHG emissions intensity values measured per unit of output (kg CO_2eq product kg^{-1}) are presented in Fig. 2.

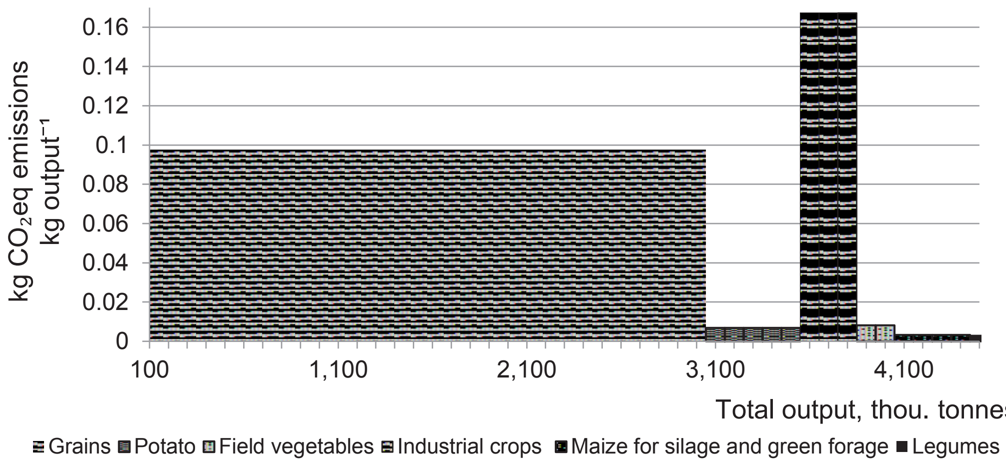

Figure 2. Total crop output (thou. t.) and the EI (kg CO_2eq product kg^{-1}) of N fertiliser applied to agricultural soils for selected crops in Latvia in 2015.

The calculations revealed that industrial crops had the highest per-unit emissions intensity (0.17 kg CO_2eq product kg^{-1}). In grain production, the GHG emission intensity was 58% lower, reaching 0.09 kg CO_2eq production kg^{-1}.

CSB and FAO data were employed to calculate changes in GHG EI in Latvia in the period 2005–2015. In the period of analysis, grain yields rose by 60%, while the GHG EI of grains rose by 12% (0.09 kg CO_2eq grain kg^{-1}). Milk yields per cow rose by 35%, whereas the GHG EI of milk production decreased by 25%. A negative trend was demonstrated by beef production, as the beef output decreased by 18%, while the GHG EI of beef production increased even by 35%. Latvia had the second highest proportion of agricultural GHG emissions in the total emissions among the non-ETS sectors across

EU Member States. In the period 2005–2015 in Latvia, agricultural output rose by 69%, and the GHG EI of it (kg CO_2eq UAA ha^{-1}) rose by 13%.

Changes in GHG EI values are summarised in Table 4.

Table 4. Output of grain, milk and beef and the GHG EI of grain, milk and beef production (kg CO_2eq product kg $^{-1}$) in Latvia in the period 2005–2015

Year	Grain		Milk		Beef	
	Yield, t. ha^{-1}	EI, kg CO_2eq grain kg^{-1}	Milk yield per cow, kg year^{-1}	EI, kg CO_2eq milk kg^{-1}	Beef per animal, kg year^{-1}	EI, kg CO_2eq beef kg^{-1}
2005	2.8	0.08	4,364	0.89	52.99	16.46
2006	2.26	0.09	4,492	0.88	54.91	17.6
2007	2.94	0.08	4,636	0.84	57.14	15.57
2008	3.1	0.08	4,822	0.83	56.32	18.53
2009	3.08	0.09	4,892	0.79	54.23	18.67
2010	2.65	0.09	4,998	0.77	48.54	21.03
2011	2.68	0.09	5,064	0.75	47.24	21.76
2012	3.7	0.08	5,250	0.72	44.02	22.76
2013	3.34	0.09	5,508	0.69	41.13	24.92
2014	3.4	0.08	5,812	0.65	41.94	24.89
2015	4.49	0.09	5,905	0.64	44.87	25.18
Change from 2005 base year, %	+60	+12	+35	-25	-18	+35

An increase in agricultural output considerably increases agricultural GHG emissions. The results for all the EU Member States are presented in Fig. 3.

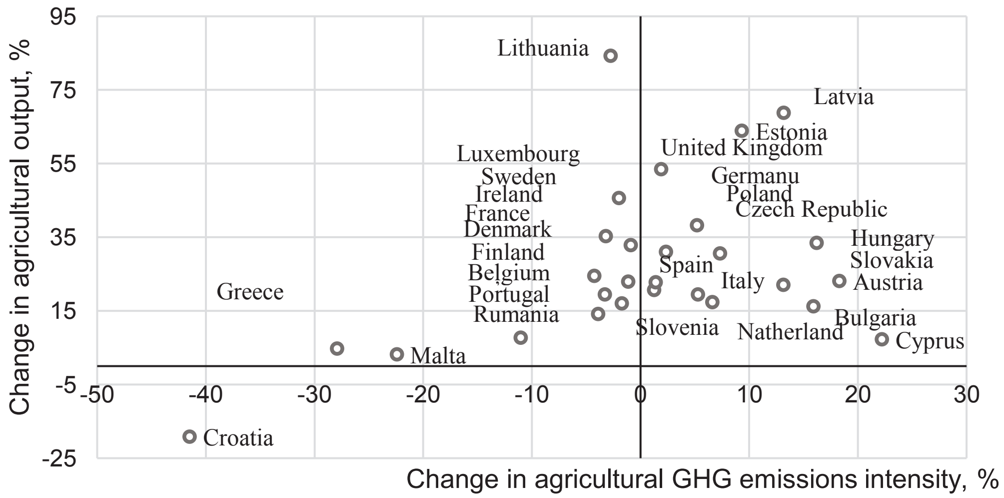

Figure 3. Changes in agricultural output and GHG emissions intensity (CO_2eq ha^{-1}), % in EU Member States in the period 2005–2015.

A positive correlation between GHG emissions and agricultural output for the period 2005–2015 was observed in the countries that increased their arable land areas and areas under grains. The amounts of N_2O emissions considerably increased in

Bulgaria, Latvia and Estonia. A group of the Member States, Lithuania in particular, have proved that they could considerably increase their agricultural output (+84%) while also lowering the GHG EI (-2% CO_2eq ha^{-1}). An increase in the output of grain in Latvia is likely to lead to a higher EI, thereby creating a serious challenge for farmers.

The benchmarking analysis of agricultural GHG EI for the EU Member States reveals the different levels of agricultural intensification. The overall GHG EI of beef production for the EU Member States are presented in Fig. 4.

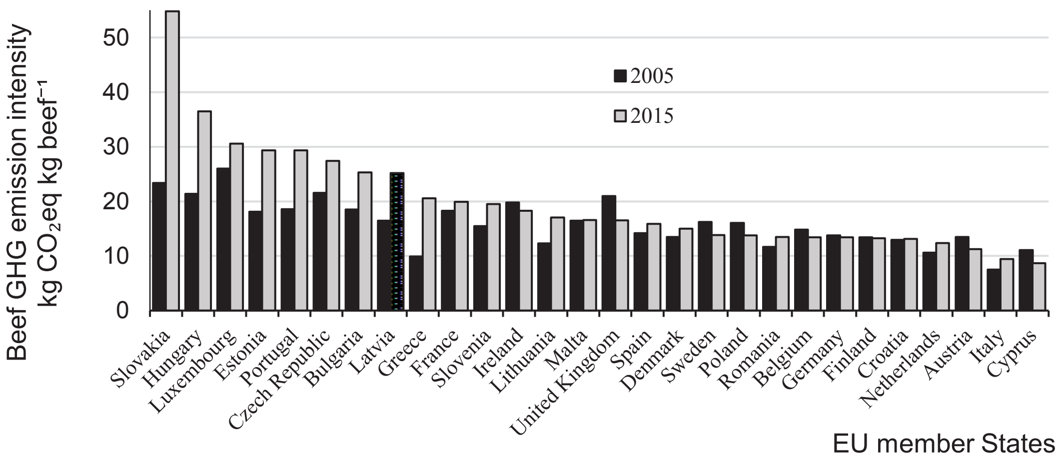

Figure 4. Beef GHG emission intensity (kg CO_2eq kg beef^{-1}) in the EU Member States in the period 2005–2015.

Among the typical agricultural commodities produced in Latvia, beef production had the highest GHG EI, exceeding the EU average by 27% (19.77 kg CO_2eq kg beef^{-1}).

The GHG emissions intensities of grain production for the period 2005 – 2015 are presented in Fig. 5.

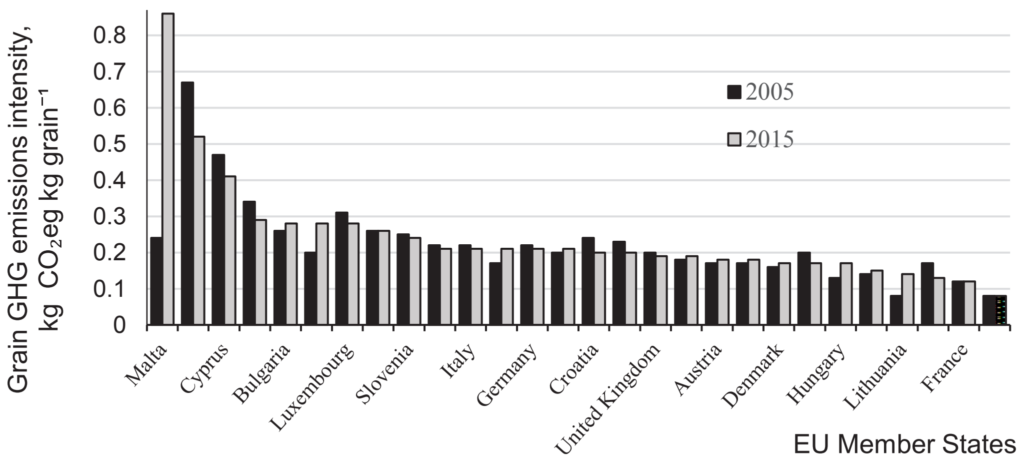

Figure 5. Grain GHG emissions intensity (kg CO_2eq kg grain^{-1}) in the EU Member States in the period 2005–2015.

The average GHG EI of grain production in the EU was 0.24 kg CO_2eq kg grain^{-1}, which was three-fold higher than in Latvia. This indicates that an increase in the output of grain was achieved by extensively increasing the area under grains and applying relatively low fertiliser rates. Using agricultural land with low quality characteristics for grain production, the GHG emissions intensity might increase in the future, as it requires applying higher fertiliser rates to increase crop yields. The differences in the GHG emissions intensity of grain production among the EU Member States affect differences in soil quality characteristics and climatic factors, which were not examined because of the limitations of the research.

The GHG emissions intensities of milk production are presented in Fig. 6.

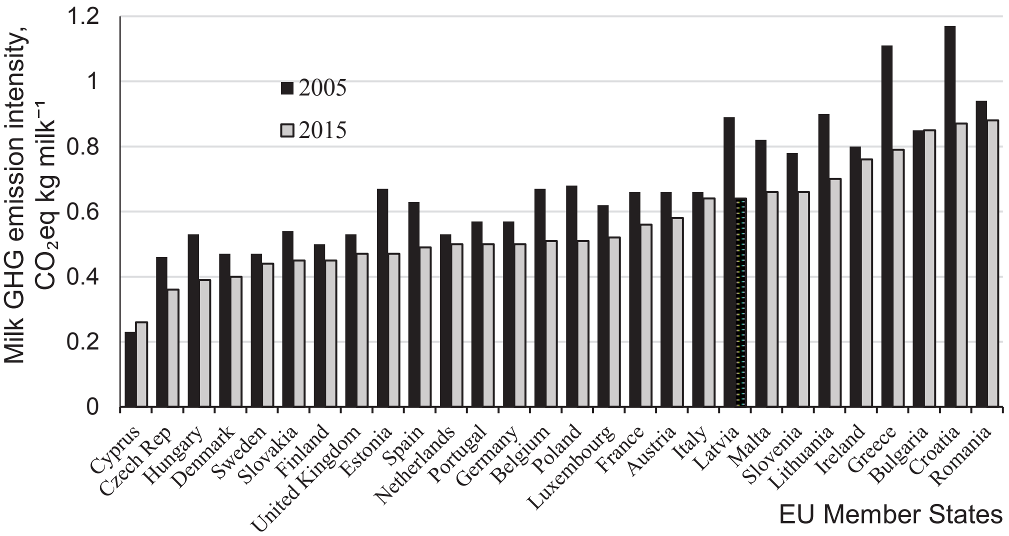

Figure 6. Milk GHG emission intensities (kg CO_2eq kg milk^{-1}) in the EU Member States in the period 2005–2015.

In the period of analysis, Latvia demonstrated the largest decrease in the GHG emission intensity of milk production at 28%, thereby approaching the EU average (0.54 kg CO_2eq kg milk^{-1}). The GHG emission intensity of milk production was strongly associated with dairy cow productivity. A strong positive correlation could be found between dairy cow productivity and GHG emission intensity among the EU Member States.

CONCLUSIONS

The quantitative (kg CO_2eq/kg product^{-1}) and value (kg CO_2eq/EUR^{-1}) metrics better explain production efficiency of agricultural commodities and more objectively indicate agricultural GHG EI.

A positive correlation between GHG EI (CO_2eq ha^{-1}), and agricultural output for the period 2005–2015 was observed in the countries that increased their arable land areas and areas under cereals. The amounts of N_2O emissions considerably increased in Bulgaria, Latvia and Estonia.

Study found Lithuania considerably increased its agricultural output (+84%) while also lowering the GHG EI (-2%) with changes in arable crops structure.

Calculated among the typical agricultural commodities produced in Latvia, beef production had the highest GHG EI, exceeding the EU average by 27% (19.77 kg CO_2eq kg beef^{-1}). Results show we need to improve production efficiency.

Growing cereals in Latvia may be more intense as the average GHG EI of grain production in the EU was 0.24 kg CO_2eq kg grain^{-1}, which was three-fold higher than in Latvia.

Improving production efficiency Latvia demonstrated the largest decrease in the GHG EI of milk production at 28%, thereby approaching the EU average (0.54 kg CO_2eq kg milk^{-1}).

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