GHG EMISSIONS INTENSITY IN AGRICULTURE: CASE OF LATVIA

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Abstract. International and regional incentives towards environmental sustainability (e.g. the Paris Agreement, the European Green Deal, the EU Action Plan on Sustainable Finance) not only include measures to mitigate climate change and contribute to other environmental objectives but also introduce sustainability reporting. Sustainability reporting is expected to become a key element of corporate reporting, potentially at least as significant as financial reporting. Sustainability reporting involves the use of new indicators and metrics, e.g. GHG emission intensity or GHG intensity based on net revenue. GHG emissions intensity is becoming a significant indicator within the suitability reporting framework. It measures GHG emissions in relative terms, enabling the comparison of companies (undertakings) not only within the same sector but also among different sectors. Financial institutions are likely to incorporate this indicator into their decision-making models and procedures, including credit provision. The aim of the study is to assess GHG emissions intensity in agriculture, also in comparison with other sectors (manufacture of birch plywood products, manufacture of metal products and electricity power generation). The findings of the study imply that GHG emissions intensity in agriculture is rather high compared to other sectors. However, incomplete data on Scope 3 emissions limit the generalisation of these findings. The results suggest that inter-sector comparisons based on this indicator may be unfavourable for agricultural companies. Therefore, further research is required before this indicator is widely adopted and incorporated into decision-making models, particularly in the banking sector.

Keywords: GHG emissions intensity, sustainability reporting, environmental sustainability, crop production.

Introduction

In the context of global and regional sustainability initiatives, such as the Paris Agreement and European Green Deal, the need to mitigate greenhouse gas (GHG) emissions across various sectors has been emphasized. For the EU member states the goal is set in the European Climate Law to achieve net-zero GHG emissions by 2050 and to reduce net GHG emissions by at least 55% by 2030, compared to 1990 levels [1]. However, current nationally determined contributions remain seriously inadequate to achieve the climate goals of the Paris Agreement [2] and stronger national-level strategies are required to significantly reduce GHG emissions in the coming years [3].

To support the goals of the European Green Deal by directing financial flows toward sustainable investments, the EU Action Plan on Sustainable Finance was launched in 2018 with standardized sustainability reporting system as a key component of this framework, and is expected to become a key element of corporate reporting, potentially at least as significant as financial reporting [4]. The sustainability reporting introduces a broad set of new environmental, social, and governance (ESG) indicators and metrics, including energy and water consumption, biodiversity impact, supply chain sustainability, and also GHG emissions intensity or carbon footprint relative to net revenue [5]. The last has gained particular attention because it allows comparisons across industries, providing valuable insights for sectoral benchmarking. Financial institutions are likely to incorporate this indicator into their decision-making models and procedures, including credit provision.

The KPMG Survey of Sustainability Reporting (2024) shows that sustainability reporting and carbon target-setting have become usual practices worldwide. Among the 5 800 companies surveyed, 79% report on sustainability, and 80% disclose their carbon targets [6]. All the companies surveyed by KPMG in Japan, Malaysia, Singapore, South Africa, South Korea, Thailand and the United States report on ESG and sustainability and according to KPMG forecasts Corporate Sustainability Reporting Directive (CSRD) will make reporting on sustainability mandatory for around 50 000 companies including thousands headquartered outside the EU [6].

At the moment, sustainability reporting is not widespread in Latvia. In terms of numbers, small and medium-sized enterprises (SME) dominate Latvia's economy [7] and it is highly likely that most of them will not become direct subjects of the CSRD and the Taxonomy Regulation. Although they are expected to face indirect requirements to disclose information on sustainability, likely coming from banks and larger supply chain participants that are subject to sustainability regulations.

This largely applies to agricultural enterprises as well. The authors have estimated that the number of farms potentially affected by the CSRD is small, accounting for no more than 18.7% of the industry total turnover and 7.2% of its workforce [8] without considering the effect on the Omnibus Simplification Package proposed by the European Commission, which would reduce the scope of the regulatory framework [9]. Nevertheless, according to the Farm Accountancy Data Network (FADN), the liabilities to assets ratio for a farm in Latvia averaged 33% in 2023 [10], indicating a relatively high need for external financing, and market-oriented farms are often involved in both upstream (resource procurement) and downstream (sales of produced goods) supply chains. Thus, research related to sustainability reporting, including carbon metrics and GHG emissions intensity measurements is important for developing knowledge and understanding in this field.

The aim of the study is to assess GHG emissions intensity for winter wheat and rapeseed production in integrated farming in Latvia, in comparison with other sectors (manufacture of birch plywood products, manufacture of metal products and electricity power generation) possibly covering Scope 1, 2, and 3 emission sources. Crop production plays a vital role in agricultural landscape in Latvia, engaging 1.36 thousand ha of arable lands [11] and making EUR 0.974 billion (56%) of total output in 2023 [12]. Wheat and oilseed rape dominate the sown area, together covering more than 53% of this area in 2023 [11]. Data from the FADN reveal that field crop farms have a debt ratio above the sector average, standing at 37.5% in 2023 [10].

According to crop rotation research conducted by Auzins *et al.*, wheat is grown across the entire country, most often alternating with oilseed rape or other cereals [13]. Additionally, 6% of the wheat area is cultivated as a monoculture. Oilseed rape is typically included in crop rotation once within a five-year cycle; however, there are fields where it is grown at least twice within the same period. The inclusion of legumes or other protein crops in crop rotation is not a common practice in Latvia, with legumes and pulses covering only 3% of the total integrated arable land [13]. Crop production, while essential for food and feed supply, contributes to GHG emissions through soil management practices, fertiliser application, and energy use in field operations [14; 15]. Understanding the emissions intensity of this sector not only provides insight into their environmental footprint but also helps identify opportunities for more efficient and sustainable farming methods [16].

Materials and methods

According to both the adopted full-frame European Sustainability Reporting Standards (ESRS) and the ESRS for listed small medium undertakings (ESRS LSME) proposed by the European Financial Reporting Advisory Group (EFRAG), the GHG emissions intensity or GHG intensity based on net revenue is calculated as the ratio of total GHG emissions (Scope 1, 2 and 3) to net revenue [17; 18]. As sometimes term “net revenue” is confused with net income, which refers to profit not revenue, the term “net sales” or “revenue” is used in this paper. To make the analysis of this indicator more comprehensive, in this study, the indicator has been calculated not only based on total GHG emissions but also on Scope 1, 2, and 3 emissions. The GHG emissions intensity has been calculated using 2023 data, as it is the latest year for which data is available, particularly for benchmarks.

To assess both GHG emissions and revenue of the cultivation of winter wheat and winter oilseed rape, the annual agricultural gross margins calculated for 2023 by the Latvian Rural Advisory and Training Centre (LLKC) [19] have been used as a data source. Scope 1 biogenic emissions have been assessed based on the yield and consumption of nitrogen (N) fertilisers, using a Tier 1 approach and the emission factors from the 2019 Refinement to the 2006 IPCC Guidelines [20].

To calculate direct nitrous oxide (N_2O) emissions, an emission factor of 0.016 kg N_2O-N per kg N is used for synthetic fertiliser inputs and 0.006 kg N_2O-N per kg N for crop residues. N inputs from crop residues are calculated using a combination of ratios and N content from Table 11.1A of the 2019 Refinement, national data for wheat from the Latvia’s National Inventory Report [21], and the Cool Farm Alliance data for oilseed rape [22].

According to the Latvia's National Inventory Report, a ratio of 1.00 is used for above-ground residue to harvested yield for winter wheat. The N content of above-ground residues is 0.005 kg N per kg of dry matter, while for below-ground residues, it is 0.006 kg N per kg of dry matter. The ratio of below-ground root biomass to above-ground shoot biomass is 0.23 (Table 11.1A of the 2019 Refinement). The standard dry matter fraction is 0.86 [21].

For winter oilseed rape, crop residue parameters are taken from the Cool Farm Alliance: the ratio of above-ground residue to harvested yield is 2.3; the ratio of below-ground root biomass to above-ground shoot biomass is 0.085; and the N content of both above-ground and below-ground residues is 0.0053 kg N per kg of dry matter. The standard dry matter fraction is 0.92 [21].

Indirect N_2O emissions from volatilisation/deposition are obtained by considering that 11% of synthetic fertilisers N volatilise, with an emission factor of 0.014 kg N_2O-N per kg NH_3-N and NO_x volatilised. To calculate indirect N_2O emissions from leaching and runoff, it is assumed that 23% of applied N is lost by leaching/runoff (according to the Latvia's National Inventory Report), with an emission factor of 0.011 kg N_2O-N per kg N lost [21].

Scope 1 emissions from fuel combustion are calculated according to estimated diesel fuel consumption for machinery operations and CO_2 emission factor. The tool for designing the appropriate land cultivation system (developed within the agricultural European Innovation Partnership (EIP-AGRI) project "Progressive land cultivation system as the basis for environmentally friendly and effective crop production") [23] has been used to estimate diesel fuel consumption. These figures of specific fuel consumption are very similar to the study by Auzins *et al.* [24]. The emission factor for diesel fuel has been derived from the Methodology for Calculating Greenhouse Gas Emissions – 2.663334 kg CO_2 per litre (l or dm^3) [25]. Scope 2 emissions have not been estimated due to unavailable data on electricity consumption. Nevertheless, the cultivation of winter wheat and winter oilseed rape do not involve significant consumption of electricity, and the main energy input is related to fuel. Thus, the lack of Scope 2 emission assessment should not significantly affect the results of the study.

According to the Corporate Value Chain (Scope 3) Accounting and Reporting Standard by the Green House Gas Protocol, Scope 3 emissions are categorised into 15 distinct categories [26]. In this study two categories have been considered and assessed:

1. Purchased goods and services – only emissions from the production of mineral fertilisers and pesticides (plant protection products) consumed in the cultivation of winter wheat and winter oilseed rape;
2. Fuel- and energy-related activities (not included in Scope 1 or 2) – emissions from the production, transportation, and distribution of fuels consumed in the cultivation of winter wheat and winter oilseed rape.

The other categories have not been considered both due to data unavailability and their low significance. However, some categories (e.g. processing of sold products) could be potentially significant.

The methodology (including emission factors) by Cool Farm Alliance has been used to assess Scope 3 emissions related to both mineral fertilisers and pesticides. The following emission factors have been used for N fertilisers: ammonium nitrate – 1.14460337 kg CO_2-eq per kg product, ammonium sulphate nitrate – 0.79715551 kg CO_2-eq per kg product and ammonium sulphate – 0.56354129 kg CO_2-eq per kg product [22]. To assess the emissions from consumed NKP (Nitrogen, Phosphorus, and Potassium) fertilisers, the general (base) emission factor (0.06734666 kg CO_2-eq per kg product) and specific fertiliser nutrient production emissions factors (2.78882141 kg CO_2-eq per kg N, 0.12460127 kg CO_2-eq per kg P_2O_5, and 0.413667 kg CO_2-eq per kg K_2O) have been used [22].

The annual agricultural gross margins calculated by the LLKC provide only information about the costs of pesticides but do not provide application rates. The application rates have been derived from crop technological models developed by the LLKC within the EIP-AGRI project "Development of an electronic farm management system" [27]. The content of active ingredient has been derived from the list of plant protection products by the State Plant Protection Service [28]. The following emission factors have been used for pesticides: herbicides – 8.7346 kg CO_2-eq per kg active substance (winter wheat) and 9.3435 kg CO_2-eq per kg active substance (winter oilseed rape), fungicides – 13.5031 kg CO_2-eq per kg active substance (winter oilseed rape), insecticides – 10.4984 kg CO_2-eq per kg active substance (winter oilseed rape) [22]. According to the data by the LLKC, plant growth regulators (retardants) are typically used in winter wheat cultivation. However, the Scope 3 emissions of this product have not been assessed due to the lack of emission factors.

Emissions from the production, transportation, and distribution of diesel fuels consumed in crop production have been assessed by applying the well-to-tank (WTF) factor. To ensure cautious assessment, the lowest WTF factor (for diesel – average biofuel blend) by the DEFRA 0.60986 kg CO_2-eq per l has been used [29].

The assessed Scope 1 and 3 emissions for the cultivation of winter wheat and winter oilseed rape are presented in Table 1.

Table 1

Assessed GHG emissions in crop production (kg)

Indicator	Winter wheat	Winter oilseed rape
Scope 1, kg CO_2-eq·ha^{-1}:		
Direct and indirect N_2O emissions	1 021.28	1 055.10
Emissions from fuel combustion	154.29	165.15
Total	**1 175.57**	**1 220.25**
Scope 3, kg CO_2-eq·ha^{-1}:		
Emissions from consumed mineral fertilisers	374.56	382.51
Emissions from consumed mineral pesticides	0.16	7.78
Emissions from the production, transportation, and distribution of diesel fuel	35.33	37.82
Total	**410.05**	**428.10**

In Latvia, public sustainability reporting is not yet developed and hardly any agricultural enterprises report their GHG emissions. Therefore, AUGA group, AB, a Lithuania-based company with core business in farming and listed on NASDAQ Vilnius, is selected as a benchmark for agriculture. It should be noted that *AUGA group* has reported Scope 1 emissions both including and not including GHG emission sources from the Land Use, Land-Use Change, and Forestry (LULUCF) sector (see Table 2) [30]. The other selected benchmarks are derived from Latvia-based companies which report GHG data:

1. Latvijas finieris, AS – core business in the manufacture of products of wood, cork, straw and plaiting materials (NACE code rev.2 16.2), specifically production, research and development of birch plywood products;
2. Jensen metal, SIA – core business in the manufacture of other fabricated metal products (25.9);
3. Latvenergo, AS – core business in electricity generation and trade (35.1).

It should be noted that *Jensen metal* reports GHG emissions as a single figure without explicitly specifying the scope. It is assumed that these emissions include Scope 1 and 2 but do not include Scope 3. The calculated GHG emission benchmarks are presented in Table 2.

Table 2

GHG emissions intensity benchmarks (2023 data)

Indicator	AUGA group (LT)*	AUGA group (LT)**	Latvijas finieris (LV)	Jensen metal (LV)	Latvenergo (LV)
Emissions, t CO_2-eq:					
Scope 1	76 192	72 069	21 163	N.A.	717 000
Scope 2	4	4	13 777	N.A.	107 000
Scope 1 + 2	*76 196*	*72 073*	*34 940*	*1 033*	*824 000*
Scope 3	4 535	4 535	120 179	N.A.	2 976 000
Total	**80 731**	**76 608**	**155 119**	**N.A.**	**3 800 000**
Net sales, EUR	**77 442 000**	**77 442 000**	**404 773 045**	**45 393 675**	**2 034 425 000**
GHG emissions intensity, kg CO_2-eq·EUR^{-1}:					
Scope 1	**0.984**	**0.931**	**0.052**	**N.A.**	**0.352**
Scope 2	**0.000**	**0.000**	**0.034**	**N.A.**	**0.053**

Table 3 (continued)

Indicator	AUGA group (LT)*	AUGA group (LT)**	Latvijas finieris (LV)	Jensen metal (LV)	Latvenergo (LV)
Scope 1 + 2	**0.984**	**0.931**	**0.086**	**0.023**	**0.405**
Scope 3	**0.059**	**0.059**	**0.297**	**N.A.**	**1.463**
Total	**1.042**	**0.989**	**0.383**	**N.A.**	**1.868**

* with GHG emissions form LULUCF
** without GHG emissions form LULUCF
N.A. – not available
Source: the authors' calculations based on the companies' data [30-35]

Results and discussion

Based on the methodology, the data and the assumptions described above, GHG emissions intensity has been calculated for the cultivation of winter wheat and winter oilseed rape. The results are presented in Table 4.

Table 4

GHG emissions intensity in crop production (2023 data)

Indicator	Winter wheat	Winter oilseed rape
Emissions, kg CO_2-eq·ha^{-1}:		
Scope 1	1 175.57	1 220.25
Scope 2	N.A.	N.A.
Scope 1 + 2	1 175.57	1 220.25
Scope 3*	410.05	428.10
Total	**1 585.62**	**1 648.36**
Revenue, EUR·ha^{-1}	**903.00**	**955.20**
GHG emissions intensity, kg CO_2-eq·EUR^{-1}		
Scope 1	**1.302**	**1.277**
Scope 2	**N.A.**	**N.A.**
Scope 1 + 2	**1.302**	**1.277**
Scope 3*	**0.454**	**0.448**
Total	**1.756**	**1.726**

* partial assessment
N.A. – not assessed

As Scope 3 emissions of the cultivation of these two winter crops have been assessed partially and Scope 2 emissions have not been assessed (see above), the actual total GHG (Scope 1 + 2 + 3) emissions intensity is probably higher. Moreover, the calculated GHG emissions intensity exceeds almost all the benchmarks, except the benchmarks of electricity power generation. The calculated GHG emissions intensity also exceeds the benchmarks of *AUGA group*. However, *AUGA group* mainly practices organic farming, and its agricultural activities include not only crop cultivation but also dairy farming and mushroom growing. Thus, the input of fertilisers, which are a significant source of GHG emissions, is lower than in conventional crop production.

The results of the study imply that crop production, particularly winter crop and conventional production, has rather high GHG emissions intensity. However, due to incomplete data on Scope 2 and 3 emissions the generalisation of these findings is limited. Therefore, the inter-sector comparisons based on this indicator may be unfavourable for agricultural companies. The incorporation of this indicator into decision-making models, particularly in the banking sector, could possibly hinder the access to finance for agricultural companies. Therefore, further research is required before this indicator is widely adopted.

It should be also noted that prices of agricultural commodities (e.g. grains, oil seeds) are considerably volatile and generally more volatile than prices of many other commodities. Moreover, the future trends of commodity prices are very uncertain. Therefore, in the future, the GHG emissions intensity in agriculture could be affected by price fluctuations and divergence in price trends.

The assessment of GHG emissions intensity in agriculture has become increasingly common in recent years, as agriculture is one of the main contributors to global emissions [36]. However, typically, GHG emissions intensity in agriculture is measured as a ratio to a unit of production. This can be expressed per tonne of product [37], per kilogram of protein [38] or per kilocalorie of food produced [39]. These approaches are used because they provide insight into the efficiency of agricultural production and the environmental footprint of specific food items. However, they also present limitations, particularly when it comes to comparing the emissions intensity across different economic sectors. Moreover, when assessing GHG emissions within the agricultural sector itself, using production units such as tonnes of product may not always be the most meaningful approach. Agricultural products vary significantly in their nutrient content, e.g. a tonne of one product does not necessarily provide the same nutritional value as a tonne of another [40]. In such cases, measuring GHG emissions per kilogram of protein or per kilocalorie offers a more precise and relevant comparison and aligns better with the goal of optimizing food production for both environmental sustainability and nutritional efficiency.

The approach used in this study, i.e. attributing GHG emissions as a ratio to net revenue, has been less commonly used in research to date, although this method allows for direct comparison with other industries, providing a broader economic perspective on emissions. For example, the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) has found that the amount of cropland required to produce USD 1 000 worth of crop commodities such as rice, corn, and wheat decreased significantly – from 1.1 hectares to 0.6 hectares from 1990 to 2020. This reduction has been attributed to improvements in farm production efficiency, which have played a key role in reducing agricultural GHG emissions intensity [41]. In comparison to conventional methods, this approach can help policymakers evaluate trade-offs between environmental impact and economic sustainability.

Conclusions

1. The findings of the study imply that GHG emissions intensity in agriculture, as demonstrated by the example of crop production, is rather high compared to other sectors. Only electricity power generation has probably higher GHG emissions intensity.
2. To carry out more comprehensive assessment of Scope 3 emissions in agriculture, particularly at the company level, further research is required to improve methodologies and develop proxies and estimates.
3. As the study suggests that crop production has rather high GHG emissions intensity, the technical incorporation of this indicator into decision-making models, particularly in the banking sector, could possibly hinder agricultural companies' access to finance.
4. GHG intensity based not only on revenue but also on production amounts (e.g. grains, milk, etc.) or calorific value of nutrients (e.g. kcal) is used in both academia and ESG reporting. However, the alternative metrics based on production amounts do not allow inter-sector comparisons.

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Author contributions

Conceptualization, A.A., A.K. and I.L.; methodology, A.A. and A.K.; validation, A.A. and A.K.; investigation, A.A., A.K. and I.L.; data curation, A.A., and A.K.; writing – original draft preparation, A.A., A.K. and I.L.; writing – review and editing, A.A., A.K. and I.L.; project administration, A.A.; funding acquisition, A.A. All authors have read and agreed to the published version of the manuscript.

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