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Organic versus Conventional Agriculture: Comparison of Economic and Environmental Sustainability

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Abstract **– Reduction of the level of greenhouse gas emissions from agriculture is one of the most serious issues across the European Union. The dairy industry generates significant emissions from enteric fermentation, manure and long-term storage. The emissions produced depend greatly on factors such as livestock feeding, manure management systems, feed content, and quality. The research aims to evaluate the environmental and economic dimensions of conventional wheat production and dairy farming and compare them in terms of their environmental and economic sustainability. The core element of the sustainability assessment is the construction of the composite sustainability index using data from scientific literature, reports, and statistics. The comparison between organic dairy farming and conventional dairy farming based on sustainability indexes provides valuable insight into the strengths and weaknesses of each system. Organic farming systems present stronger environmental sustainability but require substantial financial support. Organic and traditional farming have their advantages and disadvantages. Policymakers, farmers, and consumers play crucial roles in shaping a future where farming systems can be both productive and sustainable.**

Keywords **– Composite sustainability index; dairy farming economic dimension; environmental dimension; greenhouse gas emissions; organic agriculture.**

Nomenclature	
GHG	Greenhouse gas emissions
EU	European Union
CO_2	Carbon dioxide
CH_4	Methane emissions
N_2O	Nitrous oxide

1. Introduction

The agricultural sector is one of the sectors that create challenges for the European Union (EU) member states in achieving the set goals of climate neutrality by 2030 and 2050. Depending on how it is managed, the agricultural sector can be both a source of greenhouse gas (GHG) emissions and an attractor of GHG emissions [1]. The agricultural sector plays an

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essential role in promoting safe food, economic competitiveness, and sustainable development [1]. European Green Deal states that by 2030, emissions must be reduced by at least 55 % compared to the level of GHG emissions in 1990 [1], [2]. The European Green Deal incorporates the achievable goals in the agricultural sector set in the European Common Agricultural Policy Plan (CAP) [3]. CAP is one of the key policies designed to promote sustainable agriculture and reduce GHG emissions in the agricultural sector [4]–[6].

The European Green Deal and the Farm to Fork strategy established by the CAP promote organic farming [3], [4]. Similar to the national energy and climate plans, each EU member state must develop national CAPs [3] to set priorities and achievable goals in the agricultural sector [3], [5]. The Farm to Fork strategy aims to reduce pesticide use in the EU by 50 % by 2030 and fertiliser use by 20 % [7]. The Farm to Fork strategy and action plan encourage an increase in organic farming, intending to convert 25 % of agricultural land to organic farming by 2030 [4], [7]. According to 2023 data, about 13.2 % of total GHG emissions in the EU in 2021 were directly related to agriculture [7], [8]. Agricultural emissions come primarily from manure management and livestock intestinal fermentation, croplands, and nitrous oxide (N2O) emissions from soil management [8]. In the EU, more than ~54 % of GHG emissions from agriculture are methane (CH4) emissions from agricultural processes [1], [9]. According to 2022 data, the agricultural sector accounted for 2253.8 kt CO_2 eq. [10], or more than 22 % of the total national emissions that year, ranking just behind the energy sector [10]. Emissions from agricultural soils were the largest contributor to agricultural emissions in this period, creating about 46.5 % of the sector's greenhouse gas emissions. This period's second largest emission source was GHG emissions from enteric fermentation processes, contributing approximately 42 % of the total agricultural emissions [10]. According to the data from 2022, the largest volume of the harvested crop was winter wheat, accounting for more than 69 % of the harvested grains. The area for wheat was 539 thousand hectares in 2022 [10]. The importance of organic farming is emphasised in the EU agro-environmental policy and strategies, which stipulate that by 2030, at least 25 % of agricultural land should be farmed with organic farming methods [11], [12]. Sustainable agriculture is characterised by the interaction of environmental, economic and social dimensions, taking into account the impacts of these dimensions [13], [14]. Several factors influence agriculture, including subsidies, technological capabilities, and knowledge of sustainable agricultural development [14]. Clear indicators characterising farming systems are needed to evaluate organic farming [14]. There are literature sources in which organic farming, with an emphasis on organic dairy farming and organic cereals, is considered economically or ecologically more disadvantageous than conventional farming [14]. Previous literature shows a gap in data regarding relevant indicators for comparing organic and conventional dairy farming at the farm level [15]. From the above-mentioned data, it follows that dairy farming and emissions from agricultural soils, including wheat production, which make up a large part of the amount of harvested grain, are important sources of emissions, and it is necessary to evaluate alternative solutions for increasing sustainability in these sectors. The National Energy and Climate Plan of Latvia (NECP) states to promote organic dairy farming (low-emission dairy farming) [16]. The main goal of the policy measure is to promote the transition of small and medium-sized conventional dairy farms to the organic farming system, promoting low-emission dairy farming. The article aims to evaluate and compare the sustainability of biological dairy farming, conventional dairy farming, and conventional and organic wheat production, using economic and environmental indicators and the composite index method. Data from scientific literature sources and reports are collected and used to construct the composite index. The study includes two sections: 1) To assess organic and conventional agriculture based on scientific literature and report data; 2) In the second part of the study, a composite index with additional indicators was created to assess small and medium-sized organic and conventional dairy farms in Latvia. Considering that the largest sources of emissions in agriculture in Latvia in 2022 were GHG emissions from agricultural soils and emissions from livestock intestinal fermentation, the study examines the comparison of organic wheat cultivation and organic dairy farming with conventional farming systems.

2. ORGANIC VERSUS CONVENTIONAL FARMING

Organic agriculture is a production system that relies on prevention to control pests and maintain productivity. The area of organic farming in the EU is estimated to be more than 14.7 million hectares (ha) [17]. Regarding organic agriculture in the EU, France makes up more than 2.5 million hectares, Spain more than 2.4 million hectares, Italy more than 2 million hectares, and Germany 1.6 million ha [18] Organic farms make up a total of more than 9.1 % of agricultural land in the EU [18] Sustainable agricultural activity is characterised as the management of agriculture and the use of resources in a way that preserves biological diversity promotes regeneration and productivity in the future, and combines social, economic, and environmental functions [19]. Organic farming has been assessed for its potential for carbon sequestration, increasing the organic matter content in the soil, and reducing GHG emissions [20].

2.1. Crop Farming and Organic Crop Farming

Cereals include wheat, barley, oats, rye, buckwheat, and corn [21]. In the EU, the yield (kilogram/hectare of harvested land) from cereals is estimated to reach 5260 kg in 2022 [21]. The areas of arable land managed in biological agriculture can be evaluated as an important indicator of reducing GHG emissions because mineral fertilisers are not used in these areas [22]. Grain cultivation in Latvia is estimated to account for ~ 60 % of the production of agricultural products [23]. Organic farming areas have grown since 2015. Cereals occupy more than three-quarters of the organic crop cultivation area, and organic cereals have increased more than twice compared to 2015. However, yield rates are lower than in organic farming areas [24]. In 2021, 4121 farms switched to organic farming, 63 more than in 2020. The number of organic farming operators also increased, reaching 4439 in 2021 (in comparison to 3587 operators in 2012) [24], [25]. In Latvia, it is estimated that more than 304 000 ha, of the land used for agriculture is certified organic farming areas [24]. Based on the 2021 data, the share of cereals by crop type in organic agriculture was 62863 ha. Of these, 1 270 367 ha were wheat [25]. Grain areas are increasing, and the amount of organic grain produced in the total organic farming system has also increased from 70 000 tons in 2018 to 111 000 tons in 2022 [26].

2.2. Dairy Farming and Organic Dairy Farming

It is estimated that in the EU, around 77 % [27] of methane emissions are generated in agriculture from the intestinal fermentation of dairy cattle [19], [28]. In Latvia, intestinal fermentation is one of the biggest sources of methane emissions in agriculture. In 2022, CH4 emissions from cattle intestinal fermentation accounted for about 42 % of the total emissions in the agriculture sector or ~946 kt CO_2 equivalent [10]. Emissions depend on the feeding tactics and feed content quality [9]. The increased GHG emissions in intensive agriculture are partially explained by the fact that as the production yield increases, the milking of cows also increases, and the amount of manure produced causes higher CH4 emissions [9]. Both conventional and organic dairy farming produce CH_4 emissions from manure and enteric processes, CO_2 emissions from feed production, and N_2O emissions from feed production. The amount of methane emissions generated from manure is largely influenced by the composition of the cow's diet and the digestibility of the feed, manure management method [10]. Farms with herd sizes between ten and fifty cows were estimated to have the highest environmental impact, which decreased with increasing herd size. GHG emissions in dairy farming are affected by both the number of animals and their variability, as well as the amount of nitrogen fertilisers [9].

Forage quality has a significant impact on methane production; if forage is low digestible, the amount of methane gas emissions increases [10], [29]. The optimal digestibility index is 67 %; if it is 50 % and below, there is an increased risk of methane emissions and a decrease in productivity [10], [30]. Factors such as the species composition of dairy cow forage influence the quality of forage; the inclusion of legumes can improve the quality of feed. The inclusion of legumes in the composition of pasture is an essential element for obtaining higher-value forage, increasing the protein content in the feed [31]. One of the requirements set for organic farms is the presence of legumes in grasslands and balanced feed rations. There must be a balance between protein in the feed and energy in the feed, if there is no balance in the feed distribution, then a larger amount of nitrogen is excreted into the environment [32]. Dairy cows feed on pastures; in organic dairy farming, most of the feed must be home-grown. Forage available on pasture contains more fibre, which can reduce methane emissions. Methane emissions can be reduced if high-quality grass fodder and concentrated feed with high-fat content are used [1], [33].

TABLE 1. DIFFERENCES IN ORGANIC DAIRY FARMING

Factors	Organic dairy farming	Source
Fertiliser	Synthetic fertilisers and pesticides are not used in organic dairy farming; biopesticides are subject to separate regulation regulations.	[35]
Differences in feed	– There should be a large proportion of roughage in the feed of cows. – in biological dairy farming, there is a condition that the feed ration must consist of at least 60 % coarse dried or fresh fodder or silage. – At least 60 % of the feed must be self-grown on a biological farm. – The minimum amount of fodder should be pasture grass that is used as feed.	[1]–[3]
Health and antibiotics	*One of the main conditions of organic farming is the maximum restriction of antibiotics and regular veterinary care and welfare maintenance of dairy cows.	[35]
Welfare	Compared to conventional dairy farming, biological dairy farming has stricter conditions regarding the improvement of animal welfare in animal housing as one of the main conditions. However, such a requirement is not stipulated in the law.	[36]
Holding conditions	– Dairy cows must be outdoors for longer periods in addition to the grazing period. During the grazing period, they must be outdoors for at least twelve hours a day. – Free pasture – During the summer season, Animals must have freedom of movement and be led to pasture. – The need for a high level of welfare and free access to pasture. Livestock tethering is allowed only on a case-by-case basis after obtaining a special permit.	[35]
Requirements for Dairy Cow Shelters	In organic dairy farming, animal housing without litter is prohibited for the welfare of dairy cows.	[35]
Milk production	Lower milk yield compared to conventional farms due to the consumption of less feed concentrate.	[36]

In organic farming, chemical fertilisers and pesticides are prohibited, reducing nitrogen oxide emissions formed from chemical fertilisers in conventional agriculture [3], [5]. Using organic fertilisers and including buttercups can reduce carbon dioxide emissions and increase carbon accumulation in the soil. Switching to organic farming from conventional farming is considered a promising alternative for reducing GHG emissions by reducing the use of synthetic fertilisers [34]. Table 1 lists and briefly describes the requirements for organic dairy farming, which differ from those for conventional dairy cow farming.

In 2022, the number of cows in dairy farming was 127 759, but in 2023, 119042 cows [37]. In 2022, 15 800 were cows in organic dairy farming (Fig. 1). In 2020–2021, the produced cow's milk was 988 000, of which 87 000 was organic milk [38]. Although the number of dairy cows continued to decrease, the average milk yield per dairy cow increased by 1.8 %, reaching 7492 kg per year [39]. Less than half of the organic milk produced is processed as organic milk products due to logistical problems in collecting organic milk, high retail prices and low consumer demand [37], [39].

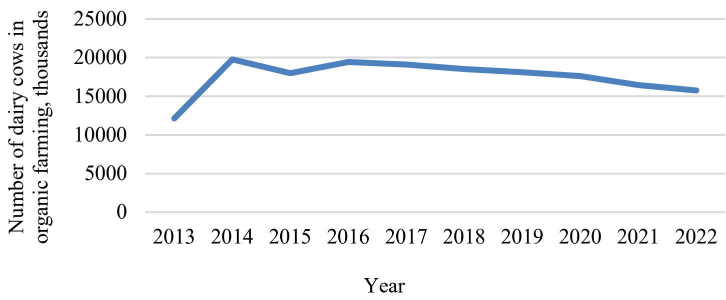

Fig. 1. Number of dairy cows in organic farming [41].

According to the 2022 data from the Agricultural Data Center, less than 5 % (~4.8 %) of farms have a cow count exceeding 50. Compared to 2021, the number of dairy farms decreased by ~9.4 % [39].

3. METHODOLOGY

3.1. Framework of the Study and Criteria

The study includes two sections: 1) An assessment of organic and conventional agriculture based on scientific literature and data from reports, and 2) a comparison of economic and environmental sustainability of small and average-size organic and conventional dairy farming. To evaluate alternative solutions in decision-making, different dimensions should be evaluated and their interrelationships [42]. Sustainability index are widely used in policy development and evaluation. For policymakers, such indicators would make it possible to evaluate ex-ante policies, develop or improve policy instruments, and evaluate climate policy measures [15]. The study compares several systems to better assess the potential benefits and drawbacks of each system based on the values of different indicators. Therefore, the composite index serves as a suitable method to show what performance can be expected if several dimensions, not only the economic or the environmental dimension, are taken into account. Databases such as Science Direct, Scopus and Web of Science were used to determine the indicators and their values. After identifying the indicators and collecting the data, the data were normalised using the Min-max normalisation method. Then, the normalised economic and environmental indicator values were collected and calculated to create a composite index for conventional and organic farming strategies (Fig. 2) [34].

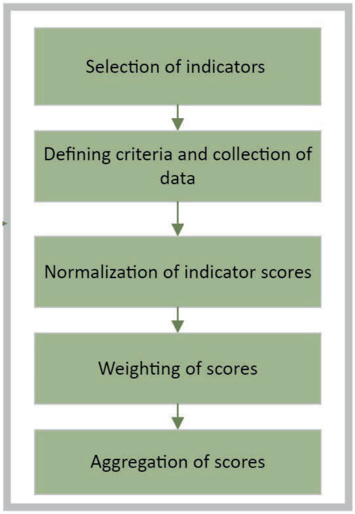

Fig. 2. Methodology of the study.

Inclusion criteria for the first part of the study:
- Only Organic and conventional dairy cow farming;
- Only Organic and conventional wheat production;
- Only average values from scientific literature and reports.

Inclusion criteria for the second part of the study:
- Only data based on Latvian case studies;
- Calculations in environmental dimension based on IPCC 2006, national inventory report [10], [44];
- Only dairy farms with cows in small and average size farms (1–99 cows).

3.2. Dimensions and Indicators Selection

Indicators to assess the sustainability of agriculture in scientific publications are scattered, and it is difficult to group them. There is no consensus on whether the sustainability indicators of agriculture should be assessed together or separately by indicator [45].

Literature-based studies regarding organic and conventional wheat production, dairy farming

In the first part of the study, based on sources found in the literature, indicators are identified whose values could be compared with each other in relation to both organic and conventional wheat production, as well as dairy farming. In the economic dimension, agricultural productivity and earned income are assigned numerical values. Profitability is determined by comparing revenues and costs or by farm net income product production [13]. Sustainability in the environmental dimension can be described as a decrease in potential degradation related to pesticides, degradation of soil quality, reduction of GHG emissions, and biodiversity conservation [42], [43]. The indicators were selected based on an analysis of scientific literature and reports. The indicator values used in the study were obtained from literature, reports, and calculations based on average values. Each indicator is assigned either a negative or positive value. Indicators with a negative value (−) worsen the composite index, e.g., costs, emissions, carbon footprint, while indicators with a positive value (+) increase the composite index, e.g., milk yield, income (see Table 2).

TABLE 2. SELECTED INDICATORS FOR THE CONSTRUCTION OF THE COMPOSITE INDEX

No	Indicator	Units	Negative/positive
I1	Mean total costs, EUR	EUR/ha	–
I2	Production value	EUR/ha	+
I3	Net income	EUR/ha	+
I4	Subsidies, green payments, support payments	EUR/ha	+
I5	Carbon footprint per land unit	Mg CO_2eq ha^{-1}	–
I6	Carbon footprint per product	kg CO_2eq	–

The values of the indicators are based on scientific literature and local reports. For some indicators, the average value from different studies is used, and for others, values based on scientific literature or reports are used (Table 1 in the Annex).

3.3. Normalisation

Data calculated or obtained from literature must first be normalised. Min-max method is a common normalisation approach used in decision-making analysis, where the results are scaled from 0 to 1 [46]–[48].

$$I^{+}_{\mathrm{N},ij} = \frac{I^{+}_{\mathrm{act},ji} - I^{+}_{\mathrm{min},ji}}{I^{+}_{\mathrm{max},ji} - I^{+}_{\mathrm{min},ji}}\ , \tag{1}$$

where

$I^{+}_{\mathrm{N},ij}$ normalised indicator;

$I^{+}_{\mathrm{act},i}$ indicator actual values;

$I^{-}_{\mathrm{min},i}$ indicator minimum value;

$I^{+}_{\mathrm{max},i}$ indicator maximum value;

i indicator.

3.4. Indicator Weighting

Each selected indicator receives a weight proportional to its weight, assuming equal importance for each. Six indicators with normalised values, each with an equal weight of 0.17, were used in the construction of the CI.

Assuming equal importance for each, each with an equal weight of 0.33 was used in the construction of the CI.

3.5. Aggregation of Normalised Indicator Values into CI

The last step is to calculate normalised indicator values using Aggregation. Results multiply with the normalised indicator value.

$$I_{\mathrm{CI}} = \sum_j^n W_j \times I_i, \tag{2}$$

where

I_{CI} composite index;
W_j indicator weight (equal for each indicator) [46], [49], [50];
I_i indicator value (normalised).

3.6. Comparison of Economic and Environmental Sustainability of Small and Average-size Organic and Conventional Dairy Farming

In the second part of the study, indicators were selected that would allow for a comparison between organic and conventional dairy farming. The indicators were divided into three dimensions – technical, which is characterised by the amount of milk produced; economic – which is characterised by the costs of each system; and environmental – which is characterised by GHG emissions from enteric fermentation, manure management, and emissions from grazing in the soil section. As before, to perform normalisation, the indicators were divided into + or − impact indicators, and then the Min-max normalisation method was used. Then, the normalised data was aggregated into a composite index (Fig. 3).

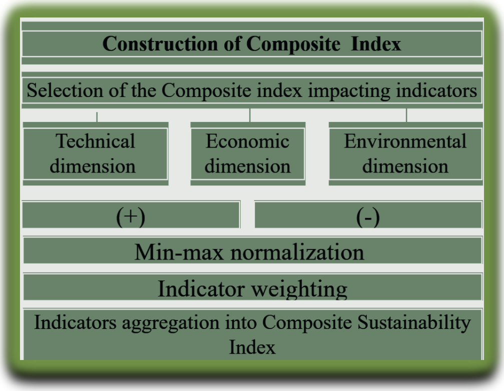

Fig. 3. Structure of the construction of the composite index.

3.6.1. Technical dimension

t_1 milk, tons/day per amount of milking cows and t_2 average milk yield, tons of milk per number of cows, are calculated based on the average amount of milk in organic and conventional dairy farming Eq. (3).

$$\text{Milk, tons/day/year} = \text{Amount of milk (kg day/year)} \times \text{number of cows)}/1000 \tag{3}$$

All input data for the calculation of t_1 and t_2 are shown in Table 2 in the Annex.

3.6.2. Environmental dimension

Calculation of emissions in conventional and organic dairy farming was conducted using the 2023 data of the Central Statistical Office on the number of cows in small and medium-sized dairy farms [37]. The number of cows is divided into categories (1–9), (10–29), (30–49), and (50–99).

Emissions calculation is based on the Intergovernmental Panel on Climate Change (IPCC) 2006 methodology

- CH_4 emissions from intestinal fermentation are performed;
- CH_4 emissions from manure management are being performed;
- N_2O emissions from pastures [10].

Calculations of indicator values in the Environmental dimension are summarised in the Annex Tables 3–9.

3.6.3. *env₁ CH₄ emissions from enteric fermentation kt CH₄ yr⁻¹, CO₂ eq*

All input data for calculation on enteric fermentation is summarised in Tables 3–6 in Annex. EF for dairy cattle has been calculated according to the 2006 IPCC Guidelines methodology represented in Equation 10.21 [44], see Eq. (4).

$$EF = \left[\frac{GE \times \left(\frac{Ym}{100} \right) \times 365}{55.65} \right], \tag{4}$$

where

EF emission factor, kg CH_4 head^{-1} yr^{-1};

GE gross energy intake, MJ head^{-1} day^{-1};

Ym methane conversion factor, % of gross energy in feed converted to methane (default values in table 10.12, from 2006 IPCC Guidelines); the factor 55.65 is the energy content of methane (MJ/kg CH_4) [44];

GE gross energy intake, MJ day^{-1}.

The gross energy intake for dairy cattle was calculated according to the 2006 IPCC Guidelines and Equation 10.16 [44], Eq. (5).

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM} \right) + \left(\frac{NE_g}{REG} \right)}{\frac{DE\%}{100}} \right], \tag{5}$$

where

GE gross energy, MJ day^{-1};

NE_a net energy for animal activity, MJ day$^{-1;}$

NE_i net energy for work, MJ day^{-1};

NE_{work} net energy for work, MJ day^{-1};

NE_p net energy required for pregnancy, MJ day^{-1};

REM ratio of net energy available in a diet for maintenance to digestible energy consumed;

NE_g net energy needed for growth, MJ day^{-1};
REG ratio of net energy available for growth in a diet;
DE% digestible energy in % of gross energy [44].

NE_m – net energy required by the animal for maintenance, MJ day^{-1}, see Eq. 10.3 [44], Eq. (6).

$$NE_m = Cf_i \times (\text{Weight})^{0.75}, \tag{6}$$

where
NE_m net energy required by the animal for maintenance, MJ day^{-1};
Cf_i maintenance coefficient (default values from 2006 IPCC Guidelines, Volume 4, Chapter 10, Table 10.4 [44].

Activity (NE_a): net energy for animal activity, MJ day^{-1}, see Eq. (10.4) [44], Eq. (6).

$$NE_a = C_a \times NE_m, \tag{7}$$

where
NE_a net energy for animal activity, MJ day^{-1};
C_a coefficient corresponding to animal's feeding situation (default values from 2006 IPCC Guidelines. Volume 4, Chapter 10, Table 10.5) [44];
NE_m net energy required by the animal for maintenance, MJ day^{-1}.

Growth (NE_g): net energy needed for growth, MJ day^{-1}, see Eq. (10.6) [44], Eq. (8).

$$NE_g = 22.02\left(\frac{BW}{C \times MW}\right)^{0.75} \times WG^{1.097} \tag{8}$$

where
NE_g net energy needed for growth, MJ day^{-1};
BW the average live body weight of the animals in the population, kg;
C a coefficient with a value of 0.8 for female milking cows;
MW the mature live body weight of an adult female in moderate body condition, kg;
WG the average daily weight of dairy cows, kg day^{-1}.

Lactation (NE_l): net energy for lactation, MJ day^{-1}, see Eq. (10.8) [44], Eq. (9).

$$NE_l = Milk \times (1.47 + 0.40 \times Fat), \tag{9}$$

where
NE_l net energy for lactation, MJ day^{-1};
Milk amount of milk produced, kg of milk day^{-1};
Fat fat content of milk, % by weight.

Pregnancy (NE_p): net energy required for pregnancy, MJ day^{-1}, see Eq. (10.13) [44], Eq. (10).

$$NE_p = C_{pregnancy} \times NE_m, \tag{10}$$

where
NE_p net energy required for pregnancy, MJ day^{-1};
$C_{pregnancy}$ pregnancy coefficient (default values from 2006 IPCC Guidelines, Volume 4, Chapter 10, Table 10.7 [44].

REM – the ratio of net energy available in a diet for maintenance to digestible energy consumed [44], Eq. (11).

$$REM = \left\lfloor 1.23 - \left(4.092 \times 10^{-3} \times DE\%\right) + \left[1.126 \times 10^{-5} \times (DE\%)^2\right] - \left(\frac{25.4}{DE\%}\right) \right\rfloor, \quad (11)$$

where

REM the ratio of net energy available in a diet for maintenance to digestible energy consumed;

DE% digestible energy, %.

$$REG = \left\lfloor 1.164 - \left(5.160 \times 10^{-3} \times DE\%\right) + \left[1.308 \times 10^{-5} \times (DE\%)^2\right] - \left(\frac{37.4}{DE\%}\right) \right\rfloor, \quad (12)$$

where

REG ratio of net energy available for growth in a diet to digestible energy consumed;

DE% digestible energy, 67 % or 73 %.

In addition to feed digestibility, 67 % consider introducing legumes to organic farms could increase feed digestibility.

3.6.4. *env_3 CH_4 manure, kt CH_4 $^{y-1}$ CO_2 eq*

Part of methane emissions is also generated in manure management. Therefore, methane emissions should be estimated based on specific manure management systems Eq. (13).

$$CH_{4\,\text{manure}} = \Sigma_{(T)} \frac{EF_{(T)} \times N_{(T)}}{10^6}, \quad (13)$$

where

$CH_{4\text{manure}}$ CH_4 emissions from manure management, for a defined population, kt CH_4 yr^{-1};

$EF_{(T)}$ emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}

$N_{(T)}$ the number of heads of livestock species/category *T* in the country;

T category of livestock.

3.6.5. *CH_4 calculation of emission factor*

The emission factor (EF), kt $head^{-1}$, $year^{-1}$, EF kg CH_4 $head^{-1}$ $year^{-1}$, for estimating methane emissions from manure was determined using Equation 10.23 in IPCC 2006 [44], Eq. (14).

$$EF_T = \left(VS_T \times 365\right) \times \left\lfloor B_{o(T)} \times 0.67 \frac{\text{kg}}{\text{m}^3} \times \Sigma_{S,K} \frac{MCF_{S,K}}{100} \times MS_{T,S,K} \right\rfloor, \quad (14)$$

where

EF_T annual CH_4 emission factor for livestock category *T*, kg CH_4 $animal^{-1}$ yr^{-1};

VS_T daily volatile solid excreted for livestock category *T*, kg dry matter $animal^{-1}$ day^{-1};

$B_{o(T)}$ maximum methane-producing capacity for manure produced by livestock category *T*, m^3 (IPCC 2006 (Western/Eastern Europe) Table 10A-4);

$MCF_{(S,k)}$ methane conversion factors for each manure management system in Table 10.17 [44];

$MS_{(T,S,K)}$ a fraction of livestock category manure handled using manure management system in climate region *k*, dimensionless.

Basis for calculating annual *VS* production, days yr^{-1} [44] Eq. (15).

$$VS = \left[GE \times \left(1 - \frac{DE\%}{100} \right) + (UE \times GE) \times \left(\frac{1 - ASH}{18.45} \right) \right], \tag{15}$$

where

VS volatile solid release excretion per day on a dry-organic matter basis, kg day^{-1};
GE gross energy intake, MJ head^{-1} day^{-1};
DE% digestibility of the feed in % (67 % for dairy cows);
UE×GE urinary energy expressed as a fraction of *GE*;
ASH the ash content of manure calculated as a fraction of the dry matter feed intake (0.08 for cattle);
18.45 conversion factor for dietary *GE* per kg of dry matter (MJ kg^{-1}).

The number of animals and IPCC 2006 methodology used in the calculation to convert CH_4 emissions into CO_2 equivalents, the obtained emissions were multiplied by 28 [1]. Calculated data are summarised in Table 7 in the Annex.

3.6.6. env$_2$ Total N_2O emissions kt CO_2 eq.

Direct N_2O emissions (kg N_2O yr^{-1}) from manure management were calculated using the IPCC 2006 Guidelines Equation 20.25. $N_{(T)}$, $Nex_{(T)}$ and $MS_{(T,S)}$ data were taken from Enteric fermentation calculations, see Eq. (16).

$$N_2O_{D(\mathrm{mm})} = \left[\Sigma_s \left[\Sigma_T \left(N_{(T)} \times Nex_{(T)} \times MS_{(T,S)} \right) \right] \times EF_{3(\mathrm{S})} \right] \times \frac{44}{28}, \tag{16}$$

$N_2O_{D(\mathrm{mm})}$ direct N_2O emissions from Manure Management, kg N_2O yr^{-1};
$N_{(T)}$ number of head of livestock category *T*;
$Nex_{(T)}$ annual N excretion rates, kg N animal^{-1} yr^{-1} (IPCC, 2006 Eq.10.31);
$MS_{(T,S)}$ fraction of total annual nitrogen excretion for each livestock category;
$EF_{3(\mathrm{S})}$ emission factor for direct N_2O emissions from manure management system S kg N_2O-N kg^{-1} N in manure management system;
S manure management system;
T category of livestock [44];
$N_2O_{G(\mathrm{mm})}$ indirect N_2O emissions due to volatilisation of *N* from Manure Management, kg N_2O yr^{-1} were calculated according to IPCC 2006 Equation 10.29. The default value for the emission factor (0.01) was used [44].

To convert total N_2O emissions (sum of direct and indirect) emissions into CO_2 equivalents, the obtained emissions were multiplied by 265 [1]. Input data and calculated data are shown in Table 8 in the Annex.

3.6.7. env$_4$ N_2O kt CO_2 eq. from soils urine and dung deposited by dairy cows

On organic farms, dairy cows can be on pasture for up to 160 days per year in Latvian conditions. Also, on small and medium-sized conventional farms, cows can be on pasture for part of the time. FPRP is the annual amount of N deposited in the pasture, range and paddock soils by grazing animals, in this case, dairy cows. FPRP is calculated using the 2006 IPCC guidelines, Equation 11.5 [44], Eq. (17).

$$F_{PRP} = \Sigma_T \left\lfloor \left(N_{(T)} \times Nex_{(T)} \right) \times MS_{T,P,RP} \right\rfloor , \tag{17}$$

where

$Nex_{(T)}$ average annual amount of N excreted;

$N_{(T)}$ the number of heads of livestock species/category T in the country;

$MS_{T,P,RP}$ a fraction of livestock category manure handled using manure management system in climate region k.

It describes nitrogen from milking cows that is deposited on pasture. Table 9 in Annex summarises input data and calculations.

3.7. Economic Dimension Sustainability Evaluation

For input data (Table 4), the number of cows was multiplied by costs in organic and conventional dairy farming, see Eq. 18.

EUR/number of cows in dairy farming = number of cows × EUR/number of cows. (18)

TABLE 4. INPUT DATA FOR THE ECONOMIC DIMENSION ESTIMATION [55]

Economic indicators	Conventional dairy farming, EUR/number of cows	Organic dairy farming, EUR/number of cows
Ec_1 Homemade fodder EUR/number of cows	269	364
Ec_2 Purchased fodder, EUR/number of cows	355	82
Ec_3 Equipment depreciation, EUR/number of cows	270	232
Ec_4 Wages and social insurance payments, EUR/number of cows	286	213
Ec_5 Veterinary costs EUR/number of cows	112	104
Ec_6 Administration costs, EUR/number of cows	150	173
Ec_7 Other costs, EUR number of cows	213	139

A summary of the obtained indicator values, which were further used to create the composite index, is available in Table 10 in the Annex.

4. RESULTS AND DISCUSSION

The overall score in CI for organic wheat production is 0.51, which is smaller than for conventional wheat production (Fig. 4). Organic wheat production has the highest score in CI for carbon footprint per land unit. Previous literature studies confirm that the transition to organic farming increases both the carbon sequestration capacity and also reduces the carbon footprint per land unit [56]. Conventional wheat production gets the greatest score among strategies for carbon footprint per product EUR/ha (wheat) The lowest overall score among strategies is based on possible low income during seasons. Organic wheat farming has the second-highest mean total costs score. It is less expensive, considering operations like fertilisation and weeding are restricted [1]. Regarding total costs EUR/ha, conventional wheat production got a lower score than organic wheat production but got a considerably higher score in CI for net income EUR/ha. Previous studies show that during 2019–2020 average price for wheat was 420 EUR/tons [57]. The lowest overall score among strategies is based on possible low income during seasons.

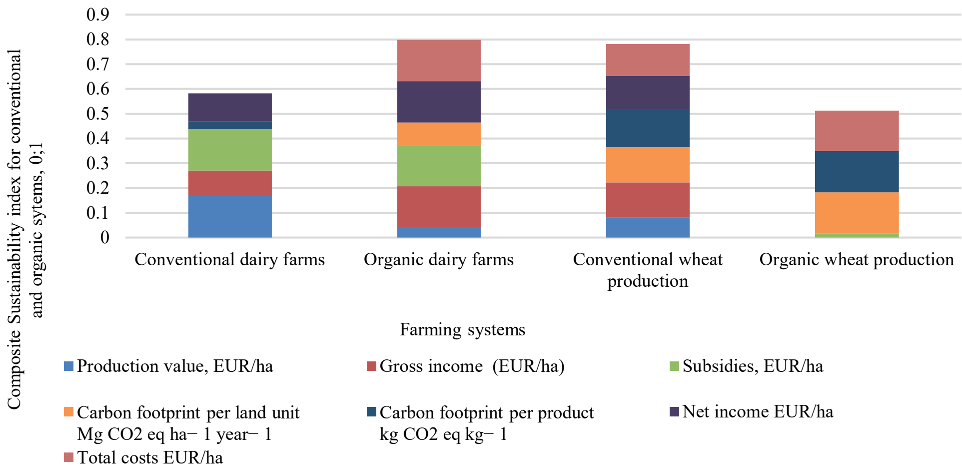

Fig. 4. Composite index for conventional and organic farming strategies.

Conventional dairy farming has the lowest score in CI regarding total costs, which means the highest total costs EUR/ha for traditional farming of dairy among strategies. Organic dairy farms got the highest overall score in CI, but conventional dairy farming had the lowest score among farming strategies based on total costs EUR/ha. The highest score for organic dairy farming is mainly partly based on total costs (EUR/ha) and net income (EUR/ha). Organic dairy farming has the highest score in CI among strategies for net income EUR/ha. Organic farming has lower operating costs and higher product costs, which can increase overall incomes. The highest support payments in net added value are for organic dairy farms. In organic farms, support payments play a significant role in generating revenue that can compensate for costs and lower yield in organic dairy farming [56]. EU member states can receive compensation and support payments to ensure the transition from conventional to organic agriculture, compensate for financial losses, and cover expenses that arise in organic farming [12]. Organic dairy farming has a lower production value in CI than conventional dairy farming. Conventional dairy farms have the highest score in CI regarding production value EUR/ha, with a score of 0.17. Based on 2021 data, conventional dairy farming is the leader in creating production value [24]. Organic dairy farming has a lower carbon footprint per land unit than conventional dairy farming, which got the lowest score in CI for carbon footprint per land unit. The more dairy cows in a group of farms, the higher the GHG emissions per land unit. The carbon footprint per land unit is thought to be lowest in organic farms [38]. By improving the quality of cow feed, CH_4 emissions from cow manure can be reduced [44]. Literature shows that the carbon footprint per product can be higher for organic farming than for conventional dairy farming [39].

The economic viability of small dairy farms depends on the existing European Union support for agriculture [58]. The results suggest that farms with 30–49 cows are more economically efficient in terms of profitability than larger or smaller farms. Because results indicate that having 30–49 or 50–99 cows indicates that larger operations benefit from economies of scale – where the cost per cow decreases as the farm grows in size. On the other hand, farms with fewer than 30 cows might struggle to cover fixed costs and achieve profitability, potentially due to higher per-cow costs and lower overall efficiency. In the figure, it is also shown that organic dairy farms are more profitable than traditional ones when they operate with the same number of cows. Organic farms may have cost advantages in terms of lower feed and chemical inputs, although they might also have higher labour costs or certification costs [38]. The costs EUR/number of cows tend to be lower than those in conventional farms of the same size, especially in terms of purchased fodder [55]. This could be because organic dairy farms often grow their own feed, there is the absence of chemical inputs, and they rely on natural methods, for example, in fertility management (e.g., composting, manure), which can reduce the overall cost of production and lower veterinary costs [38]. Organic dairy farms tend to have higher quality feed, and organic standards encourage the use of natural remedies and holistic approaches to animal care; the animals usually have better health, lowering the veterinary costs [55]. These findings suggest that there are notable trade-offs between the two farming systems, with each excelling in different areas. Organic dairy farming is better aligned with sustainability goals, while conventional dairy farming provides more efficient production through technological advancements.

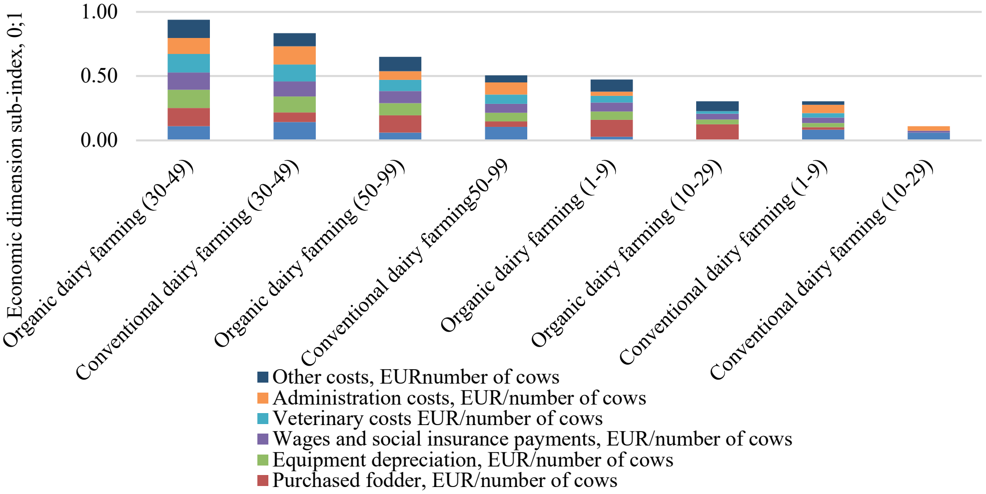

Fig. 5. Local-based economic dimension sub-index for conventional and organic dairy farming strategies.

The results of the sustainability index (Fig. 5) suggest that organic dairy farming has advantages in comparison to conventional dairy farming in terms of overall sustainability. From an environmental perspective, organic dairy farming outperforms conventional farming, regardless of herd size. This could suggest that practices in organic farming – such as the use of organic feed and reduced chemicals contributed positively to the cow's digestive system and produced lesser amounts of N_2O and CH_4 [61]. Results show that Increasing feed digestibility positively affects emissions resulting from intestinal fermentation processes (Fig. 6 and Fig. 7). On a per-cow basis, results show that organic dairy farms produce lower GHG emissions. On the other hand, conventional dairy farming seems to have an advantage in the technical dimension. From an economic point of view, based on results organic dairy farms are profitable compared to conventional ones of the same size. This could be because organic products often fetch higher market prices, and there may be lower input costs for chemicals and fertilisers despite potentially higher labour and certification costs [55]. In summary, organic dairy farming shows stronger environmental performance and better economic outcomes, while conventional dairy farming is more technically efficient in terms of production metrics. These findings highlight the trade-offs involved in dairy farming systems and the need to balance environmental, technical, and economic factors when evaluating sustainability (Fig. 6).

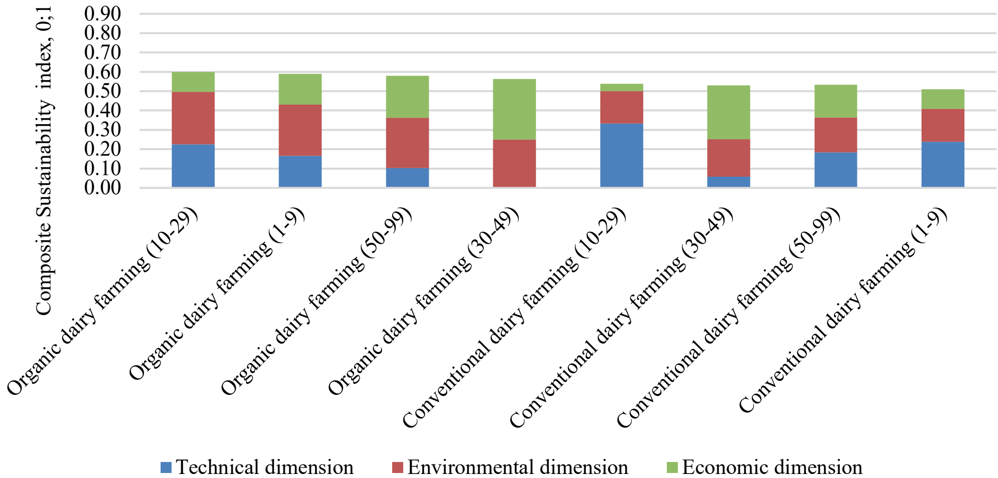

Fig. 6. Local-based Composite index for conventional and organic dairy farming strategies with DE 67 %.

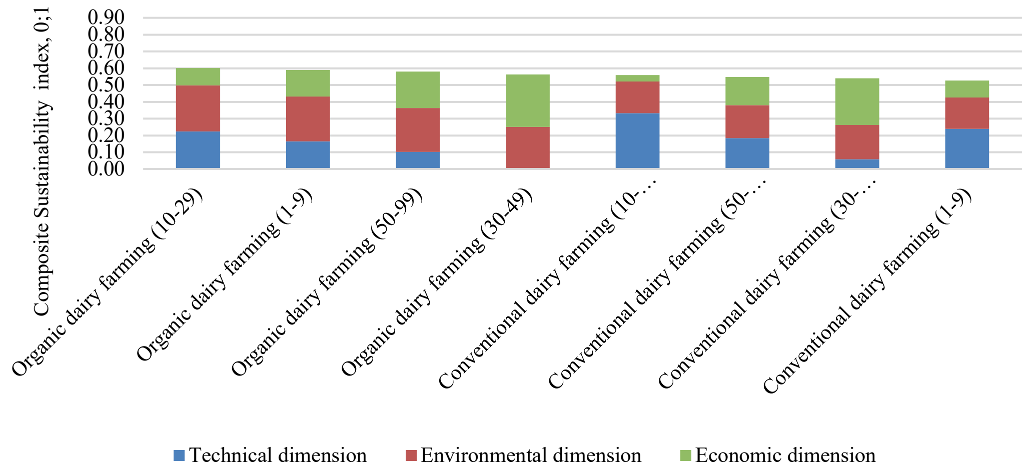

Fig. 7. Local-based Composite index for conventional and organic dairy farming strategies with DE 73 %.

4.1. Limitations of the Study

The composite index created in the first part of the study was based on data available in the literature on wheat cultivation and dairy farming in organic and conventional systems. The authors included only those indicators that can be compared with each other. Future research envisages additional indicators. including the inclusion of a biodiversity indicator if reliable data is found. Some data are averaged based on calculations, and some are from scientific articles or local reports. Additional environmental indicators, like the biodiversity index or parameters describing soil quality, should be included. Carbon footprint should be compared in different studies, geographic-based on locations, which can greatly impact carbon footprint [14]. Findings suggest that there are notable trade-offs between the two farming systems, with each excelling in different areas. Organic dairy farming is better aligned with sustainability goals, while conventional dairy farming provides more efficient production through technological advancements. However, the broader implications of strengths and weaknesses could be considered. For example, while conventional farming may be more technically efficient, it could promote ecological (social indicators like employment and the opinion of the farmers). The overall picture that emerges from these sustainability indexes emphasises the necessity and benefits of the transition to organic dairy farming. Future agricultural systems may benefit from integrating the method used in this study for evaluating other industry areas from a sustainability perspective. This could improve the adoption of sustainable practices in this sector and help achieve the European Union's goals.

5. CONCLUSION

Organic dairy farms received the highest overall score in CI, while conventional dairy farming had the lowest score among farming strategies. Organic farming has a smaller footprint per land unit than conventional dairy farming, which got the lowest score in CI for carbon footprint per land unit. However, the carbon footprint per product unit in CI was higher for organic dairy farming than for conventional dairy farming. Organic wheat systems have a lower carbon footprint per unit of land compared to conventional systems. However, organic farming and its economic viability are greatly influenced by the availability of financing and support programs. Results suggest that organic farming systems, particularly in wheat production, present stronger environmental sustainability due to lower carbon footprints but require substantial financial support to remain economically viable. The comparison between organic dairy farming and conventional dairy farming based on sustainability indexes provides valuable insight into each system's strengths and weaknesses. In general, organic dairy farming shows an advantage in terms of environmental sustainability and economic performance, while traditional farming excels in technical efficiency. In terms of environmental indicators, case studies show that organic dairy farming can be superior to conventional dairy farming regardless of herd size by producing smaller amounts of greenhouse gases and contributing to their reduction if the cow's feed digestibility values are higher than the used feed values in conventional dairy farms. Conventional dairy farming outperforms organic systems in terms of technical indicators. both organic and traditional dairy farming have their advantages and disadvantages, and specific goals and long-term sustainability objectives should guide the choice between them. Policymakers, farmers, and consumers play crucial roles in shaping a future where farming systems can be both productive and sustainable. The method can be used for an initial analysis in decision-making, evaluating which farming strategies are more economically viable, which has the lowest carbon footprint, and how to choose from different alternatives.

ANNEX

Available at: https://zenodo.org/records/14636964

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