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Application of the LMAW-DNMA method in the evaluation of the environmental problem in the agriculture of selected European Union countries

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A B S T R A C T

The research of environmental problems in all sectors, and therefore in agriculture, is very challenging, significant and complex. For that purpose, special indicators adapted to the very nature of its business were developed for the agricultural sector. Environmental problems in agriculture are caused by the use of chemical inputs, animal waste, packaging waste, soil pollution, water and air pollution, etc. Bearing in mind the significance of the environmental problem in agriculture, this paper evaluates (selection and ranking) the environmental problem in the agriculture of selected European Union countries based on the LMAW-DNMA method as a function of mitigation by applying relevant environmental measures. According to the results of the LMAW-DNMA method, the top five countries of the European Union in terms of environmental problems in agriculture are, in the following order, Poland, France, Spain, the Netherlands and Italy. In countries such as Slovenia (twentieth place), Estonia (twenty-first place) and Luxembourg (twenty-second place), the environmental problem in agriculture is less pronounced than in the other observed countries of the European Union. In order to alleviate the environmental problem in agriculture in the European Union countries, environmental measures are taken, such as increasing organic production, digitization, and environmental taxation.

Keywords: Agri-ecological indicators, European Union, LMAW-DNMA method.

И З В О Д

Истраживање еколошког проблема у свим секторима, што значи и у пољопривреди, врло је изазовно, значајно и сложено. У те сврхе, за сектор пољопривреде развијени су посебни индикатори прилагођени самој њеној природи пословања. Еколошки проблем у пољопривреди проузрокован је коришћењем хемијских инпута, анималним отпадом, амбалажним отпадом, загађењем земљишта, загађењем воде и ваздуха итд. Имајући у виду значај еколошког проблема у пољопривреди, у овом раду се врши евалуација (селекција и рангирање) еколошког проблема у пољопривреди одабраних земаља Европске уније на бази LMAW-DNMA методе у функцији ублажавања применом релевантних еколошких мера. Према резултатима LMAW-DNMA методе, у првих пет земаља Европске уније по еколошком проблему у пољопривреди спадају, редом, Пољска, Француска, Шпанија, Холандија и Италија. У Словенији (двадесето место), Естонији (двадесет прво место) и Луксембургу (дведесет друго место) мање је изражен еколошки проблем у пољопривреди у односу на остале посматране земље Европске уније. У циљу ублажавања еколошког проблема у пољопривреди у земљама Европске уније, предузимају се еколошке мере, као што су повећање органске производње, дигитализација, еколошки порези.

Кључне речи: Агро-еколошки индикатори, Европска унија, LMAW-DNMA метода.

1. Introduction

In modern agriculture, there is an environmental problem. Agriculture, after the energy sector, is one of the biggest polluters of the environment. Excessive and uncontrolled use of pesticides and mineral fertilizers, deforestation, soil pollution, destruction of biodiversity, encouragement of erosion, water and air pollution, etc. contribute to this to a great extent. Also, significant ecological problems in agriculture are posed by animal and packaging waste and the destruction of natural resources. In order to alleviate the ecological problem in agriculture, it is important to rationally reduce production costs, increase organic production, use subsidies for the purchase of new agricultural machinery, digitize agricultural activities, apply ecological taxes, etc.

Starting from the expression, importance and complexity of the environmental problem in modern agriculture, the subject of research in this paper is the application of the LMAW-DNMA method in the evaluation (selection and ranking) of the environmental problem in the agriculture of selected European Union countries.

The research of the environmental problem in agriculture in selected European Union countries is based on the fact that realistic knowledge of the magnitude of the environmental problem in agriculture is a fundamental assumption for its mitigation by applying relevant agro-environmental measures. This reflects the primary research hypothesis in this paper. A significant role in the analysis of the given hypothesis is played by the application of various multi-criteria decision-making methods, including the LMAW-DNMA method.

Recently, in the literature, great importance has been attached to the environmental problem in all sectors, and hence in agriculture. In this context, the impact of agriculture on the environment has specifically been analyzed due to its importance (Bartzas & Komnitsas, 2020; Bathaei & Štreimikienė, 2023; Karapandžin, 2018). In this regard, appropriate agri-ecological indicators have been developed (Gürlük & Uzel, 2016; Magrini & Giambona, 2022; Zekić et al., 2018; Marada et al., 2023). In a separate study, the agri-ecological EUROSTAT ('European Statistical Office'; DG ESTAT) indicators, OECD (Organization for Economic Co-operation and Development) indicators, FAO (Food and Agriculture Organization) indicators, as well as in other publications (Spânu et al., 2022), are presented in detail. In the literature, agri-ecological indicators were evaluated by individual countries (Gürlük & Uzel, 2016; Jurjevic et al., 2022), regions and products. When evaluating ecological agriculture from different angles based on agri-ecological indicators, the authors used multi-criteria decision-making methods (dos Reis et al., 2023; Manafi Mollayousefi & Hayati, 2023; Morkunas & Volkov, 2023; Romero-Perdomo & González-Curbelo, 2023; Lukić et al., 2014, 2018, 2020, 2021; Lukić, 2017, 2021; Vojteški Kljenak & Lukic, 2022), thus enabling a realistic evaluation of the environmental problem in agriculture as a prerequisite for mitigation by applying relevant environmental measures.

2. Materials and methods

The necessary empirical data for the research of environmental problems in the agriculture of the selected countries of the European Union were collected from the OECD statistics.

The methodology for evaluating environmental problems in agriculture in selected European Union countries is based on the use of the LMAW-DNMA method.

The **LMAW** (Logarithm Methodology of Additive Weights) method is the latest method used to calculate criteria weights and rank alternatives (Liao, & Wu, 2020; Demir, 2022). It takes place through the following steps: m alternatives $A=\{A_1,A_2,\dots,A_m\}$ are evaluated in comparison with n criteria $C=\{C_1,C_2,\dots,C_n\}$ with the participation of k experts $E=\{E_1,E_2,\dots,E_k\}$ and according to a predefined linguistic scale (Pamučar et al, 2021).

Step 1: Determination of weight coefficients of criteria

Experts $E=\{E_1,E_2,\dots,E_k\}$ set priorities with criteria $C=\{C_1,C_2,\dots,C_n\}$ in relation to previously defined values of the linguistic scale. At the same time, they assign a higher value to the criterion of greater importance and a lower value to the criterion of less importance on the linguistic scale. In this way, the priority vector is obtained. The label γ_{cn}^{e} represents the value of the linguistic scale that the expert $e(1\le e\le k)$assigns to the criterion $C_t(1\le t\le n)$.

Step 1.1: Defining the absolute anti-ideal point γ_{AIP}

The absolute ideal point should be less than the smallest value in the priority vector. It is calculated according to the equation:

$$\gamma_{AIP}=\frac{\gamma_{min}^{e}}{S}$$

where γ_{min}^{e} is the minimum value of the priority vector and S should be greater than the base logarithmic function. In the case of using the function Ln, the value of S can be chosen as 3.

Step 1.2 : Determining the relationship between the priority vector and the absolute anti-ideal point

The relationship between the priority vector and the absolute anti-ideal point is calculated using the following equation:

$$(1n_{Cn}^{e}=\frac{\gamma_{Cn}^{e}}{\gamma_{AIP}})$$

Therefore, the relational vector $R^{e}=(n_{C1}^{e},n_{C2}^{e},\dots,n_{Cn}^{e})$is obtained, where n_{Cn}^{e} represents the value of the real vector derived from the previous equation, and R^e represents the relational vector e (1≤e≤k).

Step 1.3: Determination of the vector of weight coefficients

The vector of weight coefficients $w=(w_1,w_2,\dots,w_n)^T$ is calculated by the expert $e(1\le e\le k)$ using the following equation:

$$w_j^{e}=\frac{\log_A(n_{Cn}^{e})}{\log_A(\prod_{j=1}^{n}n_{Cn}^{e})},A>1 \quad (2)$$

where w_j^{e} represents the weighting coefficients obtained according to expert evaluations e^{tn} and the n_{Cn}^{e} elements of the realization vector *R*. The obtained values for the weighting coefficients must meet the condition that $\sum_{j=1}^{n}w_j^{e}=1$.

By applying the Bonferroni aggregator shown in the following equation, the aggregated vector of weight coefficients is determined $w=(w_1,w_2,\dots,w_n)^T$:

$$W_j=\left(\frac{1}{k.(k-1)}.\sum_{x=1}^{k}\left(w_j^{(x)}\right)^p.\sum_{\substack{y=1\\y\neq x}}^{k}\left(w_{ij}^{(y)}\right)^q\right)^{\frac{1}{p+q}} \quad (3)$$

The value of p and q are stabilization parameters and $p,q\ge 0$. The resulting weight coefficients should fulfill the condition that $\sum_{j=1}^{n}w_j=1$.

The **DNMA** (Double Normalization-based Multiple Aggregation) method is a more recent method for showing alternatives (Demir, 2022). Two different normalized (linear and vector) techniques are used, as well as three different coupling functions (Complete Compensation Model – CCM, Uncompensatory Model – UCM, and Incomplete Compensation Model – ICM). The method goes through the following steps (Liao & Wu, 2020; Ecer, 2020):

Step 1.4: Normalized decision matrix

The elements of the decision matrix are normalized with linear $(\hat{x}_{ij}^{1N})$ normalization using the following equation:

$$\hat{x}_{ij}^{1N}=1-\frac{|x^{ij}-r_j|}{max\{\max_i x^{ij},r_j\}-min\{\min_i x^{ij},r_j\}} \quad (4)$$

The vector $(\hat{x}_{ij}^{2N})$ is normalized using the following equation:

$$\hat{x}_{ij}^{2N} = 1 - \frac{|x^{ij} - r_j|}{\sqrt{\sum_{i=1}^{m}(x^{ij})^2 + (r_j)^2}} \quad (5)$$

The value r_j is the target value for $c_j$the criterion and is considered $\max_i x^{ij}$ for both utility and $\min_i x^{ij}$ cost criteria.

Step 2: Determining the weight of the criteria

This step consists of three phases:

Step 2.1: In this phase, the standard deviation $(\sigma_j)$for the criterion c_j is determined with the following equation, where *m* is the number of alternatives:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}} - \frac{1}{m}\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}}\right)\right)^2}{m}} \quad (6)$$

Step 2.2: Values of the standard deviation calculated for the criteria are normalized with the following equation:

$$w_j^{\sigma} = \frac{\sigma_j}{\sum_{i=1}^{n}\sigma_j} \quad (7)$$

Step 2.3: Finally, the weights are adjusted with the following equation:

$$\hat{w}_j = \frac{\sqrt{w_j^{\sigma}.w_j}}{\sum_{i=1}^{n}\sqrt{w_j^{\sigma}.w_j}} \quad (8)$$

Step 3: Calculating the aggregation model

Three aggregation functions (CCM, UCM and ICM) are calculated separately for each alternative.

The CCM (Complete Compensation Model) is calculated using the following equation:

$$u_1(a_i) = \sum_{j=1}^{n}\frac{\hat{w}_j.\hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}} \quad (9)$$

The UCM (Uncompensatory Model) is calculated using the following equation:

$$u_2(a_i) = \max_j \hat{w}_j\left(\frac{1-\hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}}\right) \quad (10)$$

The ICM (Incomplete Compensation Model) is calculated using the following equation:

$$u_3(a_i) = \prod_{j=1}^{n}\left(\frac{\hat{x}_{ij}^{2N}}{\max_i \hat{x}_{ij}^{2N}}\right)^{w_j} \quad (11)$$

Step 4: Integration of utility values

The calculated utility functions are integrated with the following equation using the Euclidean principle of distance:

$$DN_i = w_1\sqrt{\varphi\left(\frac{u_1(a_i)}{\max_i u_1(a_i)}\right)^2 + (1-\varphi)\left(\frac{m - r_{1(a_i)+1}}{m}\right)^2} - w_2\sqrt{\varphi\left(\frac{u_2(a_i)}{\max_i u_2(a_i)}\right)^2 + (1-\varphi)\left(\frac{r_2(a_i)}{m}\right)^2} + w_3\sqrt{\varphi\left(\frac{u_3(a_i)}{\max_i u_3(a_i)}\right)^2 + (1-\varphi)\left(\frac{m - r_3(a_i) + 1}{m}\right)^2} \quad (12)$$

In this case, the means $r_1(a_i)$ and $r_3(a_i)$ represent the ordinal number of the alternative a_i sorted by CCM and ICM functions in a descending value (higher value first). On the other hand, $r_2(a_i)$ shows the sequence number in the obtained order according to an increasing value (smaller value first) for the UCM function used. The label φ is the relative importance of the child value used and is in the range [0.1]. It is considered that it can be taken as $\varphi = 0.5$. The coefficients w_1, w_2, w_3 are obtained weights of the used functions CCM, UCM and ICM, respectively. The sum should be equal $w_1 + w_2 + w_3 = 1$. When determining the weights, if the decision maker attaches importance to a wider range of performance alternatives, he can set a higher value for w_1. In case the decision maker is not willing to take risks, i.e., to choose a poor alternative according to some criterion, he can assign a higher weight to w_2. However, the decision maker may assign a greater weight to $w_3$if he simultaneously considers overall performance and risk. Finally, the *DN* values are sorted in a descending order, with the higher value alternatives being the best.

It should be emphasized that, in this paper, alternatives (22) are only countries of the European Union that are members of the OECD.

3. Results and discussions

The empirical research of environmental problems in the agriculture of the selected countries of the European Union using the LMAW-DNMA method is based on the following criteria: C1 – Total sale of agricultural pesticides, C2 – Total area of agricultural land, C3 – Direct energy consumption on the farm, C4 – Ammonia (NH3), and C5 – Total greenhouse gas emissions by gas (without LULUCF). These indicators, along with soil, water and air pollution, are considered good measures of environmental problems in agriculture. Alternatives are considered selected countries of the European Union, members of the OECD. Table 1 shows agri-environmental indicators, alternatives and initial data for 2020. (Data for 2021 and 2022 are not yet available in the OECD statistics.)

Table 1.
Initial data

		Total sales of agricultural pesticides Tonnes	Total Agricultural Land area Hectares, Thousands	Direct on-farm energy consumption Tonnes of oil equivalent (toe), Thousand	Ammonia (NH3) Tonnes	Total greenhouse gas emissions by gas (without LULUCF) Tonnes of CO2 equivalent, Thousands
		C1	C2	C3	C4	C5
A1	Austria	5566.034	2646.96	512.091	65419.531	73592.017
A2	Belgium	5391.957	1367.08	802.946	67996.287	106433.258
A3	Czech Republic	4359.751	3523.87	634,896	68428.142	112788.578
A4	Denmark	3167.46	2620	567.126	76254.497	43457.975
A5	Estonia	632.591	985.46	110.017	9353.874	9353.874
A6	Finland	4916.941	2270	662,937	30661.41	47716.296
A7	France	64743.288	28897.88	4170.839	572984.854	399412.668
A8	Germany	47973.969	16595	3628.04	537267.993	728737.653
A9	Greek	4901.423	5267.52	277.301	63623.354	74835.612
A10	Hungary	8679.09	4997.88	700.36	74931.372	62818.386
A11	Ireland	2909.819	4511.42	219,381	123403.364	57716.091
A12	Italy	56372.591	13122.14	2758.885	362630.758	381247.962
A13	Latvia	1900.41	in 1969	205,448	15937.061	10446.626
A14	Lithuania	2558.762	2942.78	113.357	39056.513	20182.554
A15	Luxembourg	64.101	132.14	23,653	6148.221	9064.902
A16	Netherlands	9823.805	1814.45	3814.606	124373.91	163915.182
A17	Poland	24616.368	14754.86	3846.049	320817.329	376037.978
A18	Portugal	9706.261	3970.41	408.514	63280.874	57453.771
A19	Slovak Republic	2330.981	1910.04	132,499	26593.8	37002.706
A20	Slovenia	963,765	484.06	71,952	18166.135	15851.442
A21	Spain	66471.881	24434.63	2695.059	480202.446	274742.895
A22	Sweden	2047.474	3005.54	590.204	53308.908	46284.753

Source: OECD.Stat

Table 2 shows the descriptive statistics of the initial data.

Table 2.
Descriptive statistics

Statistics						
		Total sales of agricultural pesticides Tonnes	Total Agricultural Land area Hectares, Thousands	Direct on-farm energy consumption Tonnes of oil equivalent (toe), Thousand	Ammonia (NH3) Tonnes	Total greenhouse gas emissions by gas (without LULUCF) Tonnes of CO2 equivalent, Thousands
N	Valid	22	22	22	22	22
	Missing	0	0	0	0	0
Mean		15004.4874	6464.6873	1224.8255	145492.7560	141322.4172
Median		4909.1820	2974.1600	578.6650	66707.9090	60267.2385
Std. Deviation		22012.44538	7957.88788	1464.90221	180841.58610	181864.53720
The minimum		64.10	132.14	23.65	6148.22	9064.90
Maximum		66471.88	28897.88	4170.84	572984.85	728737.65

Source: Author's research

Descriptive statistics therefore show a large range between statistical variables. In its own way, this is reflected in the environmental problem in individual countries of the European Union.

Table 3 shows the correlation matrix of the initial data.

Table 3.
Correlation

Correlations						
		1	2	3	4	5
1 Total sales of agricultural pesticides	Pearson Correlation	1	.946 **	.791 **	.957 **	.815 **
	Sig. (2-tailed)		.000	.000	.000	.000
	N	22	22	22	22	22
2 Total Agricultural Land area	Pearson Correlation	.946 **	1	.778 **	.956 **	.775 **
	Sig. (2-tailed)	.000		.000	.000	.000
	N	22	22	22	22	22
3 Direct on-farm energy consumption	Pearson Correlation	.791 **	.778 **	1	.860 **	.850 **
	Sig. (2-tailed)	.000	.000		.000	.000
	N	22	22	22	22	22
4 Ammonia (NH3)	Pearson Correlation	.957 **	.956 **	.860 **	1	.911 **
	Sig. (2-tailed)	.000	.000	.000		.000
	N	22	22	22	22	22
5 Total greenhouse gas emissions by gas (without LULUCF)	Pearson Correlation	.815 **	.775 **	.850 **	.911 **	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	22	22	22	22	22
**. Correlation is significant at the 0.01 level (2-tailed).						

Source: Author's research

Therefore, there is a strong correlation between the given statistical variables at the level of statistical significance.

Table 4 shows the prioritization scale

Table 4.
Prioritization Scale

Linguistic Variables	Abbreviation	Prioritization
Absolutely Low	AL	1
Very Low	VL	1.5
Low	L	2
Medium	M	2.5
Equal	E	3
Medium High	MH	3.5
High	H	4
Very High	VH	4.5
Absolutely High	AH	5

Source: Demir (2022)

The weighting coefficients of the criteria were calculated using the LMAW method. They are shown in Table 5. (In this paper, all calculations and results are the author's.)

Table 5.
Weight coefficients of the criteria

KIND	1	1	-1	1	1
	C1	C2	C3	C4	C5
E1	H	AH	H	E	MH
E2	VH	VH	MH	H	H
E3	MH	M	H	M	M
E4	MH	E	E	VH	AH
E5	H	E	H	M	L

ϒAIP	0.5

	C1	C2	C3	C4	C5	LN(Πη)
R1	8	10	8	6	7	10.199
R2	9	9	7	8	8	10.499
R3	7	5	8	5	5	8.854
R4	7	6	6	9	10	10.029
R5	8	6	8	5	4	8.946

Weight Coefficients Vector	C1	C2	C3	C4	C5
W1j	0.204	0.226	0.204	0.176	0.191
W2j	0.209	0.209	0.185	0.198	0.198
W3j	0.220	0.182	0.235	0.182	0.182
W4j	0.194	0.179	0.179	0.219	0.230
W5j	0.232	0.200	0.232	0.180	0.155

Aggregated Fuzzy Vectors	C1	C2	C3	C4	C5
W1j	0.009	0.009	0.008	0.007	0.007
W2j	0.009	0.008	0.008	0.007	0.007
W3j	0.009	0.007	0.009	0.007	0.007
W4j	0.008	0.007	0.008	0.008	0.008
W5j	0.010	0.008	0.009	0.007	0.006
SUM	0.045	0.040	0.043	0.036	0.036
Aggregated Weight Coefficient Vectors	0.2118	0.1990	0.2067	0.1907	0.1907

Source: Author's research

Likewise, the rational management of the given criteria can influence the mitigation of environmental problems in agriculture.

Tables 6–12 show the calculations and results of using the LMAW-DNMA method.

Table 6.
Initial matrix

KIND	1	1	-1	1	1
Weight	0.2118	0.1990	0.2067	0.1907	0.1907
	C1	**C2**	**C3**	**C4**	**C5**
A1	5566.034	2646.96	512.091	65419.531	73592.017
A2	5391.957	1367.08	802.946	67996.287	106433.258
A3	4359.751	3523.87	634,896	68428.142	112788.578
A4	3167.46	2620	567.126	76254.497	43457.975
A5	632.591	985.46	110.017	9353.874	9353.874
A6	4916.941	2270	662,937	30661.41	47716.296
A7	64743.288	28897.88	4170.839	572984.854	399412.668
A8	47973.969	16595	3628.04	537267.993	728737.653
A9	4901.423	5267.52	277.301	63623.354	74835.612

A10	8679.09	4997.88	700.36	74931.372	62818.386
A11	2909.819	4511.42	219,381	123403.364	57716.091
A12	56372.591	13122.14	2758.885	362630.758	381247.962
A13	1900.41	in 1969	205,448	15937.061	10446.626
A14	2558.762	2942.78	113.357	39056.513	20182.554
A15	64.101	132.14	23,653	6148.221	9064.902
A16	9823.805	1814.45	3814.606	124373.91	163915.182
A17	24616.368	14754.86	3846.049	320817.329	376037.978
A18	9706.261	3970.41	408.514	63280.874	57453.771
A19	2330.981	1910.04	132,499	26593.8	37002.706
A20	963,765	484.06	71,952	18166.135	15851.442
A21	66471.881	24434.63	2695.059	480202.446	274742.895
A22	2047.474	3005.54	590.204	53308.908	46284.753
MAX	66471.8810	28897.8800	4170.8390	572984.8540	728737.6530
MIN	64.1010	132.1400	23.6530	6148.2210	9064.9020

Source: Author's research

Table 7.
Linear Normalized Matrix

	C1	C2	C3	C4	C5	MAX
A1	0.0829	0.0874	0.8822	0.1046	0.0897	0.8822
A2	0.0802	0.0429	0.8121	0.1091	0.1353	0.8121
A3	0.0647	0.1179	0.8526	0.1099	0.1441	0.8526
A4	0.0467	0.0865	0.8690	0.1237	0.0478	0.8690
A5	0.0086	0.0297	0.9792	0.0057	0.0004	0.9792
A6	0.0731	0.0743	0.8459	0.0432	0.0537	0.8459
A7	0.9740	1.0000	0.0000	1.0000	0.5424	1.0000
A8	0.7214	0.5723	0.1309	0.9370	1.0000	1.0000
A9	0.0728	0.1785	0.9388	0.1014	0.0914	0.9388
A10	0.1297	0.1692	0.8368	0.1213	0.0747	0.8368
A11	0.0429	0.1522	0.9528	0.2069	0.0676	0.9528
A12	0.8479	0.4516	0.3405	0.6289	0.5172	0.8479
A13	0.0277	0.0639	0.9562	0.0173	0.0019	0.9562
A14	0.0376	0.0977	0.9784	0.0581	0.0154	0.9784
A15	0.0000	0.0000	1.0000	0.0000	0.0000	1.0000
A16	0.1470	0.0585	0.0859	0.2086	0.2152	0.2152
A17	0.3697	0.5083	0.0783	0.5551	0.5099	0.5551
A18	0.1452	0.1334	0.9072	0.1008	0.0672	0.9072
A19	0.0341	0.0618	0.9738	0.0361	0.0388	0.9738
A20	0.0135	0.0122	0.9884	0.0212	0.0094	0.9884
A21	1.0000	0.8448	0.3559	0.8363	0.3692	1.0000
A22	0.0299	0.0999	0.8634	0.0832	0.0517	0.8634

Source: Author's research

Table 8.
Vector Normalization Matrix

	C1	C2	C3	C4	C5	MAX
A1	0.5644	0.5273	0.9447	0.5829	0.4923	0.9447
A2	0.5631	0.5043	0.9118	0.5850	0.5177	0.9118
A3	0.5557	0.5431	0.9308	0.5854	0.5227	0.9308
A4	0.5472	0.5268	0.9385	0.5918	0.4689	0.9385
A5	0.5291	0.4974	0.9902	0.5368	0.4425	0.9902
A6	0.5597	0.5205	0.9276	0.5543	0.4722	0.9276
A7	0.9876	1.0000	0.5306	1.0000	0.7448	1.0000
A8	0.8677	0.7785	0.5921	0.9706	1.0000	1.0000
A9	0.5596	0.5745	0.9713	0.5814	0.4932	0.9713
A10	0.5866	0.5697	0.9234	0.5907	0.4839	0.9234
A11	0.5454	0.5609	0.9778	0.6305	0.4800	0.9778
A12	0.9278	0.7159	0.6904	0.8271	0.7307	0.9278
A13	0.5382	0.5151	0.9794	0.5422	0.4433	0.9794
A14	0.5429	0.5327	0.9898	0.5612	0.4509	0.9898
A15	0.5250	0.4820	1.0000	0.5342	0.4423	1.0000
A16	0.5948	0.5123	0.5710	0.6313	0.5623	0.6313
A17	0.7006	0.7453	0.5674	0.7928	0.7267	0.7928
A18	0.5940	0.5512	0.9564	0.5811	0.4798	0.9564
A19	0.5412	0.5141	0.9877	0.5510	0.4639	0.9877
A20	0.5315	0.4884	0.9945	0.5441	0.4475	0.9945
A21	1.0000	0.9196	0.6977	0.9238	0.6482	1.0000
A22	0.5392	0.5338	0.9359	0.5729	0.4711	0.9359
Adj Wj	0.2150	0.1900	0.2187	0.1992	0.1771	

Source: Author's research

Table 9.
CCM (Complete Compensatory Model)

u1(ai)	C1	C2	C3	C4	C5	SUM
A1	0.0202	0.0188	0.2187	0.0236	0.0180	0.2994
A2	0.0212	0.0100	0.2187	0.0268	0.0295	0.3063
A3	0.0163	0.0263	0.2187	0.0257	0.0299	0.3169
A4	0.0116	0.0189	0.2187	0.0283	0.0097	0.2873
A5	0.0019	0.0058	0.2187	0.0012	0.0001	0.2276
A6	0.0186	0.0167	0.2187	0.0102	0.0112	0.2754
A7	0.2094	0.1900	0.0000	0.1992	0.0960	0.6946
A8	0.1551	0.1088	0.0286	0.1866	0.1771	0.6562
A9	0.0167	0.0361	0.2187	0.0215	0.0172	0.3103
A10	0.0333	0.0384	0.2187	0.0289	0.0158	0.3352
A11	0.0097	0.0304	0.2187	0.0432	0.0126	0.3146
A12	0.2150	0.1012	0.0878	0.1477	0.1080	0.6597
A13	0.0062	0.0127	0.2187	0.0036	0.0004	0.2416
A14	0.0083	0.0190	0.2187	0.0118	0.0028	0.2606
A15	0.0000	0.0000	0.2187	0.0000	0.0000	0.2187
A16	0.1468	0.0516	0.0873	0.1931	0.1771	0.6560
A17	0.1432	0.1740	0.0309	0.1992	0.1627	0.7099
A18	0.0344	0.0279	0.2187	0.0221	0.0131	0.3163
A19	0.0075	0.0121	0.2187	0.0074	0.0071	0.2528
A20	0.0029	0.0024	0.2187	0.0043	0.0017	0.2300
A21	0.2150	0.1605	0.0778	0.1666	0.0654	0.6853
A22	0.0074	0.0220	0.2187	0.0192	0.0106	0.2780

Source: Author's research

Table 10.
UCM (Uncompensatory Model)

u2(ai)	C1	C2	C3	C4	C5	MAX
A1	0.1948	0.1712	0.0000	0.1756	0.1591	0.1948
A2	0.1937	0.1800	0.0000	0.1724	0.1476	0.1937
A3	0.1987	0.1637	0.0000	0.1735	0.1471	0.1987
A4	0.2034	0.1711	0.0000	0.1708	0.1673	0.2034
A5	0.2131	0.1843	0.0000	0.1980	0.1770	0.2131
A6	0.1964	0.1733	0.0000	0.1890	0.1658	0.1964
A7	0.0056	0.0000	0.2187	0.0000	0.0810	0.2187
A8	0.0599	0.0813	0.1901	0.0126	0.0000	0.1901
A9	0.1983	0.1539	0.0000	0.1777	0.1598	0.1983
A10	0.1817	0.1516	0.0000	0.1703	0.1613	0.1817
A11	0.2053	0.1597	0.0000	0.1559	0.1645	0.2053
A12	0.0000	0.0888	0.1309	0.0514	0.0691	0.1309
A13	0.2088	0.1773	0.0000	0.1956	0.1767	0.2088
A14	0.2067	0.1710	0.0000	0.1874	0.1743	0.2067
A15	0.2150	0.1900	0.0000	0.1992	0.1771	0.2150
A16	0.0681	0.1384	0.1314	0.0061	0.0000	0.1384
A17	0.0718	0.0160	0.1879	0.0000	0.0144	0.1879
A18	0.1806	0.1621	0.0000	0.1770	0.1640	0.1806
A19	0.2074	0.1780	0.0000	0.1918	0.1700	0.2074
A20	0.2120	0.1877	0.0000	0.1949	0.1754	0.2120
A21	0.0000	0.0295	0.1409	0.0326	0.1117	0.1409
A22	0.2075	0.1680	0.0000	0.1800	0.1665	0.2075

Source: Author's research

Table 11.
ICM (Incomplete Compensatory Model)

u3(ai)	C1	C2	C3	C4	C5	MAX
A1	0.8952	0.8951	1.0000	0.9083	0.8910	0.6485
A2	0.9016	0.8936	1.0000	0.9154	0.9046	0.6671
A3	0.8950	0.9027	1.0000	0.9118	0.9028	0.6651
A4	0.8905	0.8961	1.0000	0.9122	0.8844	0.6438
A5	0.8739	0.8774	1.0000	0.8852	0.8671	0.5885
A6	0.8971	0.8960	1.0000	0.9025	0.8873	0.6437
A7	0.9973	1.0000	0.8706	1.0000	0.9492	0.8241
A8	0.9700	0.9535	0.8917	0.9941	1.0000	0.8198
A9	0.8882	0.9050	1.0000	0.9028	0.8869	0.6437
A10	0.9071	0.9123	1.0000	0.9149	0.8919	0.6752
A11	0.8820	0.8998	1.0000	0.9163	0.8816	0.6411
A12	1.0000	0.9519	0.9374	0.9774	0.9586	0.8361
A13	0.8792	0.8851	1.0000	0.8889	0.8690	0.6011
A14	0.8788	0.8889	1.0000	0.8931	0.8700	0.6070
A15	0.8706	0.8705	1.0000	0.8826	0.8655	0.5790
A16	0.9873	0.9611	0.9782	1.0000	0.9797	0.9094
A17	0.9738	0.9883	0.9294	1.0000	0.9847	0.8808
A18	0.9027	0.9006	1.0000	0.9055	0.8850	0.6514
A19	0.8787	0.8833	1.0000	0.8903	0.8748	0.6044
A20	0.8740	0.8736	1.0000	0.8868	0.8681	0.5878
A21	1.0000	0.9842	0.9243	0.9843	0.9261	0.8292
A22	0.8882	0.8988	1.0000	0.9069	0.8856	0.6411

Source: Author's research

Table 12.
Rank Order

											w1	w2	w3	
											0.6	**0.1**	**0.3**	
		CCM		**φ**	**UCM**		**φ**	**ICM**		**φ**	**Utility Values**			**Rank Order**
		u1(ai)	**Rank**	**0.5**	**u2(ai)**	**Rank**	**0.5**	**u3(ai)**	**Rank**	**0.5**				
Austria	A1	0.2994	13	0.4384	0.1948	9	0.6930	0.6485	11	0.6348	0.5228	0.5228		**13**
Belgium	A2	0.3063	12	0.4670	0.1937	8	0.6770	0.6671	8	0.7082	0.5604	0.5604		**10**
Czech Republic	A3	0.3169	8	0.5763	0.1987	12	0.7492	0.6651	9	0.6855	0.6263	0.6263		**8**
Denmark	A4	0.2873	14	0.4069	0.2034	13	0.7791	0.6438	12	0.6129	0.5059	0.5059		**14**
Estonia	A5	0.2276	21	0.2356	0.2131	20	0.9422	0.5885	20	0.4677	0.3759	0.3759		**21**
Finland	A6	0.2754	16	0.3548	0.1964	10	0.7116	0.6437	13	0.5948	0.4625	0.4625		**16**
France	A7	0.6946	2	0.9666	0.2187	22	1.0000	0.8241	5	0.8633	0.9390	0.9390		**2**
Germany	A8	0.6562	5	0.8729	0.1901	7	0.6544	0.8198	6	0.8396	0.8411	0.8411		**6**
Greek	A9	0.3103	11	0.4943	0.1983	11	0.7321	0.6437	14	0.5781	0.5432	0.5432		**12**
Hungary	A10	0.3352	7	0.6131	0.1817	5	0.6088	0.6752	7	0.7349	0.6492	0.6492		**7**
Ireland	A11	0.3146	10	0.5223	0.2053	14	0.8019	0.6411	16	0.5469	0.5576	0.5576		**11**
Italy	A12	0.6597	4	0.8971	0.1309	1	0.4244	0.8361	3	0.9143	0.8550	0.8550		**5**
Latvia	A13	0.2416	19	0.2728	0.2088	18	0.8889	0.6011	19	0.4848	0.3980	0.3980		**19**
Lithuania	A14	0.2606	17	0.3234	0.2067	15	0.8240	0.6070	17	0.5099	0.4294	0.4294		**17**
Luxembourg	A15	0.2187	22	0.2202	0.2150	21	0.9688	0.5790	22	0.4513	0.3644	0.3644		**22**
Netherlands	A16	0.6560	6	0.8518	0.1384	2	0.4519	0.9094	1	1.0000	0.8562	0.8562		**4**
Poland	A17	0.7099	1	1.0000	0.1879	6	0.6372	0.8808	2	0.9616	0.9522	0.9522		**1**
Portugal	A18	0.3163	9	0.5493	0.1806	4	0.5977	0.6514	10	0.6566	0.5864	0.5864		**9**
Slovak Republic	A19	0.2528	18	0.2987	0.2074	16	0.8451	0.6044	18	0.4967	0.4127	0.4127		**18**
Slovenia	A20	0.2300	20	0.2486	0.2120	19	0.9180	0.5878	21	0.4615	0.3794	0.3794		**20**
Spain	A21	0.6853	3	0.9377	0.1409	3	0.4656	0.8292	4	0.8881	0.8756	0.8756		**3**
Sweden	A22	0.2780	15	0.3779	0.2075	17	0.8653	0.6411	15	0.5609	0.4815	0.4815		**15**
	MAX	0.7099			0.2187			0.9094						

Source: Author's research

According to the results of the LMAW-DNMA methods, the top five countries of the European Union in terms of environmental problems in agriculture are, in the following order, Poland, France, Spain, the Netherlands and Italy. In countries such as Slovenia (twentieth place), Estonia (twenty-first place) and Luxembourg (twenty-second place), the environmental problem in agriculture is less pronounced than in the other observed countries of the European Union.

In order to alleviate the ecological problem in agriculture in European Union countries, certain measures are taken, such as increasing organic production, adequate treatment of animal waste, adequate treatment of packaging waste, digitization, subsidies, and environmental taxes. This is also the case with other countries in the world. Significant environmental measures include digitization. Among other things, it enables a more rational use of chemical inputs and reduces energy consumption in agriculture.

Table 13 and Figure 1 show total organic area in the countries of the European Union for 2012 and 2020

Table 13.
Total organic area (fully converted and under conversion), 2012 and 2020, in the EU-27, Iceland, Norway, Switzerland, North Macedonia, Serbia and Turkey

	Organic area (ha)		2012–20 (% change)
	in 2012	in 2020	
EU-27 (1)	9,457,886	14,719,036	55.6
1.Belgium (2)	59,718	99,072	65.9
2.Bulgaria	39,138	116,253	197.0
3.Czechia	468,670	540,375	15.3
4.Denmark	194,706	299,998	54.1
5.Germany	959,832	1,590,962	65.8
6.Estonia	142,065	220,796	55.4
7.Ireland	52,793	74,666	41.4
8.Greece	462,618	534,629	15.6
9.Spain	1,756,548	2,437,891	38.8
10.France (2)	1,030,881	2,517,478	144.2
11.Croatia	31,904	108,610	240.4
12.Italy	1,167,362	2,095,364	79.5
13.Cyprus	3,923	5,918	50.9
14.Latvia	195,658	291,150	48.8
15.Lithuania	156,539	235,471	50.4
16.Luxembourg	4,130	6,118	48.1
17.Hungary	130,607	301,430	130.8
18.Malta	37	67	81.1
19.Netherlands	48,038	71,607	49.1
20.Austria (3)	533,230	671,703	26.0
21.Poland	655,499	509,286	-22.3
22.Portugal	200,833	319,540	59.1
23.Romania	288,261	468,887	62.7
24.Slovenia	35,101	52,078	48.4
25.Slovakia	164,360	222,896	35.6
26.Finland	197,751	316,248	59.9
27.Sweden	477,684	610,543	27.8
Iceland	:	4,982	:
Norway	55,260	45,181	- 18.2
Switzerland	121,213	176,337	45.5
North Macedonia	:	3,727	:
Serbia	:	20,971	:
Turkey	:	382,639	:

Notes: (:) data not available. (1) estimates. (2) estimate. (3) Organic area, 2019
Source: Eurostat (online data code: org_cropar)

The given table clearly shows that in the European Union in 2020, compared to 2012, organic area increased by 65.9%. The increase in organic area is different across countries. For example, in Germany it increased by 65.8%, in France by 144.2%, and in Italy by 79.5%. Figure 1 shows the shares of individual countries in the total organic area of the European Union: France 17.1%, Spain 16.6%, Italy 14.2%, Germany 10.8%, Austria 4.6%, Sweden 4.1%, and the other countries 32.6%.

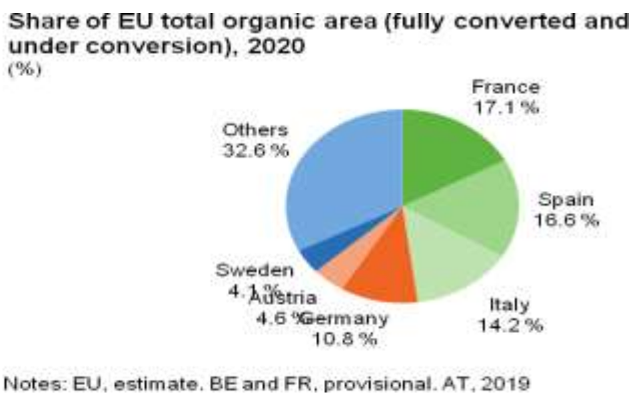

Figure 1. Share of individual countries in the total organic area of the European Union
Source: Eurostat

Table 14 shows the total environmental tax revenue by type of tax and tax payer in the EU for 2020.

Table 14.
Total environmental tax revenue by type of tax and tax payer, EU 2020

	A million Euros	% of total environmental taxes	% of GDP	% of total government revenue from taxes and social contributions (TSC)	% of (specific type of) environmental tax revenue (by tax payer)		
	in 2020				in 2020		
					Corporations	Households	Non-residents
Total environmental taxes	300,537	100.0	2.24	5.42	47.6	48.6	3.8
Energy taxes	231,552	77.0	1.73	4.19	52.0	43.3	4.6
Transport fees	57,874	19.3	0.43	1.04	31.0	68.2	0.8
Taxes on Pollution/Resources	11,111	3.7	0.08	0.20	42.0	56.8	1.2

Note: The shares by 'payer' do not necessarily add up to 100% owing to a small share of 'not allocated taxes'. The shares of GDP and TSC are calculated with the taxes reported in the national tax lists from Oct 2021
Source: Eurostat (online data codes: env_ac_tax and env_ac_taxind2

In the European Union, in order to alleviate the environmental problem, an ecological tax is applied. For example, the tax on pollution/resources in 2020 accounted for 0.08% of the gross domestic product of the European Union.

In the European Union, a short-term trend and a long-term trend of mitigating environmental problems in agriculture have been defined (Figure 2).

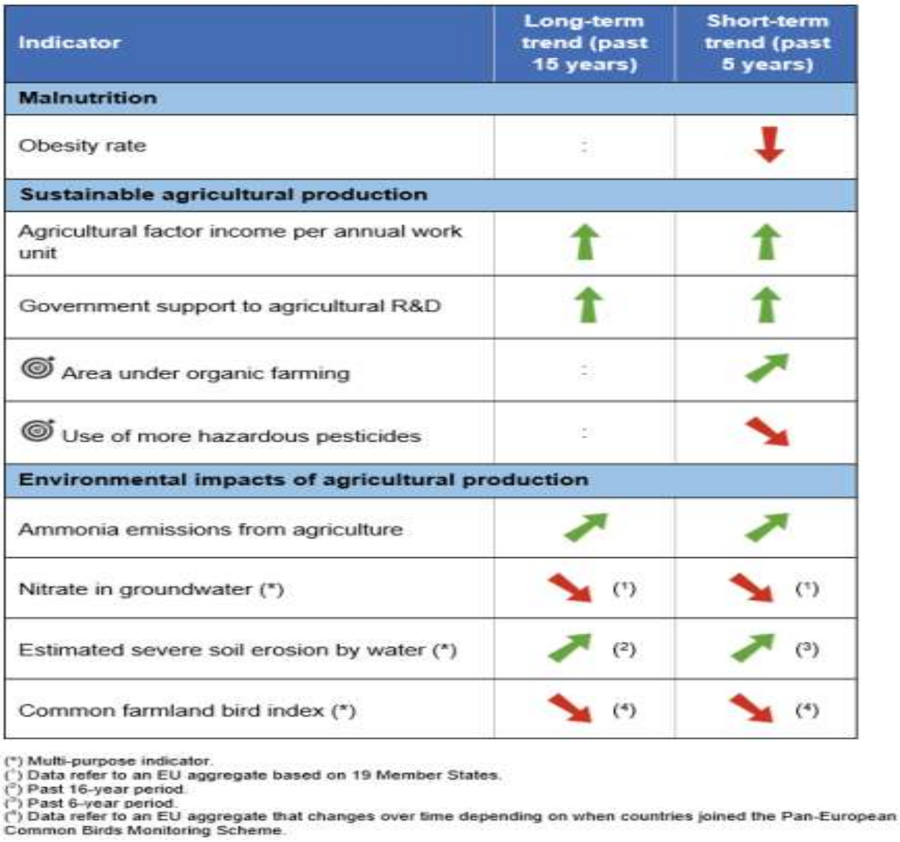

Figure 2. Agro-environmental strategy of the European Union
Source: Eurostat
Notes: The green arrow shows satisfactory progress towards the goal of the European Union. The red arrow shows unsatisfactory progress towards the goal of the European Union.

4. Conclusions

Based on the analysis of the ecological problem in the agriculture of the selected countries of the European Union, the following can be concluded: According to the results of the LMAW-DNMA method, the top five countries of the European Union in terms of environmental problems in agriculture are, in the following order, Poland, France, Spain, the Netherlands and Italy. The ecological problem in agriculture is pronounced in these countries. In countries such as Slovenia (twentieth place), Estonia (twenty-first place) and Luxembourg (twenty-second place), the ecological problem in agriculture is less pronounced than in the other observed countries of the European Union.

In the European Union countries, in order to alleviate the environmental problem in agriculture, certain measures are taken, such as increasing organic production, digitization, subsidies, and environmental taxes.

Declaration of competing interest

The author declares that he had no conflict of interests.

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