“Assessing the level of organic farming development in the European countries”

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ARTICLE INFO	Viktoriia Baidala, Vira Butenko, Vitalii Vakulenko, Pavlo Yastrebov and Liu Xiaowei (2024). Assessing the level of organic farming development in the European countries. *Environmental Economics*, *15*(1), 56-69. doi:10.21511/ee.15(1).2024.05
DOI	http://dx.doi.org/10.21511/ee.15(1).2024.05
RELEASED ON	Friday, 15 March 2024
RECEIVED ON	Wednesday, 27 December 2023
ACCEPTED ON	Tuesday, 27 February 2024
LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
33	**8**	**9**

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ASSESSING THE LEVEL OF ORGANIC FARMING DEVELOPMENT IN THE EUROPEAN COUNTRIES

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

Received on: 27th of December, 2023
Accepted on: 27th of February, 2024
Published on: 15th of March, 2024

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Abstract

Organic farming is an essential approach to agriculture that seeks to reduce the negative impact of human activities on the environment and ensure the sustainability of food production. The study aims to determine the integral index of the development of organic farming and to create a clustering model of organic farming in European countries. As a research methodology, additive-multiplicative convolution was used to determine the integral index of organic farming development. Cluster analysis (the Ward method and the k-means clustering method) identified respective clusters. The integrated index is based on eight indicators of organic farming from the Eurostat database, 2012–2020, and ranges from zero to one. The following countries have the highest value of the integral index: Italy (0.57), France (0.54), Spain (0.54), Germany (0.45), and Turkey (0.47). Three clusters were identified according to eight indicators of organic agriculture. The first cluster includes countries-leaders in agricultural territories (about 2.1 million hectare) with the highest state financial support for agricultural research and development (1.1 billion euros). The second cluster includes countries with the most minor organic farming operators (50-100 operators). The third cluster includes countries with the highest index of annual income from the sale of farm products (200-220 points) but with the highest level of usage of dangerous pesticides (250 points). The heterogeneity of clusters allows one to determine the strengths and weaknesses of organic farming in European countries.

Keywords farming, agriculture, pesticides, development, Europe, government, index, clusters

JEL Classification O13, Q10

INTRODUCTION

Organic farming is a method of agriculture that strives to create a sustainable and environmentally friendly food production system by minimizing negative impacts on the environment and providing high-quality products to consumers. Organic farmers are turning to more natural methods of controlling pests and improving soil fertility, such as compost, biodegradable fertilizers, and biological pest control. Organic farming typically undergoes certification to meet specific standards set by organizations such as the USDA in the United States or EU Organic in the European Union.

Organic farming occupies a central place in the vast mosaic of European agriculture. As countries today grapple with global climate challenges, assessing the level of development of organic farming becomes a critical lens to understand the dynamics of agricultural development.

The European Commission presented the Action Plan for the Development of Organic Production, which provides that 25% of all agricultural land should be used for organic products by 2030. This

Conflict of interest statement:
Author(s) reported no conflict of interest

plan aims to increase the production and consumption of organic products, achieve 25% of agricultural land under organic farming by 2030, and significantly increase organic aquaculture. Organic production brings several advantages both for consumers of products and for agricultural producers. Organic fields have 30% more biota in livestock than fields under conventional technology. Thus, the level of development of organic farming is a complex phenomenon that includes not only the land areas allocated for the cultivation of organic crops but also the level of sales from organic farming and ecological indicators of producers of organic products.

1. LITERATURE REVIEW

Overall, organic farming is essential in creating sustainable and environmentally friendly food production systems that help preserve natural resources for future generations. The origins of organic farming can be traced back to the early 20th century with the pioneering work of Sir Albert Howard and Rudolf Steiner. Their ideas about natural farming, composting, and biodynamic agriculture laid the philosophical foundations for breeding new varieties of crops (Mandolesi et al., 2022). Titisari et al. (2022), Bazhan et al. (2023), and Carucci et al. (2023) presented the concept of innovative organic farming. Organic farming gained popularity in the 1960s and 1970s, fueled by concerns about the use of synthetic pesticides and fertilizers and a desire to find sustainable alternatives. Thus, the sustainability of agriculture became relevant for organic farming.

Magrin (2022) proposes a method for assessing the sustainability of organic farming in EU countries. Nematollahi et al. (2021) investigate a tripartite agricultural supply chain consisting of agribusiness, organic farming, and traditional farming. Kociszewski et al. (2023) present the evolution of the formation of organic farming in Poland during 2011–2021. A similar study, but about Turkey, was conducted by Akyüz and Theuvsen (2021), about Portugal – Salavisa et al. (2021), Kazakhstan – Grigoruk et al. (2021), and African countries – Schader et al. (2021). In addition, the topic devoted to producing and using organic seeds is essential. Solfanelli et al. (2022) provide a general assessment of the supply and demand for organic seeds in Europe using the example of twelve important crops for EU organic agriculture. The main obstacle to developing organic farming in this country is the population's low level of general environmental awareness.

One of the key factors in developing organic farming was the establishment of comprehensive policies and regulations. Governments and international organizations have played a critical role in defining and standardizing organic practices. The development of organic product certification systems and the implementation of organic standards have played an important role in strengthening consumer confidence and ensuring the integrity of organic products (Stephenson et al., 2022). Gambelli et al. (2023) analyze the part of regulatory provisions regulating the introduction of organic farming in EU countries using the example of the "TP Organics" programs, the European Technology Platform (ETP). Rudnicki et al. (2021) analyzed the normative regulation of organic farming in Poland and its compliance with EU regulations. Policymakers have also introduced incentives, subsidies, and support programs to encourage the transition from conventional to organic farming.

Organic farming has gained recognition for its environmental benefits. It prioritizes soil health, reduction of synthetic chemicals, and conservation of biodiversity (Sarkar et al., 2021). These methods help mitigate soil erosion, water pollution, and greenhouse gas emissions. The degradation of fertile soils remains a severe ecological problem for many regions worldwide. Fenta et al. (2023) investigated runoff change, soil loss, soil organic carbon stocks, and land productivity based on five land use planning and management alternatives in the Aba Gerima watershed of the Upper Blue Nile Basin in Ethiopia. It was quantitatively confirmed that implementing such methods has a positive effect on the qualitative characteristics of the soil. Zhao et al. (2023) investigated how soil organic carbon content changed under the influence of chemical fertilizer treatment and nuclear magnetic resonance. Organic farming systems can be more resilient to climate change and contribute to overall health ecosystems, making them a critical component of sustainable agriculture. However, on the other hand, organic farming can also cause organic pollution in the surrounding area (Hettige et al., 2023), which will threaten the ecological state of the environment. It is also equally important to consider the qualitative composition of the soil and fertilizers applied during organic farming to minimize the negative impact on the general ecological state of the environment (Arynov et al., 2021).

The economic dimensions of organic farming have developed significantly. Originally considered a niche market, organic farming has experienced exponential growth in response to increasing consumer demand for organic products. This growth has created economic opportunities for farmers, processors, and retailers. Kowalska and Bieniek (2022) reviewed the development of organic farming in Europe and the EU to determine incentives for farmers to switch to this type of activity. Thus, with the help of organic farming in the operation of olive farms on the west coast of Palestine (Kashiwagi & Kamiyama, 2023), the level of added value of agriculture began to increase steadily. An equally important issue in this context is the financial sustainability of farms that engage in organic farming (Dono et al., 2022). However, challenges related to economies of scale, price premiums, and market competition remain relevant for developing organic farming.

The development of organic farming is closely related to the growth of consumer demand and awareness. Growing health consciousness, food safety concerns (Mahboubeh et al., 2023), and environmental awareness are driving consumers to choose organic products. Zhou and Ding (2022), using the example of farmers in Anhui province of China, identified central factors that influence their desire to engage in organic farming. These factors include the farmer's education level, political status, family disposable income, and understanding of organic farming and environmental hazards. Consumer demand for organic farming products is gradually gaining popularity. In particular, Jiang et al. (2022) presented the issue of growing organic medicinal plants in the context of actualizing healthcare issues. Prodhan et al. (2023) focus on the development of organic tea cultivation in Bangladesh, researching ways to reduce production volumes and, as a consequence, the export of tea. Zámková et al. (2023) assessed consumer demand for organic products during the spread of the COVID-19 pandemic in the Czech Republic. Accordingly, the younger population is not too inclined to consume organic products, unlike people of average and older age. Consequently, the organic market has expanded, leading to increased investment and participation by both small and large farmers.

Despite its growth, organic farming faces several challenges. The transition from conventional to organic farming can financially and technically challenge farmers (Campuzano et al., 2023). Lack of access to organic markets, price volatility, and competition with traditional agriculture create challenges for producers. In addition, issues related to falsified labeling of organic products and the need for international harmonization of organic standards require constant attention. Considering the relevance of research in organic farming, the purpose of this study is to determine the integral index of the development of organic farming and to create a clustering model of the structure of organic farming in European countries. It may shed light on the unique features of the diversity of progress, challenges, and opportunities for organic farming in European countries.

2. METHOD

This study assesses the level of development of organic farming using a statistical sample of Eurostat data. In total, data on 34 European countries during the period 2012–2020 are analyzed. As input data for the analysis, 10 indicators of organic farming are used (Table 1).

The paper follows the following stages to analyze the indicators for the sampled countries:

Stage 1. Normalize input data using the maximin method.

Stage 2. Identify relevant indicators using the method of principal components.

Stage 3. Determine weighting coefficients for each indicator during the resolution of the integral indicator of the development of organic farming.

Table 1. An array of input data

Source: Eurostat.

No.	Notation of the indicator	Indicator	Unit of measurement
1	*Org_farm1*	Organic farming operators, according to the status of the registration process	Operators
2	*Org_farm2*	The area of organic farming crops	Hectare
3	*Org_farm3*	The area of agricultural territories, excluding vegetable gardens	Hectare
4	*Org_farm4*	Number of producers of agricultural products	Producers
5	*Org_farm5*	Index of annual income from the sale of agricultural products per unit of labor	Index
6	*Org_farm6*	Nitrates in groundwater	milligrams per liter
7	*Org_farm7*	Ammonia emissions from agricultural activities	Tons
8	*Org_farm8*	Use of dangerous pesticides	Index
9	*Org_farm9*	State financial support for agricultural research and development	million euros
10	*Org_farm10*	Share of the total agricultural area used for organic farming	%

Stage 4. Calculate the integral indicator of the development of organic farming using the method of additive-multiplicative convolution.

Stage 5. Cluster the studied countries according to pre-selected indicators (Stage 2) using Ward and k-means methods.

Stage 6. Analyze the obtained results.

In the first stage, it is necessary to normalize the array of input indicators due to their different nature of origin. Since indicators describe one phenomenon under study, they usually differ in absolute units of measurement. Thus, the possibility to compare indicators with each other disappears. Therefore, data normalization allows bringing all indicators to the same area of their change and, as a result, makes them commensurate.

To normalize the data, it is necessary to know precisely the limits of change of each indicator. Therefore, it is required to determine their minimum and maximum values. Thus, the limits of normalization will be selected. Formulas for normalizing indicators-stimulators and indicators-destimulators are as follows:

$$\widetilde{x_{ikstim}} = \frac{x_{ik} - x_{\min i}}{x_{\max i} - x_{\min i}}, \tag{1}$$

$$\widetilde{x_{ikdestim}} = \frac{x_{\max i} - x_{ik}}{x_{\max i} - x_{\min i}}, \tag{2}$$

where $\tilde{x}_{ikstim}$, $\tilde{x}_{ikdestim}$ – normalized values of stimulating indicators and destimulating indicators, respectively; x_{ik} – initial values of indicators; x_{maxi}, x_{mini}, – the maximum and minimum value of indicators.

In the second stage, the study calculates the weighting coefficients for each indicator, which indicates the level of development of organic farming. A successful solution for determining the weighting coefficients of the indicators that will form the basis of the integral index of the development of organic farming is the use of factor analysis, which is based on the method of principal components. With the help of this econometric approach, one can not only identify the weighting factors in a reasoned way but also select the most relevant input indicators, which can be used in the future during the clustering of countries.

The optimal number of indicators is determined based on the factor loadings of each indicator, which is included in several factors (components) that allocate more than 70% of the cumulative variance and are correlated by their values with the Kaiser and Kettel criteria. Thus, the weighting factors are determined using:

$$w_i = \frac{|FL_i|\, p_k}{\sum_i |FL_i|\, p_k}, \tag{3}$$

where w_i – the weighting factor for the variable i; FL_i – statistically significant factor loading value of the i variable; p_k – share of the total variance allocated by the k factor.

Having the values of the weighting coefficients, there can be the next step – the calculation of the integral index of the development of organic farming (the sum of the products of the weighting coefficients and the normalized values of the input indicators), which is based on:

$$IIOF = \sum \overline{x_{ik}} \cdot w_i, \tag{4}$$

where *IIOF* – integral index of development of organic farming; x_{ik} – normalized value of the *i* indicator for the *k* country; w_i – weight factor of the *i* indicator.

After the fourth stage, which involves the calculation of the integral index of the development of organic farming, the next stage clusters the studied countries according to the indicators of organic farming selected in the previous step.

Hierarchical methods include the intergroup communication, the "nearest neighbor" method, the "distant neighbor" method, the method of weighted and unweighted pairwise averages, the method of weighted and unweighted centroids, and the Ward method. All of the listed methods make it possible to build dendrograms (a visual representation of the functional relationships between the studied indicators, which made it possible to form the corresponding clusters of countries). Ward's method was chosen from all existing hierarchical methods to carry out two-stage clustering. It differs from all other methods of this group because it uses variance analysis methods to estimate the distance between clusters. Due to the sum of these distances between indicators, the redistribution of countries in clusters is detailed. Those clusters that give the smallest increase in the total sum of variances are combined into each new cluster.

Unlike Ward's, the k-means clustering method is more sensitive to outliers and requires prior determination of the number of clusters. Therefore, there is a need for preliminary clustering by the method of hierarchical analysis, which will allow for obtaining the optimal number of clusters. Along with the identified disadvantages of the k-means method, its advantages include that it is pretty easy to use, uses Euclidean distances as metrics, and provides the possibility of visual interpretation of the obtained results by constructing a graph of the average values of clusters.

Thus, after passing all the research stages, an integral index of the development of organic farming is obtained for 34 countries participating in this analysis. A two-stage clustering of these countries identifies centers of similarity regarding organic farming development. It will allow the European community to consider potential opportunities for improving organic farming practices. All calculations are based on the software complex Stata/SE 12.0.

3. RESULTS

Among the indicators of organic farming presented in Table 1, indicators *Org_farm*6 (nitrates in groundwater), *Org_farm*7 (ammonia emissions from agricultural activities), and *Org_farm*8 (use of dangerous pesticides) are inherently disincentives about the environment and the ecological situation as a whole. They contribute to the accumulation and removal of hazardous substances. However, in modern organic farming, these indicators demonstrate the pace of intensification of its development. Therefore, this study considers them as stimulator indicators, so the array of input data is normalized using the formula 1. Having received the normalized values of the input array of data, it is necessary to proceed to the next stage – determining weighting factors. Factor analysis was carried out with the help of the corresponding module of the Statstica 12 software complex. The graph of stony scree, which is based on the value of the Kettel criterion, allows one to single out the optimal number of factors (components), which in the future must be considered when calculating weighting factors (Figure 1).

On the X-axis are the serial numbers of all factors (components), which correspond to the number of indicators that are the basis of the calculation. The values of the Kettel criterion are presented along the Y-axis, the optimal value of which is one. Thus, if one move along the line of the graph from the left side to the right, there should be a place where the value of the Kettel criterion remains below unity. In this case, the fourth factor meets the specified condition, which indicates their optimal number. This conclusion can be confirmed using the Kaiser criterion, which corresponds to the eigenvalues of the factors. If the Kaiser criterion is higher than one, the corresponding factor should be left for further research. Otherwise, the factors are not taken into account. In addition, the cumulative variance allocated by the factors should exceed 70% to determine the optimal number of factors. Table 2 shows the eigenvalues of the factors (Kaiser's criterion) and the selected variance of the factors.

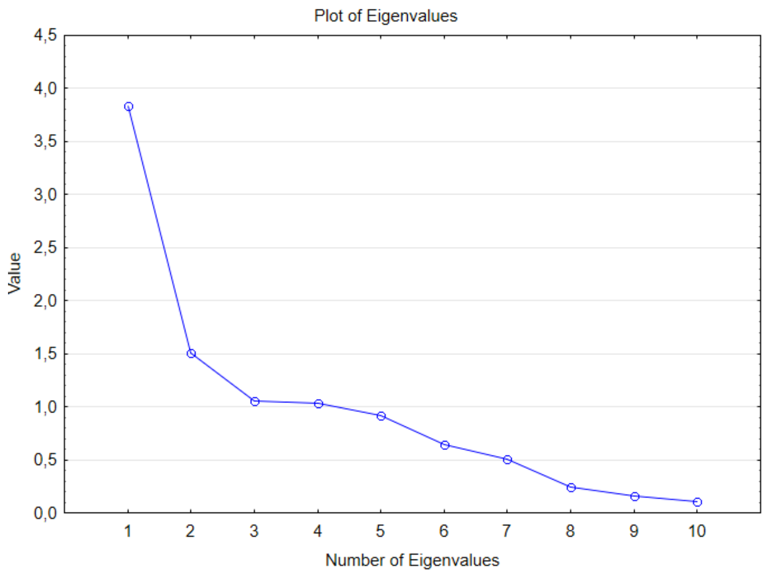


Figure 1. Graph of stony scree

Table 2. Eigenvalues (Kaiser's criterion) and extracted factor variance

Factors	Eigenvalues	Variance	Cumulative variance
Factor 1	3.834	38.335	38.335
Factor 2	1.503	15.030	53.365
Factor 3	1.058	10.581	63.946
Factor 4	1.038	10.377	74.323
Factor 5	0.899	10.010	84.323
Factor 6	0.672	8.140	92.323
Factor 7	0.462	6.120	98.323
Factor 8	0.177	1.005	99.323
Factor 9	0.017	0.610	99.9
Factor 10	0.004	0.04	100

The cumulative variance value (last column of Table 3) of 74.32% corresponds to the fourth factor. In addition, starting from the fifth factor, the eigenvalue (Kaiser's criterion) is lower than one. Therefore, the optimal number of factors for further research corresponds to four. Next, Table 3 presents the factor loadings of the first four factors needed to calculate the weights.

To determine the weighting factors according to formula 3 from Table 4, it is necessary to choose the highest factor load values by module and calculate the weighting factors. Because indicators *Org_farm*4 (the number of producers of agricultural products) and *Org_farm*10 (the share of the total agricultural area used for organic farming) have factor loadings less than 0.7 (absolute value) within all four factors, they should be excluded from the further stages of the study. Therefore, the integral index of the development of organic farming is calculated based on eight indicators. The results of the obtained weighting coefficients for the investigated indicators of organic farming are presented as a linear graph in Figure 2.

Table 3. Factor loadings of indicators of organic farming

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Org_farm1	0.895	–0.072	0.103	–0.013
Org_farm2	0.782	0.115	0.033	0.236
Org_farm3	0.486	–0.006	0.088	0.775
Org_farm4	0.690	–0.275	0.175	0.376
Org_farm5	–0.177	0.776	–0.017	0.320
Org_farm6	–0.151	0.070	–0.811	0.079
Org_farm7	0.806	–0.147	–0.154	0.335
Org_farm8	0.008	0.811	0.010	–0.308
Org_farm9	0.364	–0.113	–0.261	0.702
Org_farm10	–0.190	0.224	0.536	0.547

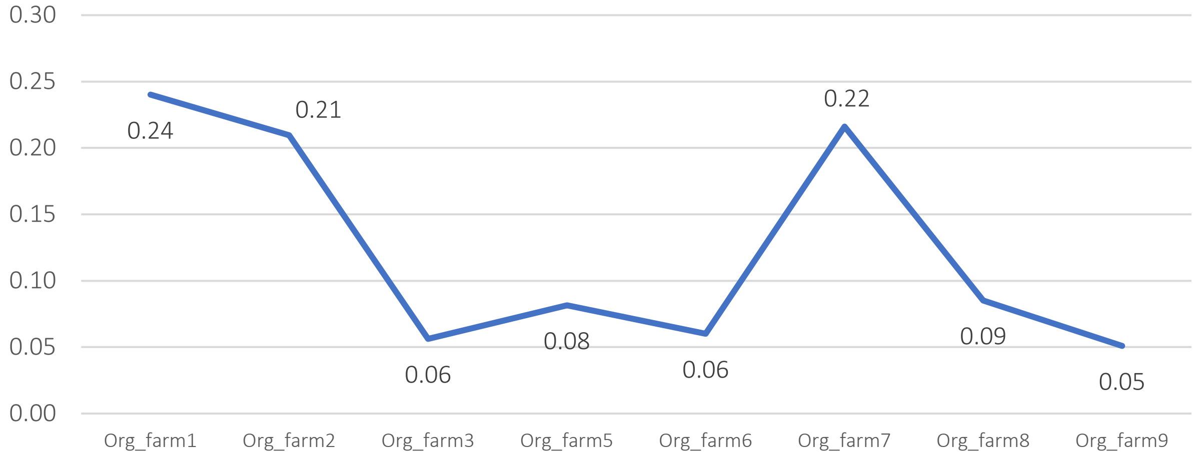


Figure 2. Weighting coefficients of indicators of organic farming

The study further analyzes the obtained weighting coefficients. Three of the eight indicators of organic farming have weighting factors greater than 0.2:

- organic farming operators, according to the status of the registration process (*Org_farm*1) – weighting factor 0.24;
- the area of organic farming crops (*Org_farm*2) – weighting factor 0.21;
- ammonia emissions from agricultural activities (*Org_farm*7) – weighting factor 0.22.

The weight coefficients of the remaining five indicators are less than 0.1:

- the area of agricultural territories excluding vegetable gardens (*Org_farm*3) – weighting factor 0.06;
- index of annual income from the sale of agricultural products per unit of labor (*Org_farm*5) – weighting factor 0.08;
- nitrates in groundwater (*Org_farm*6) – weighting factor 0.06;
- use of dangerous pesticides (*Org_farm*8) – weighting factor 0.09;
- state financial support for agricultural research and development (*Org_farm*9) – weighting factor 0.05.

Weighting coefficients of indicators of organic farming related to emissions of harmful substances (nitrates, pesticides) have minimal values, except ammonia emissions from agricultural activities.

To complete the fourth stage of the analysis, it is necessary to calculate the integrated index of the development of organic farming *IIOF*. As the targeted research period is 2012–2020, the study searched for the value of the integral index in 2012, 2016, and 2020, respectively. Therefore, several leading countries can be singled out with confidence. Their list includes Italy, France, Spain, Germany, and Turkey. These five countries demonstrate that the value of the *IIOF* integral index is at least 0.3.

An essential feature of the transformation of organic farming for the studied countries is that qualitative positive changes in this sector marked the period from 2012 to 2016, as practically all countries demonstrated positive dynamics of changes in the integral index during this period.

At the next research stage, for a better understanding of the European organic farming environment segmentation, there is clustering analysis. The chosen method of hierarchical clustering (Ward's method) will allow one, at the first step, with the help of the resulting dendrogram, to visually assess the optimal number of clusters that stand out among the 34 European countries. Clustering is based on eight indicators that are part of the integral index of organic farming development. Three

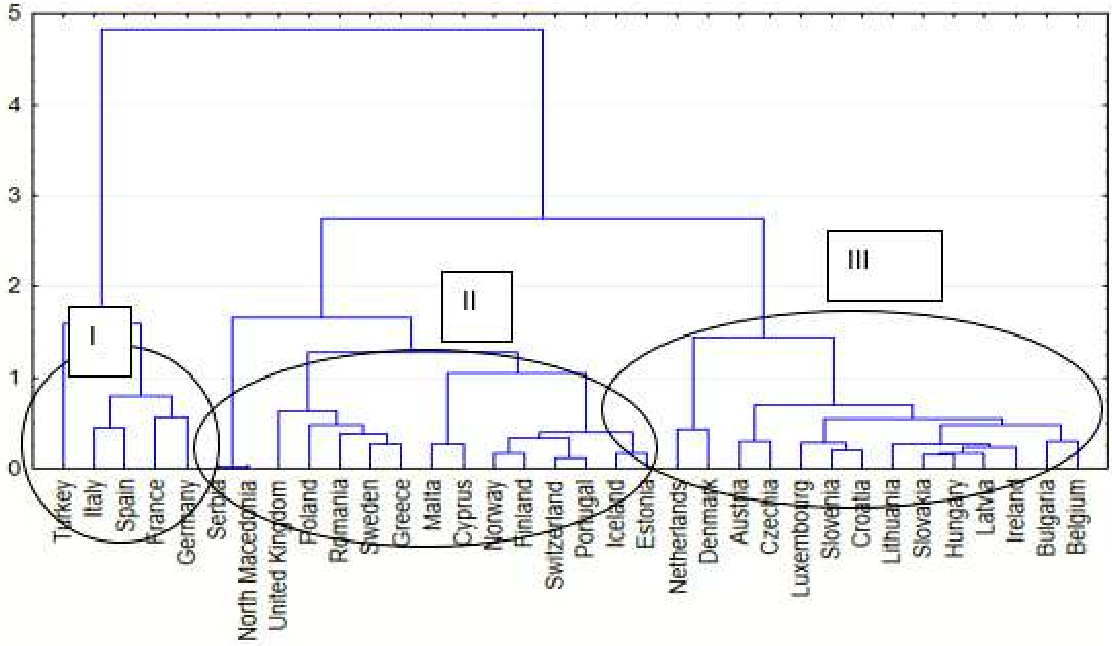


Figure 3. Dendrogram of the distribution of 34 European countries by indicators of organic farming in 2012

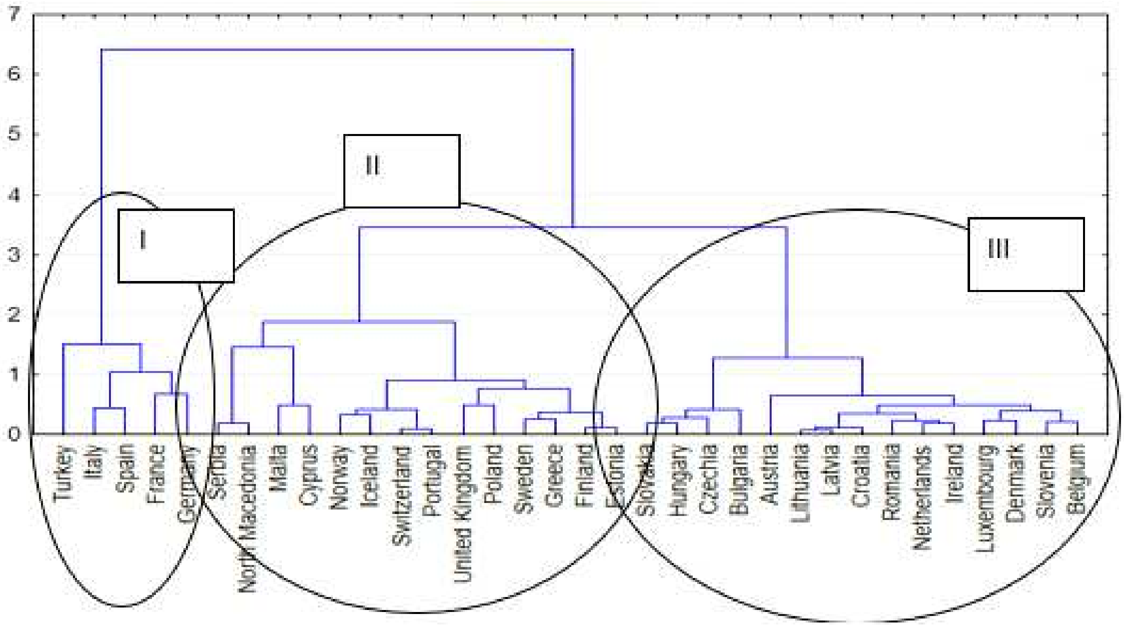


Figure 4. Dendrogram of the distribution of 34 European countries by indicators of organic farming in 2016

years were also chosen for the representativeness of the clustering results: 2012, 2016, and 2020. Figures 3-5 display dendrograms obtained from clustering by Ward's method.

After a visual assessment of the constructed dendrograms in 2012, 2016, and 2020, the studied countries were regrouped into three clusters according to the level of development of organic farming. Next, using the k-means method, the study conducts the qualitative composition of each selected cluster in 2012, 2016, and 2020 (Tables 4-6).

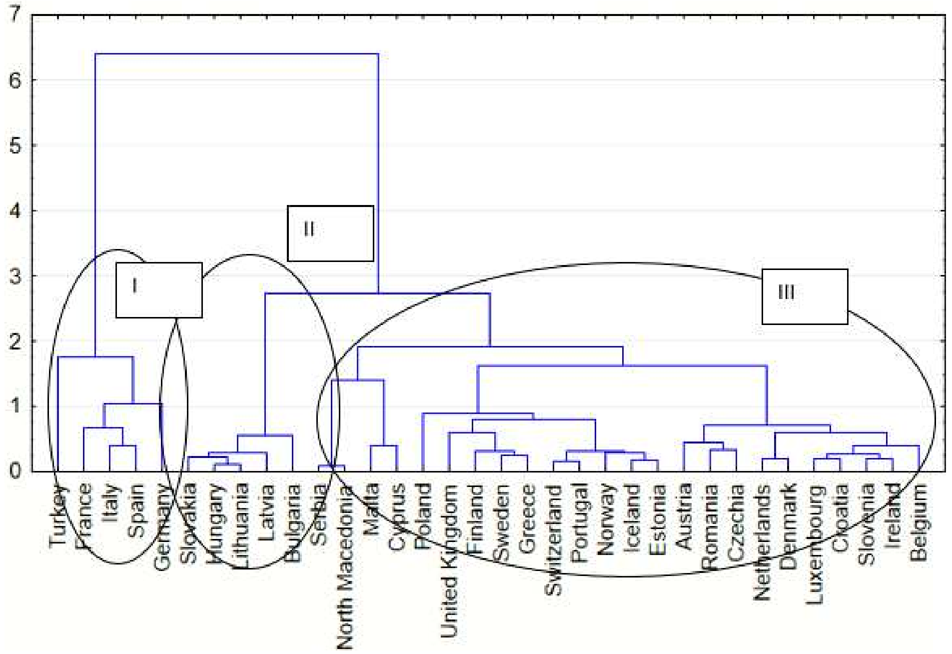


Figure 5. Dendrogram of the distribution of 34 European countries by indicators of organic farming in 2020

Table 4. Clustering of the studied European countries by the k-means method as of 2012

Cluster 1 (6)	Cluster 2 (13)	Cluster 3 (15)
Germany, Spain, France, Italy, Poland, Turkey	Estonia, Greece, Cyprus, Malta, Portugal, Finland, Sweden, Iceland, Norway, Switzerland, the Great Britain, North Macedonia, Serbia	Belgium, Bulgaria, the Czech Republic, Denmark, Ireland, Croatia, Latvia, Lithuania, Luxembourg, Hungary, the Netherlands, Austria, Romania, Slovenia, Slovakia

Table 5. Clustering of the studied European countries by the k-means method as of 2016

Cluster 1 (5)	Cluster 2 (14)	Cluster 3 (15)
Germany, Spain, France, Italy, Turkey	Estonia, Greece, Cyprus, Malta, Poland, Portugal, Finland, Sweden, Iceland, Norway, Switzerland, the Great Britain, North Macedonia, Serbia	Belgium, Bulgaria, the Czech Republic, Denmark, Ireland, Croatia, Latvia, Lithuania, Luxembourg, Hungary, the Netherlands, Austria, Romania, Slovenia, Slovakia

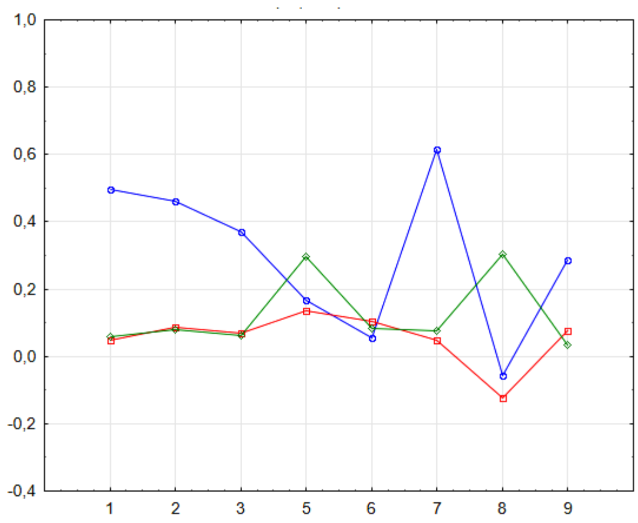
Table 6. Clustering of the studied European countries by the k-means method as of 2020

Cluster 1 (5)	Cluster 2 (18)	Cluster 3 (11)
Germany, Spain, France, Italy, Turkey	Belgium, Denmark, Estonia, Greece, Cyprus, Luxembourg, Malta, the Netherlands, Austria, Portugal, Finland, Sweden, Iceland, Norway, Switzerland, the Great Britain, North Macedonia, Serbia	Bulgaria, the Czech Republic, Ireland, Croatia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, Slovakia

During the studied period, the composition of the clusters in 2012 and 2016 practically did not differ (except for the transfer of Poland from the first cluster in 2012 to the second cluster in 2016): the first cluster included six (five) countries, the second – 13 (14) countries, to the third – 15 countries. In 2020, there were noticeable changes in the qualitative composition between the second and third clusters, while the first design remained stable.

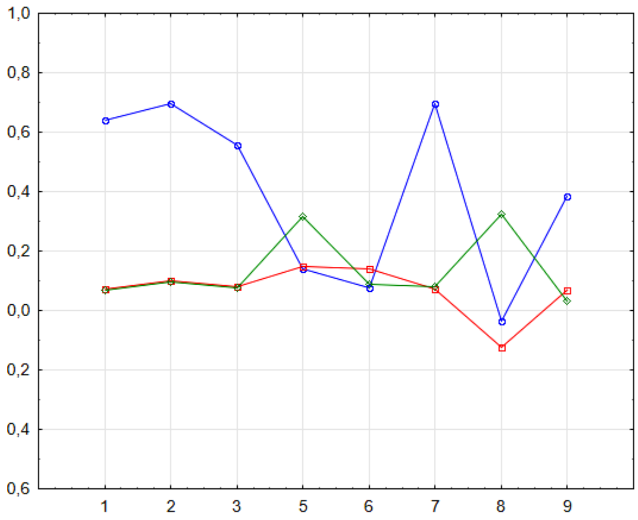
The study further analyzes the average values of indicators of the development of organic farming, which were the basis of clustering (Figures 6-8).

According to the results of the average values of the indicators of organic farming, which were the basis of the clustering, the first cluster included precisely those countries that had the maximum value of five of the eight indicators. These indica-



Note: 1 – *Org_farm*1, 2 – *Org_farm*2, 3 – *Org_farm*3, 5 – *Org_farm*5, 6 – *Org_farm*6, 7 – *Org_farm*7, 8 – *Org_farm*8, 9 – *Org_farm*9. Cluster 1 is marked in blue, cluster 2 in red, and cluster 3 in green.

Figure 6. Average values of indicators of organic farming, which were the basis of clustering of the studied sample of countries in 2012



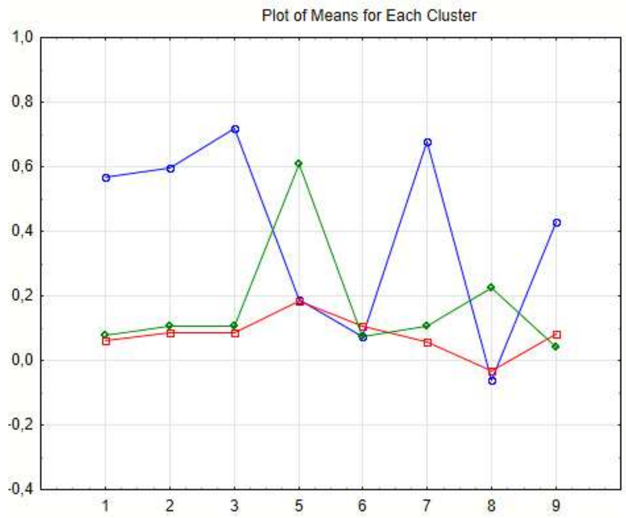
Note: 1 – *Org_farm*1, 2 – *Org_farm*2, 3 – *Org_farm*3, 5 – *Org_farm*5, 6 – *Org_farm*6, 7 – *Org_farm*7, 8 – *Org_farm*8, 9 – *Org_farm*9. Cluster 1 is marked in blue, cluster 2 in red, and cluster 3 in green.

Figure 7. Average values of indicators of organic farming, which were the basis of clustering of the studied sample of countries in 2016

tors are operators of organic farming according to the status of the registration process; the area of organic farming crops; the area of agricultural territories excluding vegetable gardens; ammonia emissions from agricultural activities; and state financial support for agricultural research and development.

Countries that demonstrated an average level of development of organic farming were included in the second cluster for all years. The third cluster consists of the countries with the lowest level, confirmed by the average values of the studied indicators.

The quality of the obtained clustering results can be confirmed using variance analysis. The results of variance analysis for clustering analysis as of 2012, 2016, and 2020 are presented in Tables 7-9.



Note: 1 – *Org_farm*1, 2 – *Org_farm*2, 3 – *Org_farm*3, 5 – *Org_farm*5, 6 – *Org_farm*6, 7 – *Org_farm*7, 8 – *Org_farm*8, 9 – *Org_farm*9. Cluster 1 is marked in blue, cluster 2 in red, and cluster 3 in green.

Figure 8. Average values of indicators of organic farming, which were the basis of clustering of the studied sample of countries in 2020

Table 7. Variance analysis for clustering countries in 2012

Indicator	Variance between clusters	Variance within a cluster	F	*p*-level
Org_farm1	0.97	0.46	32.82	0.00
Org_farm2	0.70	0.63	17.33	0.00
Org_farm3	0.45	0.41	17.33	0.00
Org_farm5	0.19	1.15	2.57	0.02
Org_farm6	0.01	0.77	0.21	0.01
Org_farm7	1.50	0.27	85.49	0.00
Org_farm8	1.40	0.90	24.14	0.00
Org_farm9	0.28	0.48	9.00	0.00

Table 8. Variance analysis for clustering countries in 2012

Indicator	Variance between clusters	Variance within a cluster	F	*p*-level
Org_farm1	1.38	0.51	42.19	0.00
Org_farm2	1.53	0.56	42.23	0.00
Org_farm3	0.98	0.36	42.23	0.00
Org_farm5	0.24	1.70	2.20	0.03
Org_farm6	0.03	1.46	0.27	0.01
Org_farm7	1.64	0.37	69.10	0.00
Org_farm8	1.55	0.18	134.70	0.00
Org_farm9	0.48	0.51	14.76	0.00

Table 9. Variance analysis for clustering countries in 2020

Indicator	Variance between clusters	Variance within a cluster	F	*p*-level
Org_farm1	1.08	0.51	32.74	0.00
Org_farm2	1.08	0.47	35.80	0.00
Org_farm3	1.67	0.66	38.96	0.00
Org_farm5	1.35	1.66	12.58	0.00
Org_farm6	0.01	0.88	0.16	0.04
Org_farm7	1.56	0.34	72.17	0.00
Org_farm8	0.53	0.71	11.50	0.00
Org_farm9	0.58	0.75	11.99	0.00

Since the significance level of p for all indicators of organic farming, which are the basis of clustering, is less than 0.05. This indicates the statistical significance of qualitative differences between the presented clusters of European countries.

4. DISCUSSION

A comparison of the results obtained within the scope of this study with similar scientific directions allowed this study to note the following. Gmitrowicz-Iwan and Ligęza (2023) analyzed the influence of the chemical treatment plant of the nitrogen fertilizer plant on the water quality of the adjacent river and lake systems and the neighboring territories of Poland. The cluster analysis determined that if reservoirs are damaged, for example, during a flood, an ecological disaster will occur not only for the Vistula but also for the Baltic Sea, affecting millions of people. However, this study did not isolate the impact on the ecosystem of the lakes and adjacent territories of other factors not related to the emission of harmful chemicals, as well as how this will be reflected in the pace of development of organic farming in Poland. This moment is critical because, since 2012, Poland has lost its leading position in terms of organic farming. At this time, this study places all the necessary emphasis on forming an integral index of the development of organic farming.

Rees et al. (2023), using the method of synthetic control on the example of 25 OECD countries, which are also members of the European Union, studied the impact of four different national organic action plans (the 1st French Organic Action Plan (2008–2012), the 2nd Swedish Organic Action Plan (2006–2010), the 2nd Czech organic action plan (2011–2015) and the 5th Austrian organic action plan (2011–2013)) regarding the size of organic agricultural land for the development of organic farming in other studied countries. The results reveal a significant impact of the French and Swedish organic action plans on the formation of organic farming. The developed approach certainly has crucial scientific value, but it excludes the organic farming markets of other European countries that are not members of the EU. The study offers a comprehensive analysis of the organic farming market for a broader range of European countries, which allows choosing more flexible mechanisms of influence on the level of organic farming. Reidsma et al. (2023) presented 10 European agricultural management systems to support the stable and sustainable development of arable farming. Using a retrospective approach, they identified relevant future strategies that will contribute to strengthening sustainability attributes. The proposed systems make it possible to form guidelines for other European countries but do not consider the current level of organic farming in such countries. This study allows one to solve this problem thanks to the defined integral index of organic farming.

Guo et al. (2023) show that renewable energy exacerbates the biodiversity crisis, and organic farming contributes to conserving European biodiversity. This study can be improved by including the integral index of organic farming calculated in this study. It is the basis for potential scientific collaboration.

CONCLUSION

The purpose of this paper is to assess the level of development of organic farming in European countries. Thus, the paper proposed a scientific and methodological approach to determining the level of development of organic farming in European countries: an integral index of the development of organic farming. Based on eight indicators of organic farming in 34 European countries, it allowed distinguishing leading and outsider countries. There are five countries with the highest level of development of organic farming for the period 2012–2020: Italy (0.57), France (0.54), Spain (0.54), Germany (0.45), and Turkey (0.47). There is a two-step clustering analysis using the Ward method and k-means method on a sample of countries. The findings show three clusters based on the eight indicators. The first cluster includes five countries with the highest area of agricultural territories (about 2.1 million ha) and state financial support for agricultural research and development (1.1 billion euros). The second cluster includes 18 countries with the lowest values of organic farming operators (50-100 operators). The third cluster includes 11 countries with a high value of the index of annual income from the sale of farm products (200-220 points) and the level of usage of dangerous pesticides (250 points).

This scientific approach can be a valuable tool for policymakers, researchers, and stakeholders to identify patterns, trends, and areas for improvement in promoting and enhancing organic farming across different regions. Further analysis and interpretation of the specific indicators and characteristics within each cluster would provide deeper insights into the factors influencing the development of organic farming in these countries.

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REFERENCES

1. Akyüz, N. C., & Theuvsen, L. (2021). Organic agriculture in Turkey: Status, achievements, and shortcomings. *Organic Agriculture, 11*(4), 501-517. https://doi.org/10.1007/s13165-021-00362-2
2. Arynov, K., Zhubatov, Z., Saruarova, G., Nurtaza, N., & Berikova, U. (2021). The use of organic farming with the introduction of organic and humic fertilisers. *Periodicals of Engineering and Natural Sciences (PEN), 9*(4), 305-322. https://doi.org/10.21533/pen.v9i4.2311
3. Bazhan, M., Sabet, F. S., & Borumandnia, N. (2023). Development and validation of a questionnaire to examine determinants of consumer intentions to purchase organic food. *BMC Nutrition, 9*(1). https://doi.org/10.1186/s40795-023-00731-y
4. Campuzano, L. R., Hincapié Llanos, G. A., Zartha Sossa, J. W., Orozco Mendoza, G. L., Palacio, J. C., & Herrera, M. (2023). Barriers to the adoption of innovations for sustainable development in the agricultural sector – Systematic literature review (SLR). *Sustainability, 15*(5), 4374. https://doi.org/10.3390/su15054374
5. Carucci, F., Gatta, G., Gagliardi, A., Bregaglio, S., & Giulian, M. M. (2023). Individuation of the best agronomic practices for organic durum wheat cultivation in the Mediterranean environment: A multivariate approach. *Agriculture & Food Security, 12*(*1*). https://doi.org/10.1186/s40066-023-00417-5
6. Dono, G., Buttinelli, R., & Cortignani, R. (2022). Financial performance of connected agribusiness activities in Italian agriculture. *Bio-Based and Applied Economics, 11*(2), 147-169. https://doi.org/10.36253/bae-12211
7. Fenta, A. A., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Yasuda, H., Kawai, T., Berihun, M. L., Ebabu, K., Sultan, D., & Mekuriaw, S. (2023). An integrated framework for improving watershed management planning. *Environmental Research, 236,* 116872. https://doi.org/10.1016/j.envres.2023.116872
8. Gambelli, D., Vairo, D., Cuoco, E., & Zanoli, R. (2023). The role of stakeholder involvement in EU research and innovation policy: A case study of technology platform organics. *Organic Agriculture, 13*(2), 293-308. https://doi.org/10.1007/s13165-023-00427-4
9. Gmitrowicz-Iwan, J., & Ligęza, S. (2023). Floodplain lakes as an indicator of increasing industrial pollution – Case study from a fertilizer factory in Poland. *Environmental Research, 238,* 117278. https://doi.org/10.1016/j.envres.2023.117278
10. Grigoruk, V. V., Akimbekova, C. U., & Umbitaliev, A. D. (2021). Forecast of organic diversification of agriculture in a global perspective. *Journal of Environmental Management and Tourism, 12*(7), 1754-1765. https://doi.org/10.14505/jemt.v12.7(55).02
11. Guo, Q., Shah, M. I., Kumar, S., Abdulkareem, H. K. K., & Inuwa, N. (2023). The roles of organic farming, renewable energy, and corruption on biodiversity crisis: A European perspective. *Environmental Science and Pollution Research, 30*(11), 31696-31710. https://doi.org/10.1007/s11356-022-24344-3
12. Hettige, N. D., Hashim, R., Kutty, A. A., & Ash'aari, Z. H. (2023). A new model for organic contamination assessments using benthic macroinvertebrates as biological indicators. *Turkish Journal of Fisheries and Aquatic Sciences, 23*(8). https://doi.org/10.4194/trjfas22423
13. Jiang, L., Chen, Y., Wang, X., Guo, W., Bi, Y., Zhang, C., Wang, J., & Li, M. (2022). New insights explain that

organic agriculture as sustainable agriculture enhances the sustainable development of medicinal plants. *Frontiers in Plant Science, 13*. https://doi.org/10.3389/fpls.2022.959810

14. Kashiwagi, K., & Kamiyama, H. (2023). Effect of adoption of organic farming on technical efficiency of olive-growing farms: Empirical evidence from West Bank of Palestine. *Agricultural and Food Economics, 11*(1). https://doi.org/10.1186/s40100-023-00266-7
15. Kociszewski, K., Graczyk, A., Sobocińska, M., Krupowicz, J., & Mazurek-Łopacińska, K. (2023). Changes in the Polish market for agricultural organic products. *Ekonomia i Środowisko, 84*(1), 259-286. https://doi.org/10.34659/eis.2023.84.1.547
16. Kowalska, M., & Bieniek, M. (2022). Meeting the European green deal objective of expanding organic farming. *Equilibrium. Quarterly Journal of Economics and Economic Policy, 17*(3), 607-633. https://doi.org/10.24136/eq.2022.021
17. Magrini, A. (2022). Assessment of agricultural sustainability in European Union countries: A group-based multivariate trajectory approach. *AStA Advances in Statistical Analysis, 106*(4), 673-703. https://doi.org/10.1007/s10182-022-00437-9
18. Mahboubeh, J., Babak, A., & Le Bodic, P. (2023). Farmland allocation in the conversion from conventional to organic farming. *European Journal of Operational Research, 311*(3), 1103-1119. https://doi.org/10.1016/j.ejor.2023.05.019.
19. Mandolesi, S., Dudinskaya, E. C., Naspetti, S., Solfanelli, F., & Zanoli, R. (2022). Freedom of choice – Organic consumers' discourses on new plant breeding techniques. *Sustainability, 14*(14), 8718. https://doi.org/10.3390/su14148718
20. Nematollahi, M., Tajbakhsh, A., & Sedghy, B. M. (2021). The reflection of competition and coordination on organic agribusiness supply chains. *Transportation Research Part E-logistics and Transportation Review, 154,* 102462. https://doi.org/10.1016/j.tre.2021.102462
21. Prodhan, F. A., Afrad, Md. S., Haque, Md. E., Hoque, M. Z., Rokonuzzaman, M., Mohana, H. P., & Pervez, A. K. M. K. (2023). Factors driving the adoption of organic tea farming in the Northern Region of Bangladesh. *Research in Globalization, 7,* 100145. https://doi.org/10.1016/j.resglo.2023.100145
22. Rees, C. W., Grovermann, C., & Finger, R. (2023). National organic action plans and organic farmland area growth in Europe. *Food Policy, 121,* 102531. https://doi.org/10.1016/j.foodpol.2023.102531
23. Reidsma, P., Accatino, F., Appel, F., Gavrilescu, C., Krupin, V., Tasevska, G. M., Meuwissen, M., Peneva, M., Severini, S., Soriano, B., Urquhart, J., Zawalińska, K., Zinnanti, C., & Paas, W. (2023). Alternative systems and strategies to improve future sustainability and resilience of farming systems across Europe: From adaptation to transformation. *Land Use Policy, 134,* 106881. https://doi.org/10.1016/j.landusepol.2023.106881
24. Rudnicki, R., Wiśniewski, Ł., & Biczkowski, M. (2021). A spatial typography of environmentally friendly common agricultural policy support relevant to European Green Deal objectives. *Land, 10*(10), 1092. https://doi.org/10.3390/land10101092
25. Salavisa, I., Ferreiro, M. F., & Bizarro, S. (2021). The transition of the agro-food system: Lessons from organic farming in the Lisbon Metropolitan Area. *Sustainability, 13*(17), 9495. https://doi.org/10.3390/su13179495
26. Sarkar, D., Dubey, P., Chaurasiya, R., Sankar, A., Shikha, Chatterjee, N., Ganguly, S., Meena, V. S., Meena, S. K., Parewa, H. P., & Rakshit, A. (2021). Organic interventions conferring stress tolerance and crop quality in agroecosystems during the United Nations Decade on Ecosystem Restoration. *Land Degradation & Development, 32*(17), 4797-4816. https://doi.org/10.1002/ldr.4094
27. Schader, C., Heidenreich, A., Kadzere, I., Egyir, I. S., Muriuki, A., Bandanaa, J., Clottey, J., Ndungu, J., Grovermann, C., Lazzarini, G. A., Blockeel, J., Borgemeister, C., Muller, A., Kabi, F., Fiaboe, K. K. M., Adamtey, N., Huber, B., Niggli, U., & Stolze, M. (2021). How is organic farming performing agronomically and economically in sub-Saharan Africa? *Global Environmental Change, 70,* 102325. https://doi.org/10.1016/j.gloenvcha.2021.102325
28. Solfanelli, F., Ozturk, E., Dudinskaya, E. C., Mandolesi, S., Orsini, S., Messmer, M., Naspetti, S., Schäfer, F., Winter, E., & Zanoli, R. (2022). Estimating supply and demand of organic seeds in Europe using survey data and MI techniques. *Sustainability, 14*(17), 10761. https://doi.org/10.3390/su141710761
29. Stephenson, G., Gwin, L., Schreiner, C., & Brown, S. (2022). Perspectives on organic transition from transitioning farmers and farmers who decided not to transition. *Renewable Agriculture and Food Systems, 37*(6), 633-643. https://doi.org/10.1017/s1742170521000119
30. Titisari, E. Y., Azizah, S., Kurniawan, S., Ridjal, A., & Yuniarti, R. (2022). The strategy of organic farming implementation through waste bio-conversion in developing Baran Edu-Tourism Kampung, Malang, Indonesia. *Universal Journal of Agricultural Research, 10*(4), 388-396. https://doi.org/10.13189/ujar.2022.100408
31. Zámková, M., Rojík, S., Prokop, M., Činčalová, S., & Stolín, R. (2023). Consumers' Behavior in the field of organic agriculture and food products during the COVID-19 pandemic in the Czech Republic: Focus on a comparison of hyper-, super- and farmers' markets and direct purchases from producers. *Agriculture, 13*(4), 811. https://doi.org/10.3390/agriculture13040811
32. Zhao, Z., Mao, Y., Gao, S., Lu, C., Pan, C., & Li, X. (2023). Organic carbon accumulation and aggregate formation in soils under organic and inorganic fertilizer management practices in a rice-wheat cropping system. *Scientific Reports, 13*(1). https://doi.org/10.1038/s41598-023-30541-y
33. Zhou, X., & Ding, D. (2022). Factors influencing farmers' willingness and behaviors in organic agriculture development: An empirical analysis based on survey data of farmers in Anhui province. *Sustainability, 14*(22), 14945. https://doi.org/10.3390/su142214945