Journal of Agriculture and Rural Development Studies
Volume 1 – Issue 1
ISSN – Online 3061-2756
www.imadr.jards.ugal.ro

DOI https://doi.org/10.35219/jards.2024.1.07

# The Economic Value of European Organic Farming in the Transition to Climate Neutrality

Monica Laura Zlati*, Costinela Fortea**, Valentin Marian Antohi***

ARTICLE INFO

*Article history*:
Accepted August 2024
Available online August 2024

*JEL Classification:*
Q00, O13

*Keywords:*
organic farming, climate change adaptation, greenhouse gas emissions, PCA, economic efficiency

ABSTRACT

Organic farming is a cornerstone of the European transition towards climate neutrality, offering sustainable solutions to reduce greenhouse gas emissions and promote a sustainable European food system. We aim to analyze the economic value of European organic farming based on a principal composites analysis to determine causal relationships and their effects between variables such as organic agricultural area, current expenditure on climate change mitigation, gross value added of organic farming, final energy consumption of agriculture and greenhouse gas emissions from agriculture. The results of the sutdi demonstrate that expanding the amount of organic agricultural land in operation and maintaining the investment process in green technologies and resources are closely linked to increasing the economic value of the sector and reducing environmental impacts. However, the significant variations in economic efficiency and pollution highlight the need to adopt appropriate policies and strategies to maximize the benefits of organic farming. The study is useful for European public policy makers to adjust current strategies on the transition to climate neutrality.



## 1. Introduction

In the current context, European organic agriculture is an important pillar of the policy of transition to climate neutrality. According to specialized studies, organic farming contributes to reducing greenhouse gas emissions, providing benefits to the economy and society in terms of food security and public health. The EU has committed to becoming the first climate-neutral continent by 2050. The European Ecological Pact was thus signed, which proposes a profound transformation of the European economy to reduce greenhouse gas emissions in two steps, in two timeframes, equivalent to the two horizons 2030 and 2050. While the threshold for the first horizon is 55% below 1990 emission levels, the second threshold aims to achieve climate neutrality. Successful strategies adopted as initiatives of the European Ecological Pact are the Farm to Fork Strategy and the Biodiversity Strategy. Under these strategies, sustainable agriculture is harnessed and it is planned to increase organic agricultural areas by 25% by 2030. Overall, these strategies are designed to improve soil health, increase biodiversity protection and ensure long-term food security. Another important tool is the Just Transition Facility, which provides financial support to regions and communities facing significant challenges in the transition to a green economy. From the perspective of organic farming, knowing the capabilities of this practice in increasing the resilience of farming systems in the face of climate change, we observe the strong promotion of this

*, **, ***Dunarea de Jos University of Galati, Romania. E-mail addresses: sorici_monica@yahoo.com (M. L. Zlati), costinela.fortea@yahoo.com (C. Fortea), valentin_antohi@yahoo.com (Corresponding author - V. M. Antohi).

type of practice throughout the European Union through European programs (Life Program or through the European Agricultural Fund for Rural Development. This promotes sustainable soil management, the use of green cover and the avoidance of intensive tillage, all of which contribute effectively to reducing carbon dioxide emissions from organic farming. In the European Union, the organic farming sector has been growing steadily in recent decades. According to Eurostat, the area of organic land has increased significantly since 2010, which has also been reflected in increased sales amid growing consumer demand for (healthy and sustainable) products.

The aim of the study is to conduct an analysis of the economic value of organic farming from the perspective of the transition to climate neutrality. To achieve this goal the following research objectives were defined:

O1: literature review to identify economic models to valorize organic farming practices;

O2: strengthening a Europe-wide database for the period 2015-2022;

O3: applying the PCA method to determine the correlation matrix of the economic value of European organic farming;

O4: disseminating the results of the PCA analysis and public policy formulation.

The study continues with the literature review to identify the economic models of valorization of organic farming practices, presentation of the methodology of analysis by main components, presentation of results, discussions and conclusions.

## 2. Literature review

Organic farming is a fundamental pillar of the European Union's efforts to achieve climate neutrality, providing sustainable solutions for reducing greenhouse gas emissions and promoting a sustainable food system. This agricultural sector not only contributes to environmental protection, it also generates significant economic benefits, highlighted by the increased added value of organic products and the stimulation of rural development. Organic farming is a system of agricultural management that promotes sustainable practices and protects biodiversity, ecological cycles and soil biological activity (Francaviglia et al., 2023; Parizad & Bera, 2023; Saffeullah et al., 2021; Wei et al., 2024), is based on the use of natural inputs and avoidance of synthetic pesticides and fertilizers, with an emphasis on techniques such as crop rotation, composting and integrated use of biological pest control (De et al., 2021; Panday et al., 2024; Rawat et al., 2021).

The importance of organic farming in the context of the transition towards climate neutrality is underlined by multiple studies highlighting its positive environmental and economic impacts. Organic practices contribute significantly to the reduction of greenhouse gas emissions through various mechanisms such as carbon sequestration in the soil and reduced use of chemical inputs that emit greenhouse gases, with studies showing that organic farming can reduce carbon dioxide emissions by more than 50% compared to conventional farming, due to soil management techniques and crop rotations (Li et al., 2024; Wang et al., 2020; Yang et al., 2024).

In addition to direct climate benefits, organic agriculture plays a key role in maintaining healthy ecosystems and biodiversity, which are essential for climate resilience. Organic practices promote healthy soil, which is able to retain more carbon and water, thus reducing vulnerability to drought and erosion (Devi & Singh, 2023; Diop et al., 2022), and research has shown that organic farms have higher biodiversity than conventional farms, contributing to the stability and health of agricultural ecosystems (Guo et al., 2023; Ramakrishnan et al., 2021).

In the context of the European Union's commitment to become the first climate-neutral continent by 2050, organic farming plays a major role. Studies show that organic farming practices contribute significantly to reducing greenhouse gas emissions by using sustainable soil and natural resource management methods (Chataut et al., 2023; Gamage et al., 2023; Holka et al., 2022; Kareem et al., 2022; Obaisi et al., 2022). According to other authors, organic farming supports biodiversity and soil health, which are essential for maintaining a balanced and resilient ecosystem needed to cope with climate change and ensure long-term food security (R. N. Meena et al., 2023; Rempelos et al., 2021; Wijerathna-Yapa & Pathirana, 2022). Organic farming can make a significant contribution to long-term food security by providing healthy and sustainable products. European Ecological Pact (European Commission, 2023a), through initiatives such as the Farm to Fork Strategy (European Commission, 2024) and the Biodiversity Strategy (European Commission, 2023b), emphasizes the importance of organic farming, setting clear targets for expanding the area under organic farming and supporting farmers in the transition to sustainable practices. These strategies are designed to improve soil health, protect biodiversity and ensure long-term food security.

From an economic perspective, organic farming offers significant benefits, including adding value to agricultural products and stimulating rural development. Organic products, due to high quality and sustainability standards, often command higher prices on the market, which can lead to higher incomes for farmers  (Durham & Mizik, 2021; Rossi et al., 2024; Stubenrauch et al., 2021). At the same time, growing demand for organic products is boosting investment in the sector, helping to create jobs and develop the rural economy (Herman, 2024; Licastro & Sergi, 2021; Long et al., 2022).

In order to gain a thorough understanding of the economic value and environmental impacts of organic farming, numerous academic studies have explored various economic models and theoretical frameworks, while also analyzing empirical studies that highlight the benefits of these practices. These case studies cover a wide range of research addressing the impact of organic farming on rural economic development, highlighting the significant value-added contributions of organic agricultural products (Clark et al., 2021; De Corato, 2021; Rahmann et al., 2017; Sansika et al., 2023; Tache, 2009).

The research methodologies analyzed include advanced techniques for assessing correlations and effects of variables involved in organic farming. For example, principal component analysis (PCA) is commonly used to determine causal relationships between variables such as organic agricultural area, climate change expenditure and gross value added of organic farming (Foissy et al., 2013; Niftiyev & Ibadoghlu, 2023; Ostandie et al., 2021). This method allows a detailed assessment of economic efficiency and environmental impacts, providing robust evidence for public policy formulation (Herman, 2024; Lamichhane et al., 2021; Pépin et al., 2021; Soulé et al., 2023).

Organic farming is a vital component in the transition towards climate neutrality in Europe. By promoting sustainable practices, reducing greenhouse gas emissions and stimulating rural economic development, organic farming not only contributes to environmental protection, but also to a sustainable and resilient food system, with studies highlighting the need to integrate these practices into public policies and support farmers to maximize the environmental and economic benefits of organic farming.

## 3. Methodology

In order to achieve the research goal of conducting an analysis of the economic value of organic farming from the perspective of the transition to climate neutrality, we used principal component analysis to disseminate the determinants of organic farming and how they contribute to climate neutrality goals. From a methodological point of view, we used a dataset of 216 observations measuring different aspects of organic farming, i.e. the agricultural areas related to organic farming, the value of current climate change expenditure related to the organic resources involved, the gross value added of organic farming, the final energy consumption and the value of greenhouse gas emissions from organic farming. The data are presented in Table 1.

Table 1. Presentation of indicators

| Symbol | Description | Source |
|---|---|---|
| ORGCA | Organic crop area by agricultural production methods and crops (Hectares) | Eurostat (Eurostat, 2024e) |
| CCRE | Contribution to the international 100bn USD commitment on climate related expending | Eurostat (Eurostat, 2024a) |
| GVAAgr | Gross value added of the agricultural industry - basic and producer prices Million euro | Eurostat (Eurostat, 2024d) |
| FECA | Final energy consumption by agriculture/forestry per hectare of utilised agricultural area | Eurostat (Eurostat, 2024b) |
| GGEA | Greenhouse gas emissions from agriculture % | Eurostat (Eurostat, 2024c) |

*Source: Elaborated by authors*

To test the correlation between variables, we used the correlation matrix design and observed that the areas cultivated organically and the associated expenditures on climate change mitigation are closely related to the economic value added in the agricultural sector. The results are presented in Table 2.

Table 2. Correlation Matrix

| Indicator[a] | | ORGCA | CCRE | GVAAgr | FECA | GGEA |
|---|---|---|---|---|---|---|
| Correlation | ORGCA | 1.000 | 0.565 | 0.922 | -0.183 | -0.050 |
| | CCRE | 0.565 | 1.000 | 0.588 | -0.019 | -0.051 |
| | GVAAgr | 0.922 | 0.588 | 1.000 | 0.024 | -0.043 |
| | FECA | -0.183 | -0.019 | 0.024 | 1.000 | -0.211 |
| | GGEA | -0.050 | -0.051 | -0.043 | -0.211 | 1.000 |
| Sig. (1-tailed) | ORGCA | | 0.000 | 0.000 | 0.004 | 0.234 |
| | CCRE | 0.000 | | 0.000 | 0.390 | 0.227 |
| | GVAAgr | 0.000 | 0.000 | | 0.364 | 0.265 |
| | FECA | 0.004 | 0.390 | 0.364 | | 0.001 |
| | GGEA | 0.234 | 0.227 | 0.265 | 0.001 | |

*Source: Elaborated by authors*

The correlation matrix study demonstrates that both final energy consumption in agriculture and greenhouse gas emissions show a weak negative correlation with organic farming while the gross value added in agriculture represents one of the most important outputs of organic farming with a correlation coefficient value tending towards 93%.

## 4. Results

We applied the Kaiser-Meyer-Olkin and Bartlett's Test to assess the adequacy of the data, a preliminary step of the PCA analysis. The test results are presented in Table 3.

**Table 3. KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.506 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 582.067 |
| | df | 10 |
| | Sig. | 0.000 |

*Source: Elaborated by authors*

According to the results in Table 3, the level of statistical significance obtained by Bartlett's test confirms the adequacy of the data and allows the extraction of the principal components by the PCA method. We used the PCA method and determined the initial variability explained on the principal components according to the communalities presented in Table 4.

**Table 4. Communalities**

| Indicator[a] | Initial | Extraction |
|---|---|---|
| ORGCA | 1.000 | 0.902 |
| CCRE | 1.000 | 0.609 |
| GVAAgr | 1.000 | 0.896 |
| FECA | 1.000 | 0.639 |
| GGEA | 1.000 | 0.586 |
| Extraction Method: Principal Component Analysis. | | |

*Source: Elaborated by authors*

The results in Table 4 confirm that the principal components explain a significant proportion of the variability in the indicators on organic farming and the economic value of agriculture expressed in GVAAgr. Thus, two main components were identified by the PCA analysis, namely the component of organic farming practices and the environmental component on the transition to climate neutrality, which explain 72.63% of the total variability of the data (Table 5).

**Table 5. Total Variance Explained**

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.409 | 48.186 | 48.186 | 2.409 | 48.186 | 48.186 | 2.409 | 48.178 | 48.178 |
| 2 | 1.222 | 24.441 | 72.628 | 1.222 | 24.441 | 72.628 | 1.222 | 24.450 | 72.628 |
| 3 | 0.795 | 15.897 | 88.524 | | | | | | |
| 4 | 0.521 | 10.415 | 98.939 | | | | | | |
| 5 | 0.053 | 1.061 | 100.000 | | | | | | |
| Extraction Method: Principal Component Analysis. | | | | | | | | | |

*Source: Elaborated by authors*

Thus, the total variance explained for the components is disseminated in the percentage of 48.19% for the first component that concerns organic farming practices and 24.44% for the environmental component on the transition to climate neutrality which suggests that most of the information in the dataset can be characterized by these two components. For interpretation of the principal components the component matrix was designed in Table 6.

**Table 6. Component Matrix**

| Indicator[a] | Component | |
|---|---|---|
| | 1 | 2 |
| ORGCA | 0.946 | -0.080 |
| GVAAgr | 0.944 | 0.060 |
| CCRE | 0.778 | 0.061 |
| FECA | -0.106 | 0.792 |
| GGEA | -0.074 | -0.762 |
| Extraction Method: Principal Component Analysis. | | |
| a. 2 components extracted. | | |

*Source: Elaborated by authors*

The results in Table 6 show that component 1 is characterized by a mix of ORGCA and GVAAgr variability which explains that the main determinants of the economic value of organic farming are driven by the increase in organic area and the increase in demand for organic products. Concerning the environmental component on the transition to climate neutrality it is observed that there is a significant relationship between the economic efficiency of organic farming and greenhouse gas emissions at European level. This component emphasizes the challenges and opportunities of balancing economic efficiency by reducing greenhouse gas emissions, an objective assumed in the perspective of the transition to climate neutrality.

The results have been centralized in the component graph in the rotated space in Figure 1.

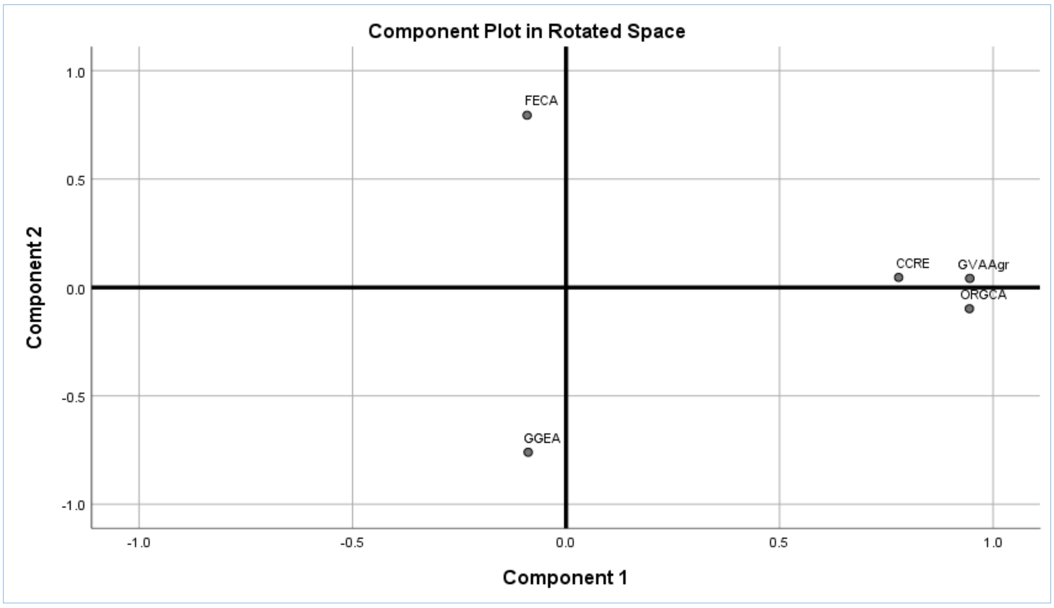


Figure 1. Component graph in rotated space
*Source: Elaborated by authors*

From Figure 1, we observe that there is a strong correlation between organic area and gross value added in organic farming which emphasizes the importance of investment in organic farming for economic growth. This proves that the increase in organic area contributes significantly to economic value reflecting a positive trend in the context of the transition towards sustainable practices. Also Figure 1 shows the significant relationship between economic efficiency and greenhouse gas emissions. This highlights the importance of optimizing agricultural practices to ensure economic and environmental sustainability.

## 5. Discussion

In order to understand the European picture of the variability of the economic value of organic farming from the perspective of the transition to climate neutrality we used the descriptive statistics analysis presented in Table 8.

**Table 8. Descriptive Statistics**

| Indicator | Mean | Std. Deviation | Analysis N |
|---|---|---|---|
| ORGCA | 502587.5648 | 657981.84556 | 216 |
| CCRE | 599.9122 | 1734.82681 | 216 |
| GVAAgr | 6673.0117 | 9871.01205 | 216 |
| FECA | 261.5757 | 401.02346 | 216 |
| GGEA | 11.6449 | 6.59869 | 216 |

*Source: Elaborated by authors*

It can be observed that organic farming practices at European level cover on average more than 500,000 hectares in the period analyzed, i.e. 2015-2022, but the variability between countries and the distribution of organic areas is significant, as evidenced by the value of the standard deviation of the indicator. This means that for some countries such as France, Spain and Italy the level of organic practices is higher (over 2600 hectares per year) while for countries such as Slovenia, the Netherlands and Malta it is at a very low level (below 80 hectares per year). This demonstrates the significant European disparity in organic farming practices and the need to improve the approach in countries whose results are well below the European average. The average expenditure on the contribution to the international commitment to combat climate change shows considerable variability between European countries, averaging around USD 600 million over the period analyzed at European level. The average value added in agriculture is € 6673 million with a significant disparity between Member States exceeding 150% of the average value suggesting different levels of efficiency and productivity among economic farms in the European Union. The indicators for final energy consumption in agriculture and greenhouse gas emissions also reflect European disparities at a significant level. We have graphically analyzed the distributions by means of bidirectional scatterplots of the economic indicators used in the analysis which are presented in Figure 2 below.

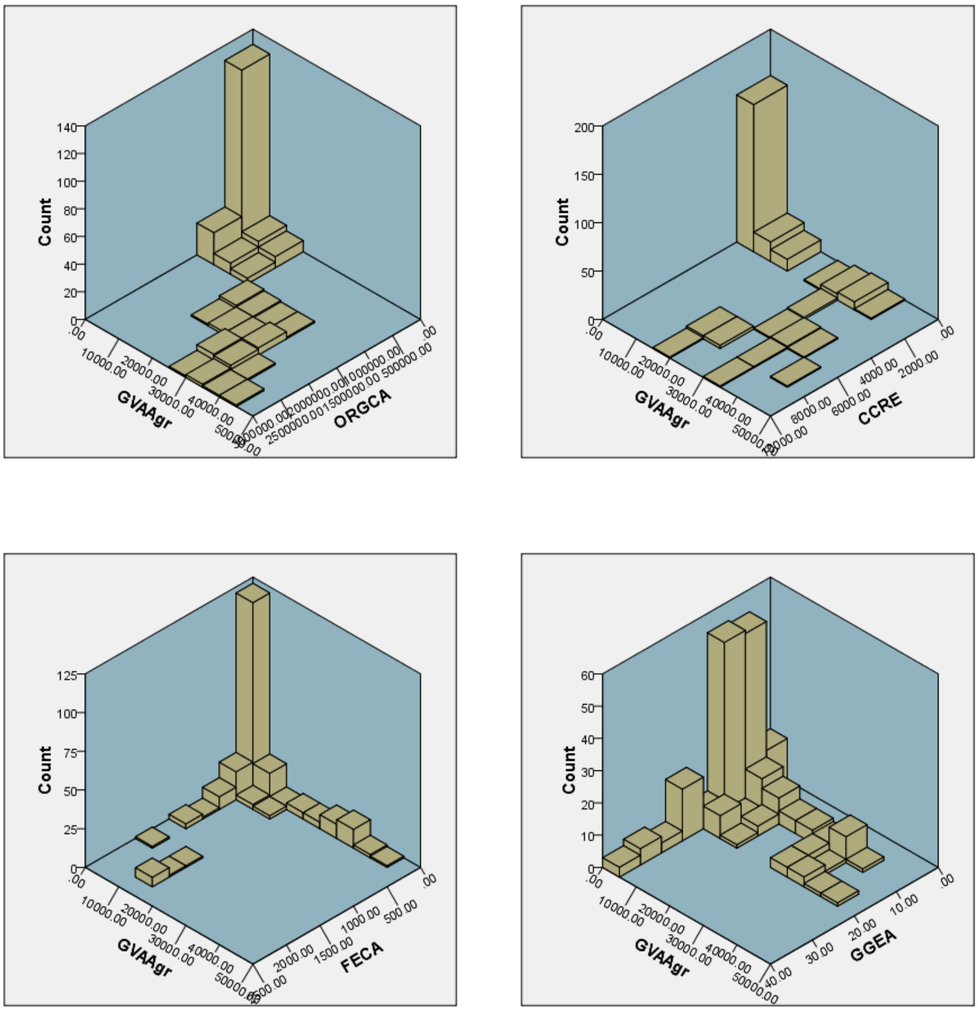


**Figure 2. Bidirectional scatterplots of economic indicators for organic farming in the European Union**

*Source: Elaborated by authors*

The distributions presented in Figure 2 reflect the suggestive variabilities in the extent of organic area expansion of economic yield and climate change mitigation efforts highlighting the diversity and complexity of European organic farming. Thus, we observe from the correlation plot of ORGCA and GVAAgr a significant positive correlation which confirms that economic value added is maximized for farms with superior organic farming practices. At least 3 levels of organic farming yield clusters emerge from the plot, the most common being small farms with lower economic yields. This underlines the need for investments in green resources that generate surplus economic value and effectively contribute to reducing the environmental impact of agriculture at European level. The correlation diagram on the effort to combat climate change is a more differentiated one with a high degree of disparity indicating that the level of involvement of managers is opportunistic with possible economic incentives offered to stimulate agriculture tending to be captured by managers in a possibly unsustainable way whose long-term effects remain still questionable at EU level. In terms of final energy consumption in agriculture, the correlation diagram is influenced by the energy dependence of the sector, and there is not yet a sustainable profile at European level to determine the economic efficiency model through the direct prism of reducing energy consumption. This demonstrates the need to implement tailored policies and strategies for the transition to green agriculture in the European area. In terms of greenhouse gas emissions, the last plot in Figure 2 shows that there is a negative correlation between GGEA and GVAAgr, which demonstrates that farms with higher economic values tend to have lower levels of greenhouse gas emissions, underlining the potential of organic farming to reduce environmental impacts.

## 5. Conclusions

Organic farming is an important pillar of the policy of transition to climate neutrality in Europe. The study aimed to conduct an analysis of the economic value of organic farming from the perspective of the transition to climate neutrality and all 4 objectives were achieved during the research. The analysis based on the PCA method revealed two main components that explain most of the variations in the data selected for the characterization of organic farming at the European level. The two components identified were the organic farming practices component and the environmental component on the transition to climate neutrality. According to the analysis we have shown that an increase in organic areas contributes significantly to the economic value which reflects a positive trend in the context of the transition towards sustainable and climate neutral farming practices. At the same time, component 2 identified the need to balance the profitability objective with the environmental objective of reducing emissions. The European Union must continue to support the development of this sector in the future through strategic policies and investments favoring the insertion of new non-polluting technologies and increasing the resilience of the agricultural sector. The limitations of the study are determined by the size and representativeness of the sample of 216 observations, which may not fully cover the diversity and complexity of European organic farming. Also, the variability of significant organic practices determined at the European level may limit the understanding of the specific impacts of organic farming at the regional level. We propose on a future occasion to extend the research by including in the observational sample a larger number of economic variables and to increase the observation period in order to improve the results of the present research and refine the conclusions on the economic value of organic farming in the perspective of the transition to climate neutrality.

## Acknowledgements

The present research was carried out within the Internal grant Dunarea de Jos University of Galati 2024: Sustainable development of the European economy from the perspective of the transition to climate neutrality, Contract no. 2464/31.05.2024.

## References:

1. Chataut, G., Bhatta, B., Joshi, D., Subedi, K., & Kafle, K. (2023). Greenhouse gases emission from agricultural soil: A review. *Journal of Agriculture and Food Research*, *11*, 100533. https://doi.org/https://doi.org/10.1016/j.jafr.2023.100533
2. Clark, J. K., Jablonski, B. B. R., Inwood, S., Irish, A., & Freedgood, J. (2021). A contemporary concept of the value(s)-added food and agriculture sector and rural development. *Community Development*, *52*(2), 186–204. https://doi.org/10.1080/15575330.2020.1854804
3. De Corato, U. (2021). Effect of value-added organic co-products from four industrial chains on functioning of plant disease suppressive soil and their potentiality to enhance soil quality: A review from the perspective of a circular economy. *Applied Soil Ecology*, *168*, 104221.

https://doi.org/https://doi.org/10.1016/j.apsoil.2021.104221

4. De, L. C., De, T., Biswas, S. S., & Kalaivanan, N. S. (2021). *Organic plant nutrient, protection and production management* (V. S. Meena, S. K. Meena, A. Rakshit, J. Stanley, & C. B. T.-A. in O. F. Srinivasarao (eds.); pp. 115–131). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-12-822358-1.00010-9
5. Devi, S., & Singh, S. (2023). *Soil Organic Carbon Sequestration in Dryland Soils to Alleviate Impacts of Climate Change BT - Enhancing Resilience of Dryland Agriculture Under Changing Climate: Interdisciplinary and Convergence Approaches* (A. Naorem & D. Machiwal (eds.); pp. 221–245). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-9159-2_13
6. Diop, M., Chirinda, N., Beniaich, A., El Gharous, M., & El Mejahed, K. (2022). Soil and Water Conservation in Africa: State of Play and Potential Role in Tackling Soil Degradation and Building Soil Health in Agricultural Lands. In *Sustainability* (Vol. 14, Issue 20). https://doi.org/10.3390/su142013425
7. Durham, T. C., & Mizik, T. (2021). Comparative Economics of Conventional, Organic, and Alternative Agricultural Production Systems. In *Economies* (Vol. 9, Issue 2). https://doi.org/10.3390/economies9020064
8. European Commission. (2023a). *A European Green Deal*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
9. European Commission. (2023b). *Biodiversity strategy for 2030*. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en
10. European Commission. (2024). *Farm to Fork strategy*. https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en
11. Eurostat. (2024a). *Contribution to the international 100bn USD commitment on climate related expending*. https://ec.europa.eu/eurostat/databrowser/view/sdg_13_50/default/table?lang=en&category=cli.cli_act
12. Eurostat. (2024b). *Final energy consumption by agriculture/forestry per hectare of utilised agricultural area*. https://ec.europa.eu/eurostat/databrowser/view/tai04/default/table?lang=en
13. Eurostat. (2024c). *Greenhouse gas emissions from agriculture*. https://ec.europa.eu/eurostat/databrowser/view/tai08/default/table?lang=en
14. Eurostat. (2024d). *Gross value added of the agricultural industry - basic and producer prices*. https://ec.europa.eu/eurostat/databrowser/view/tag00056/default/table?lang=en
15. Eurostat. (2024e). *Organic crop area by agricultural production methods and crops*. https://ec.europa.eu/eurostat/databrowser/view/org_cropar/default/table?lang=en&category=agr.org
16. Foissy, D., jean-françois, V., & David, C. (2013). Managing nutrient in organic farming system: Reliance on livestock production for nutrient management of arable farmland. *Organic Agriculture*, *3*, 183–199. https://doi.org/10.1007/s13165-014-0060-8
17. Francaviglia, R., Almagro, M., & Vicente-Vicente, J. L. (2023). Conservation Agriculture and Soil Organic Carbon: Principles, Processes, Practices and Policy Options. In *Soil Systems* (Vol. 7, Issue 1). https://doi.org/10.3390/soilsystems7010017
18. Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., & Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. *Farming System*, *1*(1),

100005. https://doi.org/https://doi.org/10.1016/j.farsys.2023.100005
19. 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
20. Herman, E. (2024). Sustainable Agriculture and Its Impact on the Rural Development in EU Countries: A Multivariate Analysis. In *Land* (Vol. 13, Issue 7). https://doi.org/10.3390/land13070947
21. Holka, M., Kowalska, J., & Jakubowska, M. (2022). Reducing Carbon Footprint of Agriculture—Can Organic Farming Help to Mitigate Climate Change? In *Agriculture* (Vol. 12, Issue 9). https://doi.org/10.3390/agriculture12091383
22. Kareem, A., Farooqi, Z. U. R., Kalsom, A., Mohy-Ud-Din, W., Hussain, M. M., Raza, M., & Khursheed, M. M. (2022). *Organic Farming for Sustainable Soil Use, Management, Food Production and Climate Change Mitigation.* (S. A. Bandh (ed.); pp. 39–59). Springer International Publishing. https://doi.org/10.1007/978-3-030-83066-3_3
23. Lamichhane, S., Eğilmez, G., Gedik, R., Bhutta, M. K. S., & Erenay, B. (2021). Benchmarking OECD countries' sustainable development performance: A goal-specific principal component analysis approach. *Journal of Cleaner Production*, *287*, 125040. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.125040
24. Li, P., Jia, L., Chen, Q., Zhang, H., Deng, J., Lu, J., Xu, L., Li, H., Hu, F., & Jiao, J. (2024). Adaptive evaluation for agricultural sustainability of different fertilizer management options for a green manure-maize rotation system: Impacts on crop yield, soil biochemical properties and organic carbon fractions. *Science of The Total Environment*, *908*, 168170. https://doi.org/https://doi.org/10.1016/j.scitotenv.2023.168170
25. Licastro, A., & Sergi, B. S. (2021). Drivers and barriers to a green economy. A review of selected balkan countries. *Cleaner Engineering and Technology*, *4*, 100228. https://doi.org/https://doi.org/10.1016/j.clet.2021.100228
26. Long, H., Ma, L., Zhang, Y., & Qu, L. (2022). Multifunctional rural development in China: Pattern, process and mechanism. *Habitat International*, *121*, 102530. https://doi.org/https://doi.org/10.1016/j.habitatint.2022.102530
27. Meena, R. N., Meena, K., & Choudhary, M. (2023). Chapter 1 - Organic farming—a key to food security and agricultural sustainability. In Sarathchandran, U. M.R., S. Thomas, & D. K. B. T.-O. F. (Second E. Meena (Eds.), *Woodhead Publishing Series in Food Science, Technology and Nutrition* (pp. 1–30). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-323-99145-2.00007-0
28. Niftiyev, I., & Ibadoghlu, G. (2023). Longitudinal Principal Component and Cluster Analysis of Azerbaijan's Agricultural Productivity in Crop Commodities. In *Commodities* (Vol. 2, Issue 2, pp. 147–167). https://doi.org/10.3390/commodities2020009
29. Obaisi, A. I., Adegbeye, M. J., Elghandour, M. M. M. Y., Barbabosa-Pliego, A., & Salem, A. Z. M. (2022). *Natural Resource Management and Sustainable Agriculture BT - Handbook of Climate Change Mitigation and Adaptation* (M. Lackner, B. Sajjadi, & W.-Y. Chen (eds.); pp. 2577–2613). Springer International Publishing. https://doi.org/10.1007/978-3-030-72579-2_133
30. Ostandie, N., Giffard, B., Bonnard, O., Joubard, B., Richart-Cervera, S., Thiery, D., & Rusch, A. (2021). Multi-community effects of organic and conventional farming practices in vineyards. *Scientific*

*Reports*, *11*. https://doi.org/10.1038/s41598-021-91095-5

31. Panday, D., Bhusal, N., Das, S., & Ghalehgolabbehbahani, A. (2024). Rooted in Nature: The Rise, Challenges, and Potential of Organic Farming and Fertilizers in Agroecosystems. In *Sustainability* (Vol. 16, Issue 4). https://doi.org/10.3390/su16041530
32. Parizad, S., & Bera, S. (2023). The effect of organic farming on water reusability, sustainable ecosystem, and food toxicity. *Environmental Science and Pollution Research*, *30*(28), 71665–71676. https://doi.org/10.1007/s11356-021-15258-7
33. Pépin, A., Morel, K., & van der Werf, H. M. G. (2021). Conventionalised vs. agroecological practices on organic vegetable farms: Investigating the influence of farm structure in a bifurcation perspective. *Agricultural Systems*, *190*, 103129. https://doi.org/https://doi.org/10.1016/j.agsy.2021.103129
34. Rahmann, G., Reza Ardakani, M., Bàrberi, P., Boehm, H., Canali, S., Chander, M., David, W., Dengel, L., Erisman, J. W., Galvis-Martinez, A. C., Hamm, U., Kahl, J., Köpke, U., Kühne, S., Lee, S. B., Løes, A.-K., Moos, J. H., Neuhof, D., Nuutila, J. T., … Zanoli, R. (2017). Organic Agriculture 3.0 is innovation with research. *Organic Agriculture*, *7*(3), 169–197. https://doi.org/10.1007/s13165-016-0171-5
35. Ramakrishnan, B., Maddela, N. R., Venkateswarlu, K., & Megharaj, M. (2021). Organic farming: Does it contribute to contaminant-free produce and ensure food safety? *Science of The Total Environment*, *769*, 145079. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.145079
36. Rawat, L., Bisht, T. S., & Naithani, D. C. (2021). *Plant Disease Management in Organic Farming System: Strategies and Challenges BT - Emerging Trends in Plant Pathology* (K. P. Singh, S. Jahagirdar, & B. K. Sarma (eds.); pp. 611–642). Springer Singapore. https://doi.org/10.1007/978-981-15-6275-4_27
37. Rempelos, L., Baranski, M., Wang, J., Adams, T. N., Adebusuyi, K., Beckman, J. J., Brockbank, C. J., Douglas, B. S., Feng, T., Greenway, J. D., Gür, M., Iyaremye, E., Kong, C. L., Korkut, R., Kumar, S. S., Kwedibana, J., Masselos, J., Mutalemwa, B. N., Nkambule, B. S., … Leifert, C. (2021). Integrated Soil and Crop Management in Organic Agriculture: A Logical Framework to Ensure Food Quality and Human Health? In *Agronomy* (Vol. 11, Issue 12). https://doi.org/10.3390/agronomy11122494
38. Rossi, C., Shen, L., Junginger, M., & Wicke, B. (2024). Sustainability certification of bio-based products: Systematic literature review of socio-economic impacts along the supply chain. *Journal of Cleaner Production*, *468*, 143079. https://doi.org/https://doi.org/10.1016/j.jclepro.2024.143079
39. Saffeullah, P., Nabi, N., Liaqat, S., Anjum, N. A., Siddiqi, T. O., & Umar, S. (2021). *Organic Agriculture: Principles, Current Status, and Significance BT - Microbiota and Biofertilizers: A Sustainable Continuum for Plant and Soil Health* (K. R. Hakeem, G. H. Dar, M. A. Mehmood, & R. A. Bhat (eds.); pp. 17–37). Springer International Publishing. https://doi.org/10.1007/978-3-030-48771-3_2
40. Sansika, N., Sandumini, R., Kariyawasam, C., Bandara, T., Wisenthige, K., & Jayathilaka, R. (2023). Impact of economic globalisation on value-added agriculture, globally. *PLOS ONE*, *18*(7), e0289128. https://doi.org/10.1371/journal.pone.0289128
41. Soulé, E., Charbonnier, R., Schlosser, L., Michonneau, P., Michel, N., & Bockstaller, C. (2023). A new method to assess sustainability of agricultural systems by integrating ecosystem services and environmental impacts. *Journal of Cleaner Production*, *415*, 137784. https://doi.org/https://doi.org/10.1016/j.jclepro.2023.137784
42. Stubenrauch, J., Ekardt, F., Heyl, K., Garske, B., Schott, V. L., & Ober, S. (2021). How to legally overcome the distinction between organic and conventional farming - Governance approaches for

sustainable farming on 100% of the land. *Sustainable Production and Consumption*, *28*, 716–725. https://doi.org/https://doi.org/10.1016/j.spc.2021.06.006

43. Tache, F. L. (2009). Advice in electronic commerce. *2009 3rd International Workshop on Soft Computing Applications*, 111–114. https://doi.org/10.1109/SOFA.2009.5254869
44. Wang, H., Wang, S., Yu, Q., Zhang, Y., Wang, R., Li, J., & Wang, X. (2020). No tillage increases soil organic carbon storage and decreases carbon dioxide emission in the crop residue-returned farming system. *Journal of Environmental Management*, *261*, 110261. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.110261
45. Wei, X., Xie, B., Wan, C., Song, R., Zhong, W., Xin, S., & Song, K. (2024). Enhancing Soil Health and Plant Growth through Microbial Fertilizers: Mechanisms, Benefits, and Sustainable Agricultural Practices. In *Agronomy* (Vol. 14, Issue 3). https://doi.org/10.3390/agronomy14030609
46. Wijerathna-Yapa, A., & Pathirana, R. (2022). Sustainable Agro-Food Systems for Addressing Climate Change and Food Security. In *Agriculture* (Vol. 12, Issue 10). https://doi.org/10.3390/agriculture12101554
47. Yang, X., Xiong, J., Du, T., Ju, X., Gan, Y., Li, S., Xia, L., Shen, Y., Pacenka, S., Steenhuis, T. S., Siddique, K. H. M., Kang, S., & Butterbach-Bahl, K. (2024). Diversifying crop rotation increases food production, reduces net greenhouse gas emissions and improves soil health. *Nature Communications*, *15*(1), 198. https://doi.org/10.1038/s41467-023-44464-9