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Assessment of Agricultural Sustainability: Case Study of Baltic States

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ABSTRACT

The agri-food sector is the world's largest economic sector having the biggest impact on environment. According to the Food and Agriculture Organization of the United Nations (FAO), sustainable agriculture must meet the needs of present and future generations while ensuring profitability, environmental health and social and economic equity. Therefore, agricultural systems need transition to become more sustainable. The use of renewables in agriculture allows to reduce energy costs and GHG emissions and implement cyclic economy principles. Sustainability assessment of agriculture can be done by applying various sets of indicators. The sustainability assessment of agriculture can be performed on country and micro level. The paper presents assessment of agricultural sustainability of Baltic States based on indicators framework and applies MCDA tool for ranking of Baltic States in terms of agriculture sustainability.

KEY WORDS: sustainability, agriculture, MCDA, Baltic States.

JEL Classification: H30, P18, Q20, Q30.

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1. Introduction

Mitigation of climate change is relevant for the agricultural sector from a dual point of view: agricultural activities require fossil and biological resources, which are related to the emission of greenhouse gases (GHG); climate change causes long-term and short-term changes in the natural environment that negatively affect agricultural productivity. In addition, the agricultural sector is important in terms of food security (i.e., to ensure availability of food at affordable prices). The vitality of rural areas is strongly related to the economic performance of the agricultural sector. Thus, it is important to ensure the implementation of economic, social and environmental goals in the agricultural sector. These goals are united by the concept of sustainable development.

The Common Agricultural Policy (CAP) of the European Union (EU) aims to achieve the abovementioned goals by applying financial incentives. In order to ensure the effectiveness of public support allocated under the CAP in terms of increasing sustainability, it is important to develop instruments for assessing the appropriateness of support. These instruments must be adapted to the Lithuanian context, taking into account the prevailing trends in farming and the possibilities of farm operations.

There are plenty of papers analyzing sustainability of agriculture sector (Bathaei & Streimikiene, 2023; Bertoni et al., 2020; Biffi et al., 2021; Bockstaller et al., 2008; Dabkiene et al., 2021; \ Derunova et al., 2019; Iocola et al., 2020; Migliorini et al., 2018; Salvan et al., 2022) however it is very important to analyse sustainability of agriculture and compare achievement of Member States by ap-

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plying consistent data. There are several studies that applied agriculture sustainability indicators in EU, however such assessments are lacking for some member states like Baltics.

This paper aims to overcome this gap and develops empirical study for comparative assessment of Baltic States in terms of agriculture sustainability development.

The methodology for country level sustainability analysis of agriculture was developed including aggregation principles. Agriculture sustainability indicators reflecting the activities of agricultural, food and fishery entities were selected by taking into account the strategic objectives of the Common agricultural policy (CAP). During the research, a multi-criteria evaluation methodology will be proposed, allowing the aggregation of selected sustainability indicators taking into account policy priorities.

In this paper, agricultural sustainability indicators framework was developed based on available EUROSTAT data and ranking of Baltic States based on achievements of agriculture sustainability was provided. The similarities and differences between countries having the similar size and similar economic development level were discussed based on analysis con conducted. Policy implications were developed based on conducted study.

2. Literature Review

The concept of sustainability, after long discussions and interpretations, was formalized in the Brundtland report (WCED, 1987). The report defines sustainable development as economically viable, socially responsible and environmentally friendly development. Since then, the concept of sustainability has become a very important concept not only in the industrial sector, but also in agriculture. Therefore, the concept of sustainability has been successfully integrated into the general objectives of the European Union's agricultural policy, the realization of which can contribute to the population's food supply, poverty reduction, and climate change mitigation (Agovino et al., 2019; Karimi et al., 2021; Petrescu-Mag et al., 2019; Pretty, 2008; Talukder et al., 2020).

Despite the modern development of economies and very high rates of urbanization, agriculture is very important for ensuring people's lives. Therefore, the conducted studies show that agriculture faces challenges in changing the use of land, which leads to changes in biodiversity, intensification of the use of chemicals in agriculture, increases in greenhouse gas emissions, and water shortages (Gomiero et al., 2011; Hristov et al., 2021; Karimi et al., 2021; Saint-Ges, 2021; Spânu et al., 2022).

Scientists often emphasize that sustainable agriculture yields less than traditional agriculture, but this cannot be said unequivocally, because in each case it depends on the specifics of the country and farming conditions (Imadi et al., 2015; Kalogiannidis et al., 2022). What is more, the majority of the population of Western countries shows a clear disillusionment with traditional farming and the products provided by such farms. Therefore, priority is given to sustainable agriculture. With the ever-rapid growth of the population and therefore the need for food, the role of agriculture is not only not decreasing, but even increasing (Laurett et al., 2021). Therefore, the question of sustainable agriculture becomes more important than ever.

Human activities and the consequences of those activities on agriculture change over time. This activity must be continuously monitored and its impact measured in order to find out whether it is positive or negative for the economy, environment and social issues (OECD, 2022). Therefore, the monitoring of the agricultural sector must be carried out continuously.

We assess sustainability in general and sustainability in agriculture through three dimensions of sustainable development: economic, environmental and social. These are like the three pillars on which the concept of sustainable development rests and sustainability is valued.

Agricultural sustainability assessment is essential to implement sustainable farming policies based on scientifically based findings and recommendations. In this case, the analysis and assessment of indicators of sustainable development in agriculture can serve as a tool for successful policy implementation (Alaoui et al., 2022). Indicators provide information on the state of agriculture and allow the formulation of reasonable goals and monitoring systems (Gómez-Limón & Sanchez-Fernandez, 2010; Nadaraja et al., 2021). Successful analysis of indicators of sustainability in agriculture allows to make decisions and manage them, increase the dissemination of information to interested parties, create common scenarios for the further development of sustainable agriculture (De Olde et al., 2017; Iocola et al., 2020; Yu & Mu, 2022;).

The process of selecting indicators for sustainable development in agriculture is very important because the conclusions depend on it. Many scientific studies have been carried out, which confirm that the selection of indicators must be carried out taking into account: economic, social and environmental aspects; the simplicity of the indicators and the possibility of their practical application; the possibility of using the indicators taking into account the cultural and geographical differences of the country (countries); the ability to meet the expectations of stakeholders and make political decisions; meaningfulness to end users; economic efficiency in data collection and processing (Alaoui et al., 2022; Clerino et al., 2023; Finkbeiner et al., 2010; Kanter et al., 2018; Reed et al., 2011; Salembier et al., 2021; Schader et al., 2016; Singh et al., 2009).

3. Data and Methods

Agri-environmental indicators were developed by European Commission for the integration of environmental concerns into the Common Agricultural Policy (CAP) in EU member states.

For sustainability assessment of agriculture, the agri-environmental indicators framework was constructed based on EU agri-environmental indicator (European Commission, 2023; EUROSTAT, 2023).

Due to the limits of data, the framework of indicators for sustainability assessment of agriculture was developed from agri-environmental indicators based on available data in EUROSTAT and are presented in Table 1.

The data for Baltic States on agricultural sustainability indicators was collected from EUROSTAT database.

The MCDM tool – COPRAS for ranking countries based on agriculture sustainability indicators was applied.

The preference ranking method of complex proportional assessment (COPRAS) method was developed by Zavadskas et al. (2008). In this

Table 1

Agricultural Sustainability Indicators Framework

Agri-environmental indicator factsheets	Most recent data (year)	Responsible
1. Area under organic farming	2020	Eurostat
2. Nitrogen fertilizer consumption	2020	Eurostat
4. Phosphorus fertilizer consumption	2020	Eurostat
5. Pesticides sales		
4. Energy use	2019	Eurostat
6. Ammonia emissions from agriculture	2020	EEA
7. Greenhouse gas emissions from agriculture	2020	EEA

Source: (European Commission, 2023; EUROSTAT, 2023).

method, the influence of maximizing and minimizing criteria on the evaluation result is considered separately. The selection of the best alternative is based considering both the ideal and the anti-ideal solutions. The main procedure of COPRAS method includes several steps (Chatterjee et al., 2011). Step 1: Set the initial decision matrix, X.

$$X = [x_{ij}]_{m*n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad (1)$$

where x_{ij} is the assessment value of i-th alternative in respect to j-th criterion, *m* is the number of alternatives and *n* is the number of criteria.

Step 2: Normalization of the decision matrix by using the following equation:

$$R = [r_{ij}]_{m*n} = {x_{ij}}\big/{\sum_{i=1}^{m} x_{ij}} \qquad (2)$$

Step 3: Determination of the weighted normalized decision matrix, D, by using the following equation:

$$D = [y_{ij}]_{m*n} = r_{ij}.W_j, i = 1, \dots, m, j = 1, \dots, n \quad (3)$$

where r_{ij} is the normalized performance value of i-th alternative on j-th criterion and w_j is the weight of j-th criterion. The sum of weighted normalized values of each criterion is always equal to the weight for that criterion:

$$\sum_{i=1}^{m} x_{ij} = w_{ij} \qquad (4)$$

Step 4: In this step the sums of weighted normalized values are calculated for both the beneficial and non-beneficial criteria by using the following equations:

$$S_{+i} = \sum_{j=1}^{n} y_{+ij}, S_{-i} = \sum_{j=1}^{n} y_{-ij} \qquad (5)$$

where y_{+ij} and y_{-ij} are the weighted normalized values for the beneficial and non-beneficial criteria, respectively.

Step 5: Determination the relative significances of the alternatives, Q_i, by using the following equation:

$$Q_i = S_{+i} + \frac{S_{-min} \cdot \sum_{i=1}^{n} S_{-i}}{S_{-i} \cdot \sum_{i=1}^{m} \left(S_{-min}/S_{-i} \right)}, i = 1, \dots, m \qquad (6)$$

where S_{-min} is the minimum value of S_{-i}.

Step 6: Calculation of the quantitative utility, U_i, for i-th alternative by using the following equation:

$$U_i = \frac{Q_i}{Q_{max}}.100\% \qquad (7)$$

where Q*max* is the maximum relative significance value.

As a consequence of Equation 6, utility values of the candidate alternatives range from 0% to 100%.

The greater the value of U_i, the higher is the priority of the alternative. Based on alternative's utility values a complete ranking of the competitive alternatives can be obtained.

4. Discussion of Results

The trends of the main agriculture sustainability indicators provided in Table 1 for Baltic States were analysed in Figures 1-7.

In Figure 1 the development area of organic farming in Baltic States during 2016-2020 period was demonstrated.

As Figure 1 indicates, the Latvia is dominating in area of organic farming among Baltic States during investigated period. However, since 2016, the area of organic farming has grown the fastest in Estonia (18 percent), while in Latvia it is 11 percent and in Lithuania only 6 percent.

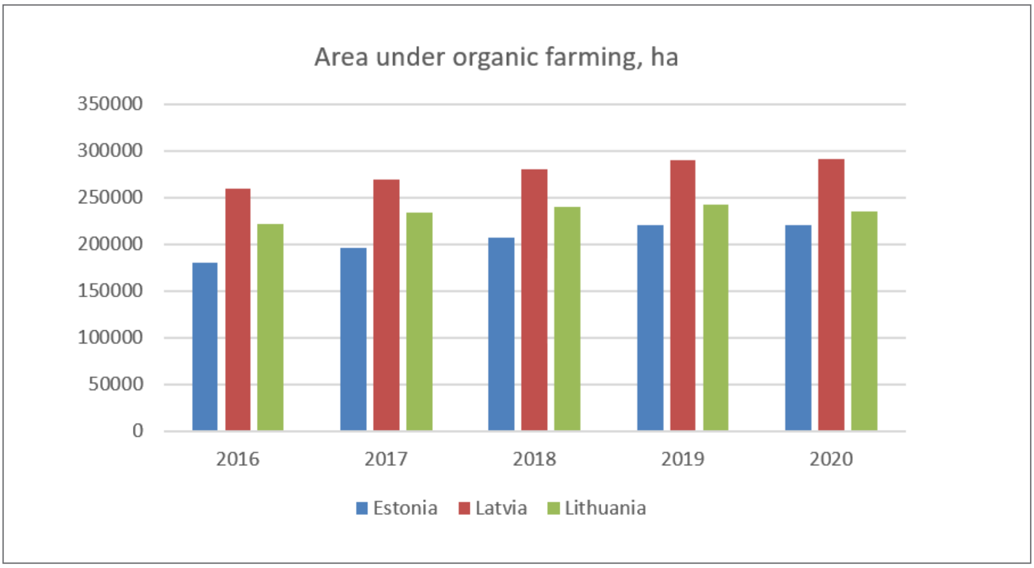
Figures 2 and 3 show Nitrogen fertilizer and Phosphorus fertilizer consumption by agriculture in the Baltic States.

As can be seen from the above figures (Fig. 2 and Fig. 3), the largest amount of both nitrogen and phosphorus fertilizers is consumed in agriculture in Lithuania. In 2020, a total of 209580 tons of inorganic fertilizers were used in Lithuania. Meanwhile, in Latvia and Estonia, respectively, 97986 tons and 46313 tons of inorganic fertilizers.

The following figure (Figure 4) presents the variation of pesticide consumption during the period under consideration.

Figure 1

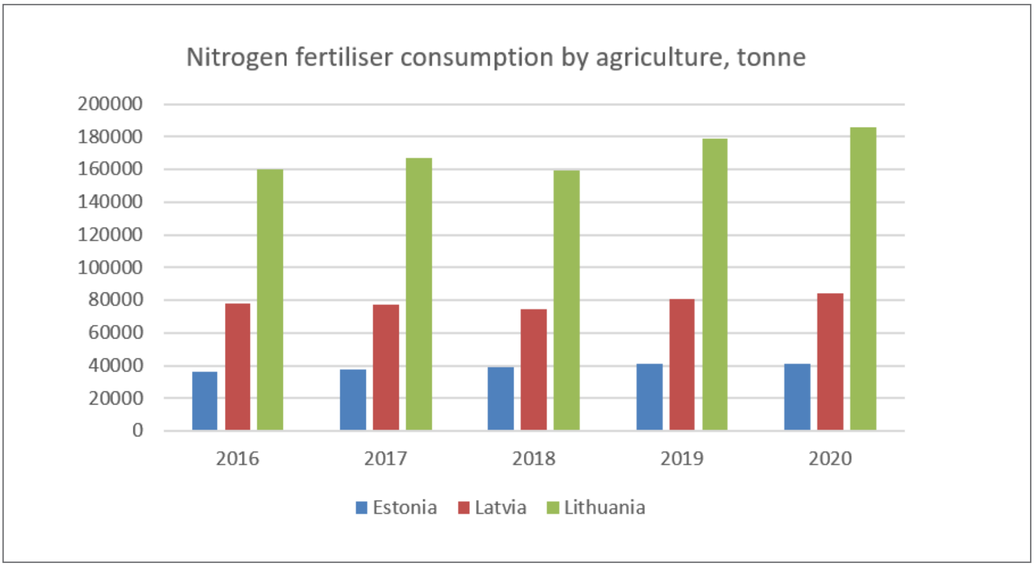
Development Area of Organic Farming in Baltic States During 2016-2020 Period



Source: Eurostat database

Figure 2

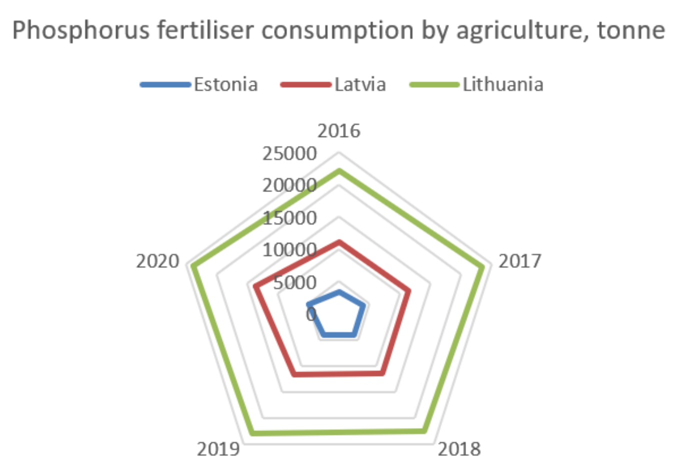
Nitrogen Fertilizer Consumption by Agriculture in the Baltic States During 2016-2020 Period



Source: Eurostat database

Figure 3

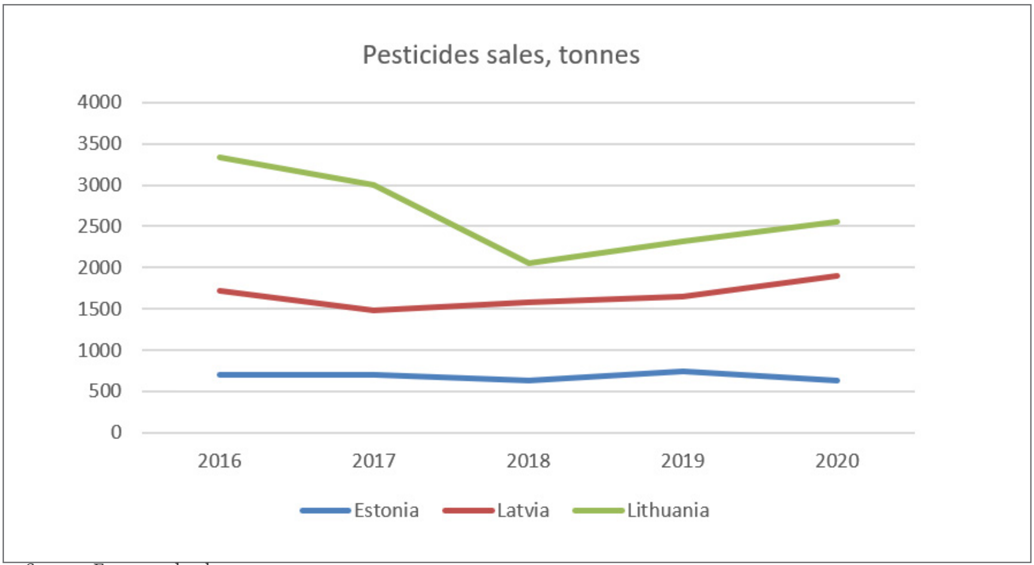
Phosphorus Fertilizer Consumption by Agriculture in the Baltic States During 2016-2020 Period



Source: Eurostat database

Figure 4

Pesticides Sales in the Baltic States During 2016-2020 Period



Source: Eurostat database

It can be noted that the most pesticides were used in the Lithuanian agricultural sector during the entire period from 2016 to 2020. Although there is a noticeable decrease from 3336.1 tons in 2016 to 2558.8 tons in 2020, these numbers are still significantly higher than in Estonia and Latvia. At the same time, it is worth noting that the growth trend of the use of pesticides in the agricultural sector of Latvia is observed from 1724.6 tons in 2016 to 1900.4 tons in 2020.

Figure 5 shows energy use in agriculture in the Baltic States during 2016-2019.

Agriculture and forestry consume approximately 3% of total energy consumption in the European Union. Latvia consumes the largest amount of energy in agriculture in the Baltic States and energy consumption is growing in Latvia. In Lithuania energy consumption in agriculture is the lowest one and it is decreasing, however the most significant decrease of energy consumption is agriculture can be noticed in Estonia.

In Figure 6 the ammonia emissions from agriculture in the Baltic States during 2016-2020 period are given.

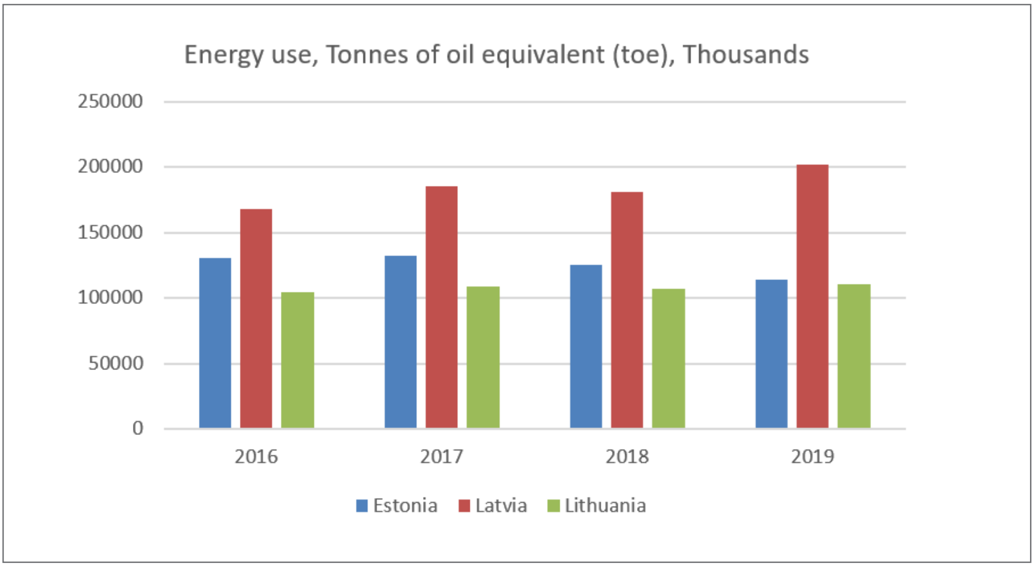
Lithuania distinguishes with the highest rate of ammonia emissions during all investigated period. Estonia has the lowest level of ammonia consumption. All countries have stable ammonia emissions during all investigated period, except Lithuania.

In Figure 7 the development of GHG emissions in agriculture of Baltic States is given.

In the next step the sums of weighted normalized values are calculated for both the beneficial and non-beneficial criteria by using the Eq. (5), and Table 7 shows that.

Figure 5

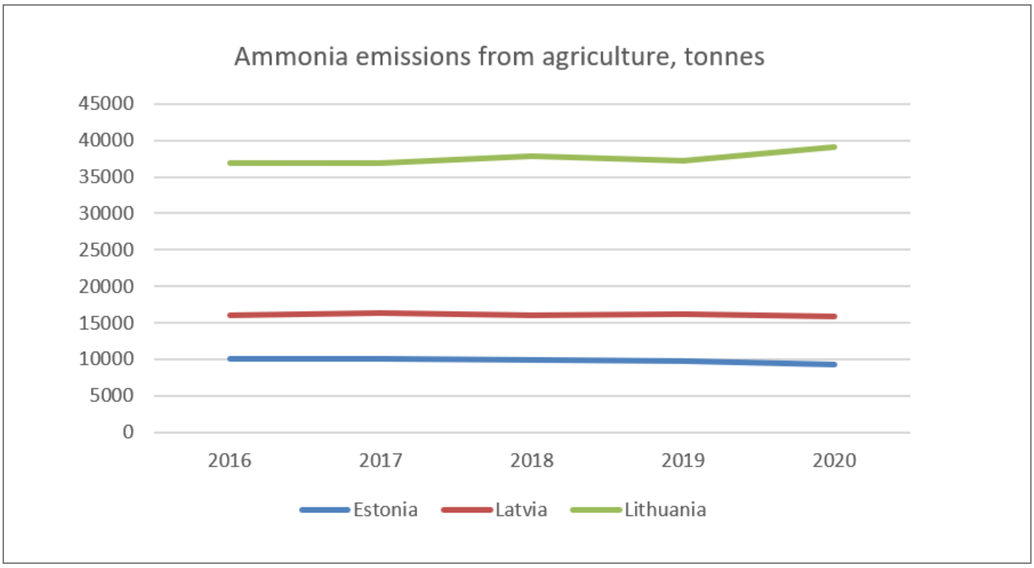
Energy Use in the Baltic States During 2016-2019 Period



Source: Eurostat database

Figure 6

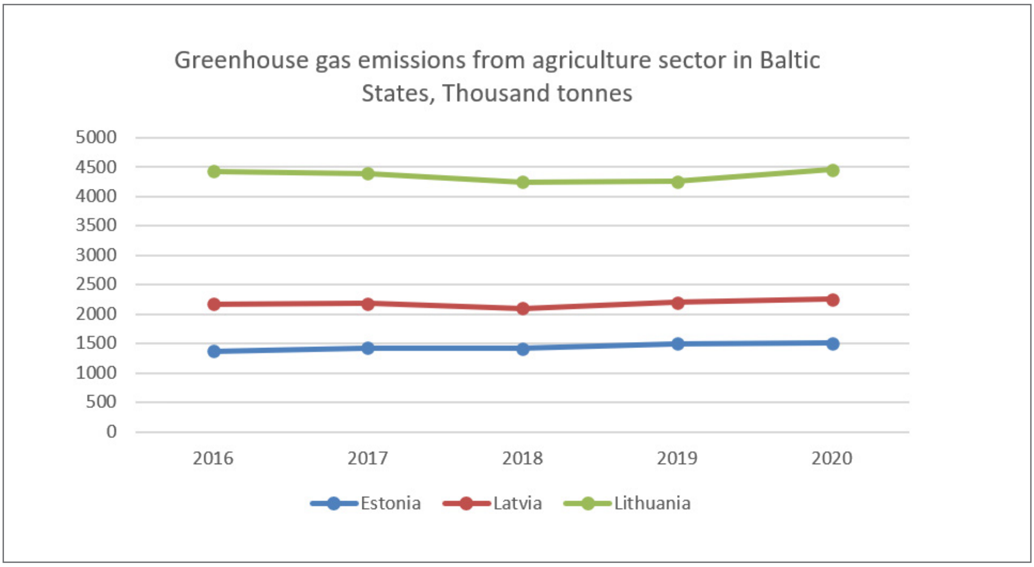
Ammonia Emissions from Agriculture in the Baltic States During 2016-2020 Period



Source: Eurostat database

Figure 7

Greenhouse Gas Emissions from Agriculture Sector in Baltic States, Thousand Tonnes



Source: Eurostat database

Lithuania has the highest GHG emissions from agriculture followed by Latvia. Estonia distinguishes with the lowest GHG emissions. The GHG emissions were stable during investigated period however in Lithuania in last year some increase of GHG emissions from agriculture can be noticed.

In Table 2 the main agri-environmental indicators for Baltic States are provided for 2016 and 2020 and the change is evaluated.

As Table 2 provides results of agricultural sustainability indicators-based ion on the newest available data form EUROSTAT (European Union, 2022), it is possible to define the positive changes in area under organic farming among Baltic States and reduction of pesticides sales however the mineral fertilizers consumption has increased during investigated period in all Baltic States. Amonia emissions has increased just in Lithuania and GHG emissions have slightly increased in all Baltic States during 2016-2020.

In further step the COPRAS multi-criteria decision aiding tool was used to rank three Baltic States based on overall agri-environmental indicators in 2020.

Table 3 shows the indicators and criteria for ranking of Baltic States. Just area under organic farming is indicator which increase is desirable trend. All other indicators are negative and they decrease is necessary to achieve sustainable agriculture development goals,

Table 4 shows the initial decision matrix for ranking Baltic States based on agricultural sustainability indicators in Step 1 based on Eq. (1).

Table 2

Agriculture Sustainability Indicators in 2016 and 2020 and Changes in Baltic States

	Main indicators	**Estonia**			**Latvia**			**Lithuania**		
		2016	2020	Change, %	2016	2020	Change, %	2016	2020	Change, %
1.	Area under organic farming, ha	180852	220796	18,1	259146	291150	11	221665	235471	5,9
3.	Phosphorus fertilliser consumption by agriculture, tonne	3,4	4,8	29,2	11,1	13,6	18,4	22,2	23,8	6,7
4.	Pesticides sales, tonnes	709,8	632,6	-12,2	1724,6	1900,4	9,2	3336,1	2558,8	-30,4
5.	Energy use, tonnes of oil equivalent (toe), Thousands	130455	113740 (2019 year)	-15	167722	202017 (2019 year)	17	104098	110429 (2019 year)	5,7
6.	Livestock density index, %	0,8	0,3	-166,7	0,29	0,24	-20,8	0,34	0,25	-36
7.	Ammonia emissions from agriculture, tonnes	10140	9354	-8,4	16090	15937	-0,9	36848	39057	5,7
8.	Greenhouse gas emissions from agriculture, %	6,9	13	46,9	19,5	21,2	8	21,5	21,9	1,8

Source: (European Commission, 2023; EUROSTAT, 2023).

Table 3

Agricultural Sustainability Indicators and Criteria for Ranking Baltic States in 2020

	Indicators	Criteria
1.	Area under organic farming, ha	C1
2.	Nitrogen fertiliser consumption by agriculture, tonne 2020	C2 Eurostat
3.	Phosphorus fertilliser consumption by agriculture, tonne	C3
4.	Pesticides sales, tonnes	C4
5.	Energy use, tonnes of oil equivalent (toe), Thousands	C5
6.	Livestock density index, %	C6
7.	Ammonia emissions from agriculture, tonnes	C7
8.	Greenhouse gas emissions from agriculture, Thousand tonnes	C8

Table 4

Initial Decision Matrix

Weights of criteria	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Kind of criteria	1	-1	-1	-1	-1	-1	-1	-1
	C1	C2	C3	C4	C5	C6	C7	C8
A1 (Estonia)	220796	41486	4.8	632.6	113740	0.3	9354	1508.38
A2 (Latvia)	291150	84346	13.6	1900.4	202017	0.24	15937	2250.88
A3 (Lithuania)	235471	185779	23.8	2558.8	110429	0.25	39057	4450.72

Table 5

Normalized Decision Matrix

Weights of criteria	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Kind of criteria	1	-1	-1	-1	-1	-1	-1	-1
	C1	C2	C3	C4	C5	C6	C7	C8
A1 (Estonia)	0.2954	0.1331	0.1137	0.1242	0.2669	0.3797	0.1454	0.1837
A2 (Latvia)	0.3895	0.2707	0.3223	0.3732	0.4740	0.3038	0.2477	0.2742
A3 (Lithuania)	0.3150	0.5962	0.5640	0.5025	0.2591	0.3165	0.6070	0.5421

Table 6

Weighted Normalized Matrix

Kind of criteria	1	-1	-1	-1	-1	-1	-1	-1
	C1	C2	C3	C4	C5	C6	C7	C8
A1 (Estonia)	0.0369	0.0166	0.0142	0.0155	0.0334	0.0475	0.0182	0.0230
A2 (Latvia)	0.0487	0.0338	0.0403	0.0467	0.0593	0.0380	0.0310	0.0343
A3 (Lithuania)	0.0394	0.0745	0.0705	0.0628	0.0324	0.0396	0.0759	0.0678

With using Eq. (2) normalized decision matrix is developed, as given in Table 5.

To reach the weighted normalize matrix Eq. (3) was used and the results shows in the Table 6.

In the next step the sums of weighted normalized values are calculated for both the beneficial and non-beneficial criteria by using the Eq. (5), and Table 7 shows that.

Then, applying Eq. (6), the relative significance or priority value (Qi) for each alternative option is determined, as shown in Table 8.

With using Eq. (7) the value of quantitative utility (Ui) for each alternative on the basis of which the complete ranking of the alternative materials is obtained and Table 7 shows the value of U and final ranking. As shown in Table 9, A1 (Estonia) is ranked first.

5. Conclusions and Policy Implications

Developed Sustainable Agriculture Indicators framework covering the most important agriculture sustainability areas like area under organic farming, use of mineral fertilizers and pesticides, livestock density, energy consumption, ammonia and GHG emissions was applied for analysis of sustainability of agriculture sectors in three Baltic States having similar size and similar economic development level.

Analysis of trends of the main Sustainable Agriculture Indicators showed positive trends in some indicators for all Baltic States, like increase of area under organic farming and decrease of livestock density index during 2016-2020 period however some indicators like the mineral fertilizers consumption has increased during investigated period in all Baltic States. Pesticides sales have increased just in Latvia and Amonia emissions has increased just in Lithuania, however GHG emissions have slightly increased in all Baltic States during 2016-2020. Energy consumption decreased just in Estonia as in Latvia and Lithuania the increase during 2016-2020 period can be noticed.

As countries have different levels in specific Agri-

Table 7

Weighted Normalized Values for Beneficial and Non-beneficial Criteria

Alternatives	S+	S-
A1	0.0369	0.1684
A2	0.0487	0.2832
A3	0.0394	0.4234

Table 8

Relative Significance Values for each Alternative

Alternatives	Q
A1	0.4762
A2	0.3098
A3	0.2140

Table 9

The Final Ranking of Baltic States Based on Agriculture Sustainability Indicators

Alternatives	U	Ranking
A1	100.00	1
A2	65.06	2
A3	44.95	3

cultural Sustainability Indicators the Multi criteria assessment of overall agricultural sustainability was performed for three Baltic States in 2020 by applying COPRAS method. The equal weights for all indicators were used. The ranking of countries produced by COPRAS revealed that Estonia has shown the highest agriculture sustainability achievements during Baltic States.

6. Limitation and Future Research

The study has several limitations. Not all agri-environmental indicators were analysed due to the lack of the paper. The other important indicators linked to CAP and sustainable development goals are necessary like land use change, soil erosion, irrigation, manure storage, Intensification / extensification etc.

Future research is necessary in order to analyze and compare policies and measures to promote sustainable agriculture in Baltic States including assessment of effectiveness of policies and measures to promote sustainable agriculture.

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