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Patterns of Organic Crops in Arable Land in the European Union - Analysis Based on the Cluster Method

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ABSTRACT

In recent years, in the context of social, economic and environmental challenges in the European Union (EU) and worldwide, the concerns to support sustainable agri-food systems, such as organic farming, have acquired increasing importance. The main objective of this paper is to analyse the current situation and evolution of the organic production sector in EU agriculture and to identify the patterns of organic crops in arable land in the EU Member States. A mix of methods were used for the purpose of the research, which included: bibliographic documentation, comparative method, statistical analysis and multivariate interdependence analysis (principal component analysis and cluster analysis). The main conclusion that emerged is that organic agriculture in arable land in the EU is highly dispersed and diversified at regional/territorial level. Using the proposed methodology, the 27 Member States were grouped into six clusters/ homogeneous groups. The classification/ typologisation of Member States into homogeneous groups can represent an important approach for informing decision-makers for the design of strategies adapted to regional conditions/ specificity.

Keywords: organic agriculture, arable crops, cluster analysis, European Union.

INTRODUCTION

In recent years, a series of changes such as population growth, expanding urbanisation, adoption of new modern technologies, climate challenges, etc., have transformed the world at a fast pace. In this context, the agricultural systems of the future will have to cope with these changes and produce sufficient food, while ensuring ecological, social and economic sustainability. One of the most important goals of humanity is to end poverty and hunger, while maintaining sustainable agriculture and food systems (Kamal, 2017).

Organic farming has developed as a reaction to the negative effects of industrialised/intensive agriculture: decrease of soil fertility, of plant vitality and immunity, use of low-quality animal feed, poor animal health and reduced life span, biodiversity decrease, decrease of food quality with a negative effect on human health, etc. (Doré et al., 2011). Organic farming, as an alternative to conventional farming systems, was largely developed by farmers themselves, then verified in practice and confirmed by science and research.

Organic farming is now regulated according to strict rules and financially supported under the agriculture and rural development programs (Šrůtek and Urban, 2008).

There are several definitions of organic farming, synonymous with ecological or biological agriculture: Lampkin and Padel (1994) regard organic farming both as a "philosophy" and a sustainable agricultural production system in social, economic and environmental terms; Mannion (1995) defines organic farming, in a holistic approach, as the existing relationship between the farm, the flora and fauna in a region, agricultural production and environment. Cacek and Langner (2009) define organic farming as a production system that largely excludes the use of synthetic fertilisers, pesticides, growth regulators and food additives.

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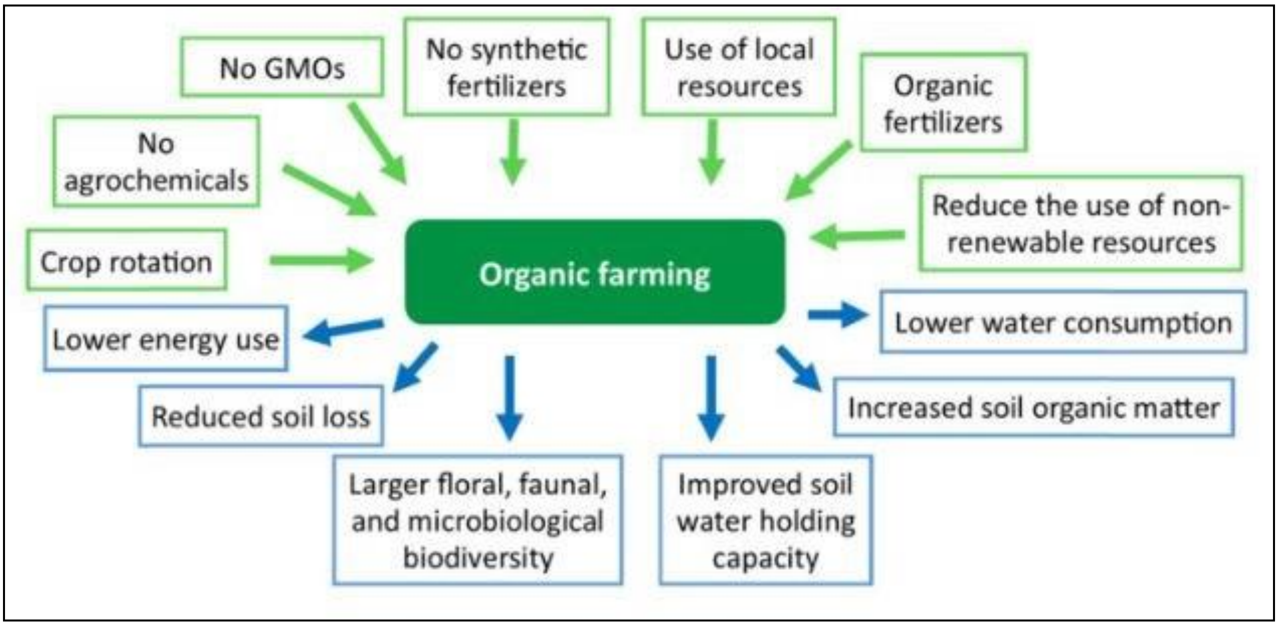


Figure 1. The main practices and effects of organic farming

The International Federation of Organic Agriculture Movements (IFOAM) proposes one of the most complete definitions: organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2005).

The importance of organic farming has been recognised in the most recent agri-environmental policies and ecological strategies of the EU, by setting the ambitious target that at least 25% of the utilised agricultural area should be under organic farming by the year 2030 (according to the European Green Deal, Biodiversity Strategy and Farm to Fork Strategy). Europe aims to become a centre of organic agriculture, hosting key milestones in its history (Paull, 2024). Despite the sustained financial support and the significant increase of the agricultural area under organic farming system, it is unlikely that many Member States will reach this objective by the set deadline, having in view that the EU's average area under organic system was only 10.4% in the year 2022. In this context, the new Common Agricultural Policy (CAP) 2023-2027 aims to provide more substantial support to organic agriculture, in the situation in which this sector will contribute to four out of the nine current CAP objectives: environment protection, contribution to preserving landscapes and biodiversity, generation of viable agricultural incomes and appropriate response to societal demands on food and health, including sustainable food and animal welfare (EC, 2023).

Arable agriculture plays an essential role in the agricultural setting of the EU. Considering the diversity of physical-geographical, economic and social factors, EU Member States cultivate a wide range of arable crops intended for both human, animal and industrial use. According to Eurostat, in the year 2022, arable crops had the largest share (45.1%) in total agricultural area under organic system in the EU. Among these crops, cereals and plants harvested green from arable land ranked first, with 35.8% and 37.5%, respectively.

MATERIAL AND METHODS

Growing concerns to support sustainable agri-food systems, such as organic farming, have gained increasing importance in the context of social, economic and environmental challenges in the Member States of the EU.

The objectives pursued in this study are: i) analysis of current situation and of the evolution of the organic production sector in the EU and ii) identification of organic cropping patterns in arable land, in the EU Member States.

A mix of methods was used to reach these objectives, including: i) bibliographic documentation (consultation of various research works and documents for a thorough knowledge of the scientific experience in the investigated field); ii) comparative method (the analysis of the structure of phenomena by component elements and their interdependence relationships); iii) descriptive statistical analysis (processing, analysis and graphic representation of statistical data); iv) multivariate interdependence analysis (principal component analysis and cluster analysis).

The analysis was based on indicators/ variables extracted from: i) Eurostat database - published by the EU (https://ec.europa.eu/eurostat/data/database); representative indicators for the analysed thematic were used, beginning from the year 2007 to the latest available year; ii) the reports "The World of Organic Agriculture. Statistics and Emerging Trends", published by FiBL and IFOAM in the years 2009, 2022, 2023 and 2024. Data were uploaded and processed by the SPSS (Statistical Package for Social Sciences).

Organic agriculture is a relatively new sector of the European agri-food sector, for which the official statistical data are quite limited. The main specific indicators of organic agriculture, used in the first part of the analysis, present in most international databases and in the reports of various specialised forums are the following: land area under organic farming, number of registered operators in organic agriculture; structure of organic agricultural land uses.

For the second part of the analysis, the organic arable land structure by groups of crops used in the EU was considered: i) cereals for the production of grains; ii) dry pulses and protein crops; iii) root crops; iv) industrial crops; v) plants harvested green from arable land; vi) fresh vegetables (including melons and strawberries); vii) other arable land crops; viii) fallow land (https://en.eustat.eus/documentos/elem_6308/definicion.html). The indicators were collected for the 27 Member States of the EU.

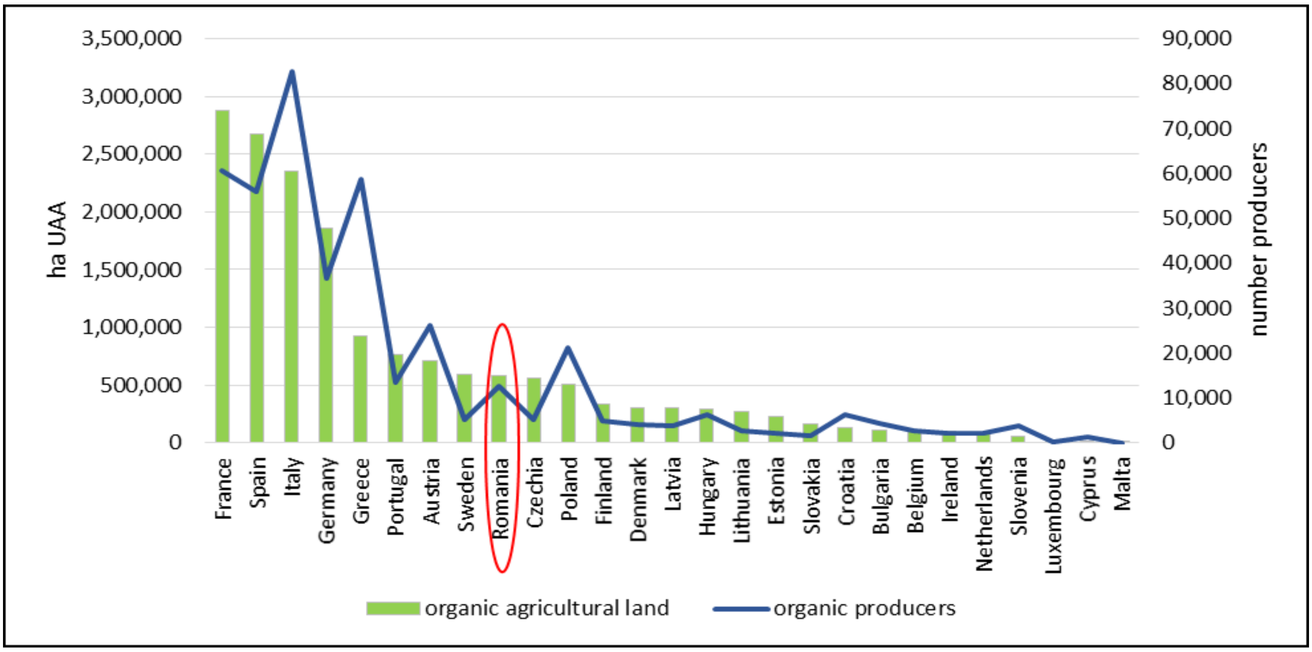
The use of indicators in the research is considered an important approach that can capture a series of phenomena in an easily understandable form. However, the method can present several limitations determined by data availability and a certain subjectivity in the choice of indicators (Luers et al., 2003).

RESULTS AND DISCUSSION

Organic farming in the European Union - current situation and trends

The agricultural sector represents only a small share of the economy of the EU: 1.4% of total GDP (215.5 billion EUR) and 4.2% of jobs (8.6 million farmers). All these farms operate about 157 million hectares of agricultural land, out of which 10.4% cultivated under organic farming system (Euronews, 2024).

In the year 2022, 16.878 million hectares were cultivated under organic system by 426.227 thousand farmers in the EU. As compared to the year 2007, the organic agricultural area increased 2.4 times (+9.717 million hectares) and the number of organic farmers increased 2.3 times (+239.556 thousand farmers). Four member countries had the largest areas under organic cultivation - France, Spain, Italy and Germany: these countries together cultivate more than half of the agricultural organic land (57.8%), and more than half of organic farmers (55.3%) are also found in these countries.

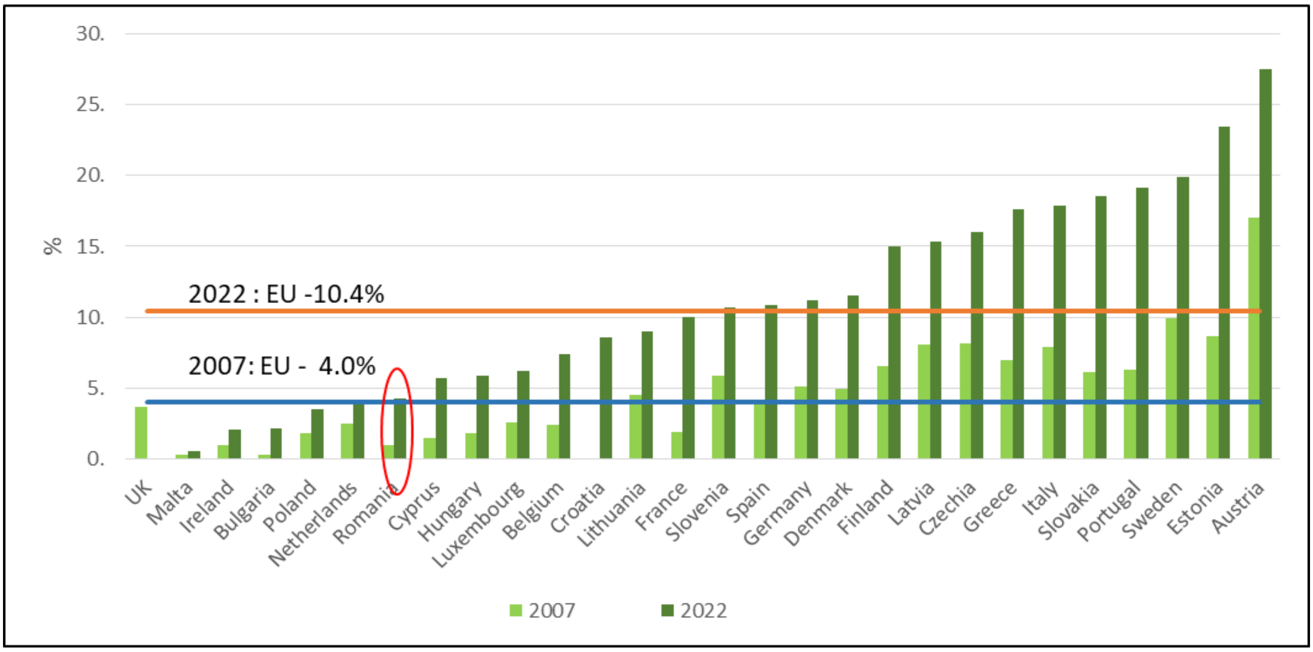


Source: processing of Eurostat data, accessed 2024.

Figure 2. Utilized agricultural area under organic system and number of organic farmers in the EU Member States, 2022

Romania ranks 9th in the EU, both as cultivated area (644520 ha) and number of organic operators (12598). Compared to the year 2007, when Romania joined the EU, the increase was significant, and much above the EU average: the agricultural area operated under organic system increased 4.4 times, and the number of organic operators increased 5.6 times.

In the period 2007-2022, the share of organic agricultural land increased both at EU level (from 4.0% to 10.4%) and at the level of each Member State (Figure 3).



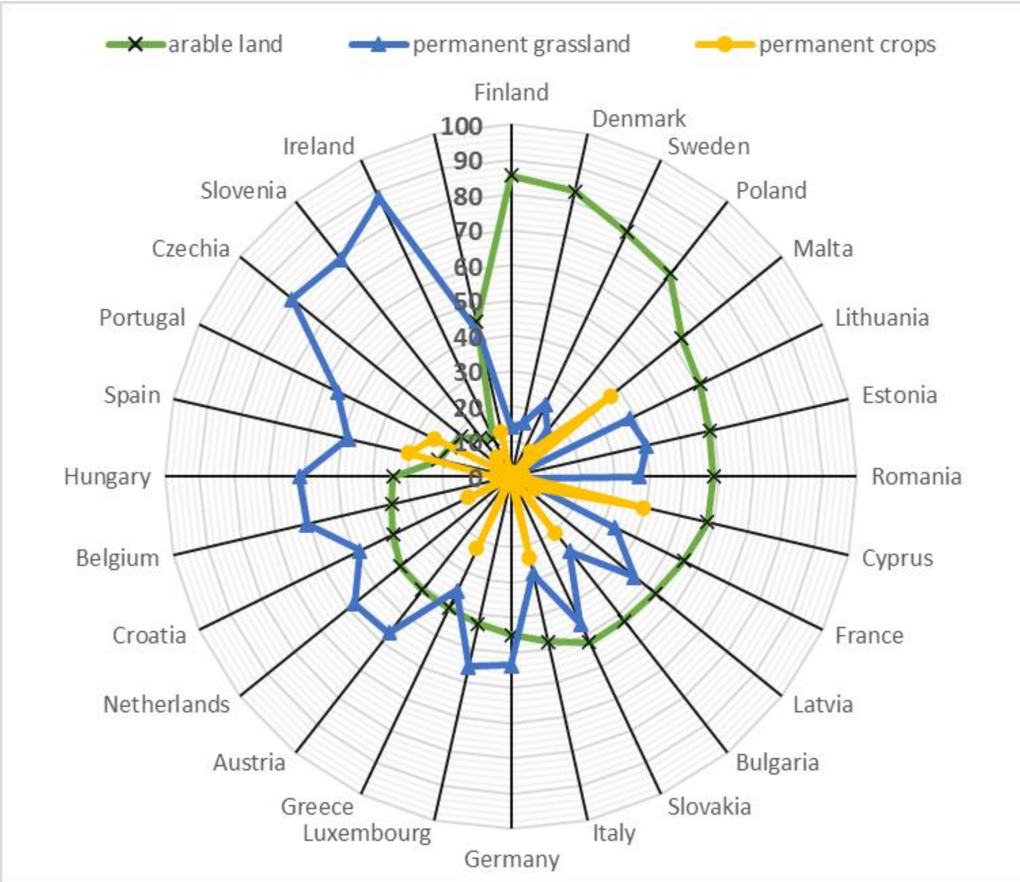
Source: processing of Eurostat data, accessed 2024.

Figure 3. Evolution of the share of agricultural land operated under organic system in the EU Member States (2007 and 2022)

15 EU Member States had more than 10% of their UAA under organic farming.

The countries with the highest shares of organic area were Austria (27.5%) and Estonia (23.4 %). Malta (0.6%), Ireland (2.1%) and Bulgaria (2.2%) lie at the opposite pole, with extremely small shares of organic area.

Romania ranks 22nd in the EU, with 4.3% organic area. Organic agriculture does not have a high level of interest and applicability on the Romanian market, although it has favourable natural conditions and benefits from stimulating European policies (Jităreanu et al., 2022).



Source: processing data based on Willer et al. (2024): 322.

Figure 4. Distribution of organic agricultural areas by categories of use

In the EU, the category of organic land with the highest share is represented by arable land (45.1%) closely followed by permanent grass (41.0%); permanent crops are on the last place, with a much lower share (13.0%) (Willer et al., 2024)[1]. The structure of organic agricultural uses has maintained a relatively constant value over time, and their distribution by Member States is heterogeneous.

Thus, the most significant shares of organic arable land, over 70%, are found in Finland (85.6%), Denmark (83.1%), Sweden (77.1%) and Poland (73.8%). At the opposite pole there are countries with shares under 15% of organic arable land: Slovenia (14.1%) and Ireland (11.9%). Romania, with a share of 58.8% of arable land operated under organic system ranks 8th in the EU, Permanent grassland, category of agricultural use intended for the cultivation of herbaceous fodder crops, which are not included in the crop rotation scheme, shows that the countries with low shares of organic arable land compensate with high shares of organic permanent grass. Ireland (87.9%), Slovenia

[1] The total includes other agricultural areas for which no land use details were available

(79.1%) and the Czech Republic (80.1%) have more than 70% organic permanent grass in the structure of organic agricultural land.

Unlike these countries, Cyprus and Malta have less than 3% land under organic permanent grass. Organic permanent crops, which yield harvests for several consecutive years and bring a higher added value per hectare than arable crops, take up more than double the EU share in Cyprus (39.4%), Malta (36.9%) and Spain (30.3%).

Patterns of organic crops in arable land - cluster analysis

In this part of the paper, we used the multivariate interdependence analysis (principal component analysis and cluster analysis) to analyse the chosen set of variables and identify the patterns of arable land use under organic system in the EU Member States. The share of the eight groups of arable crops used by Eurostat in were taken as variables: cereals for the production of grains; dry pulses and protein crops, root crops, industrial crops, plants harvested green from arable land, fresh vegetables (including melons and strawberries), other arable land crops and fallow land. The data retrieved were transposed and analysed using the SPSS software.

The first step consisted of the descriptive analysis of variables previously presented: the central and dispersion indicators were calculated - the mean, the minimum value, the maximum value and the standard deviation.

As the standard deviations of analysed variables had different values, the initial data were subjected to a standardisation process (dispersion 1, mean 0), becoming comparable to each other.

In the second step, the standardised variables were used for the Principal Component Analysis (PCA). PCA is applied to reduce a set of indicators/variables that correlate with each other to a smaller number, called latent factors, which can show the relational structure between the original indicators (Culic, 2004). The matrix of correlation coefficients shows that there are significant positive and negative correlations between the selected variables.

The third step was to extract the initial factors: establish the minimum number of common factors that satisfactorily produce correlations between variables. To determine the number of principal components that we need, we used the information from the table below, where we can find both information referring to the eigenvalues of the correlation matrix and information referring to the principal components and the quantity that they retained. The values of components that are greater than one show that these components have a greater contribution than an initial variable, and therefore it is indicated to be selected.

Table 1. Total Variance Explained

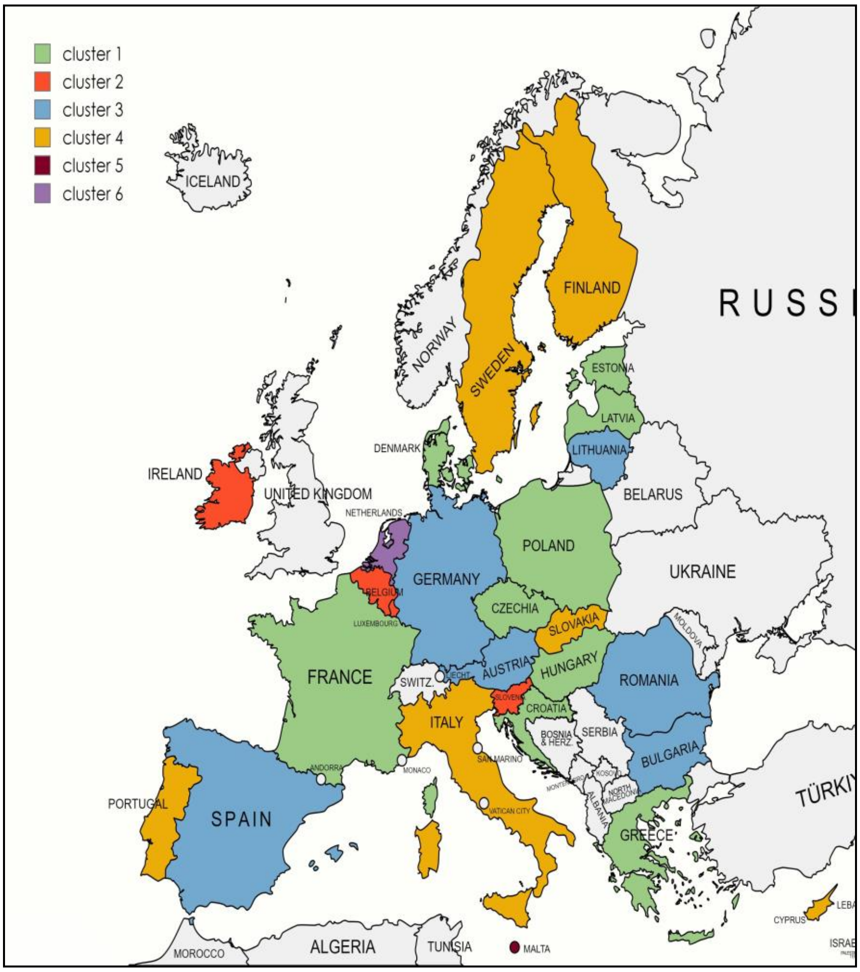
Component	Initial Eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	2.639	32.982	32.982	2.639	32.982	32.982
2	1.686	21.076	54.058	1.686	21.076	54.058
3	1.214	15.176	69.234	1.214	15.176	69.234
4	0.924	11.546	80.780			
5	0.835	10.443	91.222			
6	0.624	7.798	99.020			
7	0.078	0.980	100.000			

Source: own processing.
Extraction method: Principal Component Analysis.

The three principal components retained for the next step have Initial Eigenvalues of 2.639, 1.686 and 1.214. Using the three principal components, the total amount of information recovered is 69.234% of the initial information. The three principal components have a degree of coverage of 32.982%, 21.076% and 15.176%, respectively.

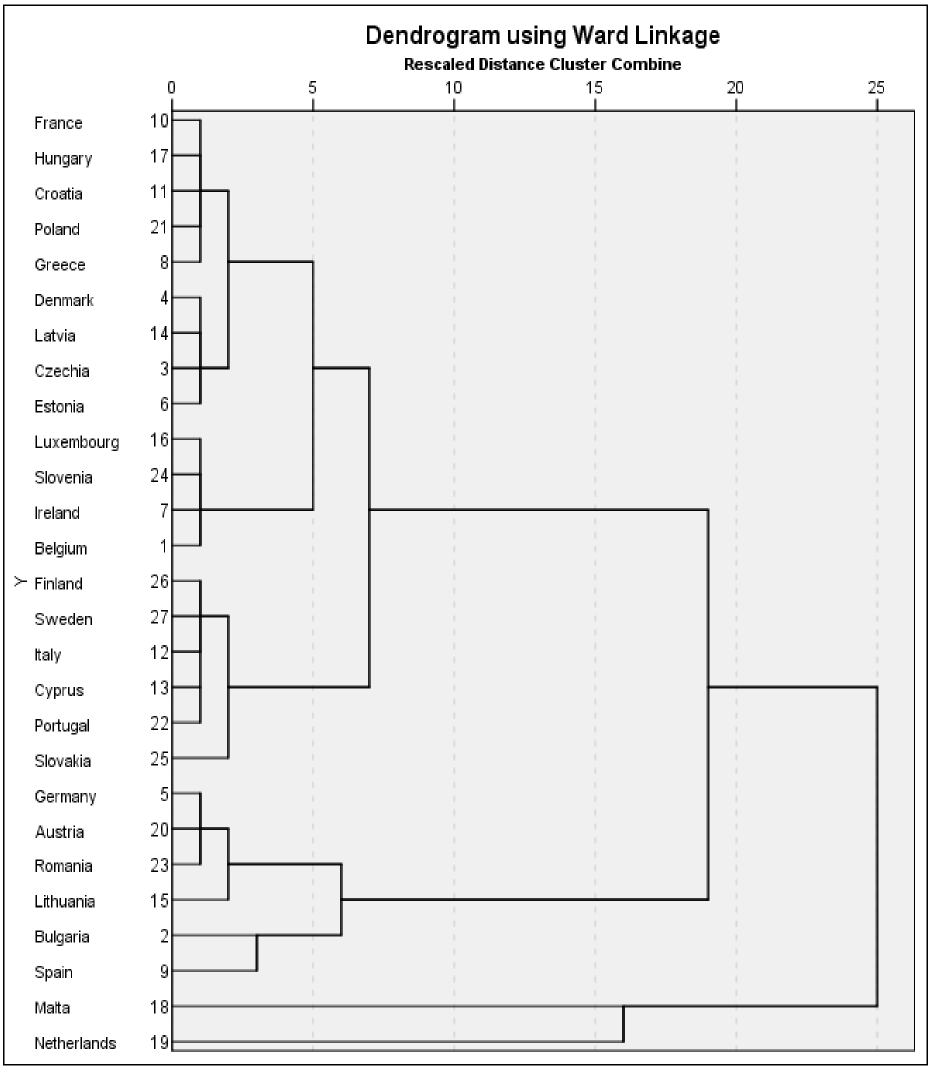
The fourth step consisted in ranking the EU Member States on the basis of selected factors. The hierarchical cluster analysis attempts to identify homogeneous groups of cases based on predetermined characteristics (Everitt et al., 2011). The variables or cases are sorted into groups (clusters) where the similarity between the members of the same cluster is high, and the similarity between the members of different clusters is low (Babucea, 2017). The Ward (Squared Euclidean Distance) method was used in this paper, considered to be an aggregation method that determines a minimum intra-cluster inhomogeneity: it best preserves the ranking tendency so that the classes are as homogeneous as possible inside and as different as possible between them (Culic, 2004).

Figure 5 shows six possibilities of grouping the 27 Member States of the EU, considering the similarities of the structure of categories of organic crops in arable land. The figure below presents the territorial distribution of the six identified clusters following the analysis.



Source: processing based on Eurostat, 2024.

Figure 5. Patterns of organic crops in arable land in the EU



Source: processing based on Eurostat, 2024.

Figure 6. WARD dendrogram

The analysis highlights the following aspects/characteristics of identified clusters:

i) Cluster 1 – includes nine member states (Hungary, France, Latvia, Greece, Denmark, Croatia, Estonia, Poland and the Czech Republic) distributed across the EU. The cluster has the following characteristic: *plants harvested green from arable land - grain cereals - dry pulses and protein crops* that together account for more than 80% of organically managed arable land. Plants harvested green from organic arable land (accounting for 30-50%) are mostly present in Greece, Lithuania and the Czech Republic. More than 40% of organic grain cereals are grown in Estonia, Denmark, the Czech Republic, Greece, France and Croatia. Organic rye is mainly grown in Hungary, Denmark and Poland, organic barley in Denmark, and organic oats in Latvia, Estonia, Poland, Denmark and the Czech Republic.

Organic maize grain is grown on significant areas in Greece and Croatia (over 20%). Organic dry pulses and protein crops have shares higher than 10% at cluster level, with higher values in France, Greece and Poland;

ii) Cluster 2 – consisting of four Member States (Belgium, Ireland, Luxembourg, Slovenia) located in the northern part of the EU, has a structure based on *plants harvested green from arable land and grain cereals* (more than 85% of the organically managed arable land). Plants harvested green from arable land account for more than 45% in all the countries of the cluster. On the other hand, organic grain cereals have lower shares, between 35% and 45%. More than

30% of organic wheat is grown in Belgium, Luxembourg and Slovenia; organic oats is grown on 64% of the arable land from Ireland;

iii) Cluster 3 includes six Member States (Spain, Bulgaria, Lithuania, Austria, Germany and Romania) and its structure is characterised by the triad: grain cereals - industrial crops - plants harvested green from arable land (with more than 80% of total organic arable land). Organic grain cereals in this cluster have significant shares, over 40%. Among organic cereals, wheat is mostly grown, mainly in Bulgaria, Austria and Romania (over 50%). Spain grows organic barley and oats (35% and 25%, respectively). Romania is the largest grower of organic maize in this group. One of the main characteristics of this cluster is given by the significant share of organic industrial crops.

In Austria and Romania, these crops cover more than 30% of the arable land. Lithuania grow organic rapeseed on 50% of the arable area. Bulgaria, Spain and Romania grow sunflower, one of the most important oil crops worldwide, on more than 90% of the area under organic industrial crops. Romania ranked first in the EU for sunflower, both in terms of production and cultivated area (Brumă et al., 2021). Germany has significant shares of organic fibre crops and Bulgaria and Spain of organic aromatic plants;

iv) Cluster 4 consists of six Member States (Cyprus, Portugal, Italy, Slovakia, Sweden and Finland) and is characterised by the structure - plants harvested green from arable land - grain cereals and fallow land. The share of plants harvested green in arable land is high (over 40%). Organic grain cereals rank second, with shares between 25% and 30%. Organic wheat is grown on large areas, with shares over 55%, in Italy and Cyprus, while organic barley is grown in Sweden and Finland.

Organic oats is mainly grown in Finland, Sweden and Portugal. Most Member States in this cluster have significant organic arable land areas as fallow land: the largest areas are found in Cyprus and Portugal;

v) Cluster 5 has only one member state, namely Malta. In the structure of organic arable land, three groups of crops account for more than 95%: fallow land - green vegetables - plants harvested green in arable land. In the analysed year (2020), Malta had more than 60% arable land as fallow land, being the EU country with the highest share of this category. As share of organic green vegetables in total organic arable land, Malta ranks second (17.5%) next to the Netherlands. More than 15% of this country’s organic arable land is cultivated with plants harvested green;

vi) Cluster 6, which includes the Netherlands, has a specific structure (more than 80% of organic arable land) - plants harvested green in arable land - green vegetables and root crops. Although its arable area under organic farming system is relatively small (29165 ha), the Netherlands grow green vegetables on 32.8%. In this category, large areas are allocated to organic roots and tubers, as well as to fresh pulses and leafy. Among the EU Member States, the Netherlands has the highest share of organically grown vegetables. The Netherlands also has the highest share of organic root crops. The Netherland ranks 5th in organic potato farming in the EU. Plants harvested green from arable land, with a significant share, of 40.7%, represent another characteristic of this cluster.

To sum up, the main characteristics of the six clusters are structured below.

Table 2. The characteristic of the clusters

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Cereals for the production of grains	+ + +	+ + +	+ + + +	+ +	+	+ +
Dry pulses and protein crops	+ +	+	+ +	+	+	+
Root crops	+	+ +	+	+	+ +	+ + + + +
Industrial crops	+ +	+	+ + +	+	+	+
Plants harvested green from arable land	+ + +	+ + + +	+ +	+ + + + +	+ +	+ + +
Fresh vegetables (including melons and strawberries)	+	+	+	+	+ + +	+ + + + +
Other arable land crops	+	+	+	+ +	+ +	+
Fallow land	+	+	+ +	+ + +	+ + + + +	+

Source: Own processing.

Note: for the graphic presentation of the characteristics of each cluster, five intensity thresholds were used, which were noted as follows: very high share +++++, high share ++++, medium share +++, low share ++ and very low share +; this classification was made according to the averages recorded at EU level.

The terms and conditions of agricultural production are strongly differentiated both within the EU as a whole and at the level of component Member States (Novak and Kobialka, 2024). The organic arable agriculture of the EU is highly dispersed and diversified across regions/territories.

A good understanding of this diversity and of factors influencing it can be useful to decision-makers in planning strategies that pursue sustainable development objectives of agriculture and rural areas.

The classification/typologisation of Member States into homogeneous groups can be an important approach for informing decision-makers and designing programmes better adapted to practical needs.

The resulted typology can represent a first step in testing the possibility to classify.

CONCLUSIONS

Organic farming is one of the best-known models of sustainable agricultural production. Success in organic farming largely depends on agri-environmental, territorial, economic, social, institutional and spatial conditions. Although organic farming in the EU Member States has over fifteen years of sustained growth (2007-2024), this is still a minor agricultural sector, occupying only 10.4% of the total agricultural area and 4.7% of total agricultural operators.

Romania has an important position in the EU, ranking 9th both in terms of organically cultivated area and in terms of number of organic operators. Compared to 2007, when Romania joined the EU, a significant increase was reported, much above the EU average: the organically operated agricultural area has increased 4.4 times, while the number of organic producers has increased 5.6 times. However, in terms of organic agricultural area in total agricultural area, our country ranks 22nd, on one of the last positions in the EU. Even though it covers only a small part of the utilised agricultural area, organic farming in Romania is an important component of sustainable agriculture (Popovici et al., 2018).

In the examined period, organic farming has gained increasing importance, being included in the agri-environmental and human health policies and objectives of the EU, with expectations of growth/ development for the next period. Unfortunately, organic farming has to face many older problems (low yields, depopulation, ageing, deagrarianisation, lack of knowledge and support), as well as actual problems (horizontal inequity, lack of market information, certification costs, regulatory discrepancies, administrative and technical requirements) with other challenges and obstacles (Ondrasek, 2023).

Decision- Member States, which could be improved in future works through deepening the typology by new variables (types of crops specific to each group), regionalising the EU analysis (the EU has different agri-ecological environments) and increasing the typology robustness through field studies makers should seize the political opportunity that target scaling up the organic farming sector, being aware of its benefits for all stakeholders, for farmers and consumers, and address critical challenges to ensure its sustainability to improve food safety and security. Organic arable farming plays an important role in the agricultural setting of the EU, occupying almost half of the total organic agricultural land. Successful organic farming largely depends on the agri-environmental, territorial, economic, social, institutional and spatial conditions (Antczak, 2021). Taking advantage of these conditions and using different agricultural techniques, the Member States of the EU grow a wide range of arable crops. Using the multivariate interdependence analysis, the 27 member states were grouped into six clusters/ homogeneous groups, with a low intra-group variability and a high inter-group variability considering the eight indicators of the structure of crop categories in organic arable land. Based on this analysis, we can conclude the following: grain cereals, with great adaptability, are by far the most important organic crops in the EU and are specific for clusters 1, 2, 3 and 4; plants harvested green from arable land are also widely cultivated. They are also specific for clusters 1, 2, 3 and 4.; root crops, mainly potatoes and sugar beets are particular to the structure of cluster 6; pulses are characteristic to cluster 1; industrial crops, which can provide resources for high value-added products and bioenergy and therefore increase farmers' incomes are the crops prevailing in cluster 4; the production of organic vegetables, with high value added, are characteristic to cluster 6.

The organic arable agriculture of the EU is very dispersed and diversified both at EU level and across regions. The classification of Member States into homogeneous groups can represent an important approach for informing decision-makers in the design of strategies and programs for the sustainable development of agriculture and rural areas.

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