EMPIRICAL EVALUATION OF SUSTAINABLE AGRICULTURAL MANAGEMENT IN SOUTHEAST EUROPEAN COUNTRIES USING PANEL DATA ANALYSIS

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A B S T R A C T

The purpose of this article is to assess the agricultural development of ten Southeast European (SEE) countries from the aspect of key environmental, economic and social indicators of agricultural sustainability management from 2011 to 2020. The article uses a Cross-section panel data Fixed Effects Model to identify relations between agricultural development in SEE countries and mentioned indicators of sustainable agricultural development management. The common sample of all SEE countries shows the economic sustainability, but also the environmental and social unsustainability of their agricultural systems. At a disaggregated level, the sub-sample of European Union (EU) membership candidate countries also yields the same findings. In contrast, the sub-sample of EU member states indicates all three dimensions of sustainability, with the exception of the aspect of using renewables. Therefore, both groups of countries should use renewables more intensively in order to contribute to the promotion of their efficient, sovereign and sustainable agricultural growth.

Introduction

Sustainability has grown into a key paradigm of connecting ecological, economic and social goals, both in science and practice, and in ongoing economic policies (Janker et al., 2019). Given the rapid growth of the global population, and thus the increase in demand for food, textiles and other agricultural goods, there is an imperative for

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sustainable management of resources in agribusiness. The United Nations (UN) estimates that the global population could grow to about 8.5 billion by 2030 and 9.7 billion people by 2050, if it continues to increase at a rate of less than 1% (United Nations, 2022). That scenario would certainly raise the pressure on the demand for basic life goods. Sustainable agriculture is a flexible and adaptable farming production that meets the needs for food and fiber of current generations, but not at the expense of the similar needs of future generations (SAREP, 2023). Guided by multidimensional sound goals, sustainable agricultural techniques are based on environmental protection, prevention of natural resources and improvement of water, air and soil quality, in their intention to increase the profitability of agricultural business, improve the quality of life on farms, and promote environmentally friendly behavior (National Institute for Food and Agriculture, 2024). The Food and Agriculture Organization (FAO, 2016) defines sustainable agriculture as practices and policies that support the integration of agricultural production with the aim of responsible management and ensuring the long-term availability of natural resources, which is why both the production of nutritious and safe food and good agricultural practices are in its immediate focus.

By relying on organic production, sustainable agriculture helps farmers in use of innovative agricultural practices and sustainable recycling methods such as crop waste and animal manure. It increases the efficiency and effectiveness of agricultural production, has a positive impact on the environment and ecosystems, ensures the long-term use of natural resources and makes its invaluable contribution to the creation of new jobs and the development of local communities (Meena, 2023). Sustainable agriculture, among other things, contributes to the preservation and improvement of natural ecosystems, biodiversity, economic systems and human civilization itself. This concept encourages practices that do not threaten agricultural resources, fosters the sustainability of natural ecosystems and resilience to climate change, preserves soil from degradation and supports agricultural production in the most lucrative and productive way (Coulibaly et al., 2021). However, despite its numerous advantages, there are still many obstacles to the realization of this ambitious concept. They primarily relate to ecological considerations, morality, socially responsible behavior and social expectations regarding the expected productivity and profitability of agricultural production, as well as the application of specific agricultural techniques and the functioning of food supply chains (Dukić et al., 2021).

The region of Southeast Europe (SEE) has a population of 55 million inhabitants, located in as many as ten countries. Although the size and population of this region is relatively small, without encouraging the development of agriculture in the SEE countries, there would also be a decrease in food security in the wider area of Europe (Andrei et al., 2023). This region also represents a special geographically, sociologically and culturally bounded entity that is important for the European Union (EU) itself, bearing in mind that it is made up of some EU members (Bulgaria, Croatia, Greece and Romania), as well as of countries officially candidates for EU membership (Albania, Bosnia and Herzegovina, Moldova, Montenegro, North Macedonia and Serbia).

Today, the countries of Southeast Europe are primarily characterized by accelerated deindustrialization induced by endogenous factors, bad strategic economic decisions, weak human capital, a large wave of emigration and exogenous shocks, as well as stagnant and insufficiently efficient agriculture, low demand and weak capital markets. Along with the slow industrialization of the region and the growth of global prices of agricultural products, there was also a shift of capital and labor force from industry to the agricultural sector, giving the region of South Eastern Europe an explicit comparative advantage in agriculture rather than in industrial production (Kopsidis, Ivanov, 2017). In addition to agriculture and industry, these countries today largely base their development on the perspective service sector. On the other hand, the OECD (2018), by analyzing the agriculture of the Western Balkans' countries, points out that they are abundant in natural resources, which gives them a good basis for the development of agriculture, both in terms of its additional values, as well as in terms of employment and the creation of new jobs. However, these countries still face problems of sustainable growth in agricultural productivity, sectorial competitiveness and rural development. Despite the affordability of basic rural infrastructure and well-established policy frameworks, they still pursue a politics of heavy agricultural subsidies that distort markets and act as a disincentive to agricultural productivity growth.

The significance of this empirical study is reflected in the fact that until now there have been relatively few published research articles devoted to the study of the important issue of sustainable agricultural development management in the SEE countries. Of the published manuscripts dedicated to this topic, they were mainly led by the reports of relevant international organizations. In addition, the findings of many published studies are not mutually comparable since most of them cover heterogeneous countries, most often including the countries of Central Europe. Therefore, the findings of this article will gain significant insights and paint a picture of the SEE agricultural systems' viability, which also gives a significant scientific contribution. This is even truer if one take into account that the previous studies on the assessment of the sustainable agricultural development are still in their infancy, as well as that there is still plenty of room for carrying out research on the sustainability of modern agrarian systems (Yu, Yongtong, 2022). The purpose of this article is to evaluate the agricultural development of the ten mentioned SEE countries at an aggregated level from the aspect of key environmental, economic and social indicators of agricultural sustainability in the period from 2011 to 2020. Following the introductory part, its second section is devoted to a review of the relevant literature sources on the most commonly used indicators of agricultural sustainability, while the third section describes the data and the research methodology applied. The fourth section discusses the obtained results, with the final section concluding the paper.

A brief literature review on sustainable agricultural management indicators

There is a reach body of articles devoted to the study of indicators of sustainable agricultural production. Sustainable agribusiness has emerged as a useful substitute for conventional agriculture that is based on extensive production and mechanization systems, labor and capital intensity, and extensive use of artificial fertilizers and insecticides. Conventional agriculture is often identified with intensive farming systems (Macrì, Perito, 2018), as well as with the practice that insists on the intensive use of agricultural chemicals and land with the aim of maximizing agricultural output (Sumberg, Giller, 2022). Hansen (1996) noted long ago that sustainability is a fundamental characteristic and rudimentary approach to agricultural development that has triggered broad changes and its reform efforts. However, although the interpretation of sustainability in this way is relevant and logical, the idea and practical implications of its conceptualization have limited the usefulness of this approach (Hansen, 1996), which is why there was a need to build a set of more concrete, reliable, quantitatively expressible, systemic and predictable indicators of the sustainable agricultural production.

Smith and McDonald (1998) classified the complex factors of agricultural sustainability into hierarchically organized classes of biophysical, economic and social factors at scientific field, farm, regional and national levels. Bearing in mind the need for adequate information in the decision-making and planning stages of agricultural production, the authors have developed a comprehensive framework for an integrated assessment of sustainable agriculture that includes all analyzed factors and measurement levels. *Table 1* from the Appendix gives a somewhat deeper insight into some of the multitude of indicators used by many authors when constructing the proposed frameworks and indices for assessing the sustainability of agriculture. The tabular representation clearly shows that the proposed indicators of sustainable agricultural management have become more complex over time, both in terms of their number and scope, as well as in terms of the recommended hierarchical determinants and classification levels.

Rao and Rogers (2006) compared and synthesized several formal systems and analytical frameworks for assessing sustainable agriculture at the global, national, regional, village and farming system levels, as basic prerequisites for designing appropriate agricultural policies. By scaling indicators from lower hierarchical levels to higher ones using Geographic Information Systems (GIS) tools, the authors proposed a kind of framework for assessing agricultural sustainability. Yu and My (2022) use an extensive bibliometric analysis of 110 scientific articles published between 2002 and 2022 with the aim of determining the growth trend of sustainable agriculture assessment research. Based on the conducted statistical analysis, the authors conclude that recent studies focused on environmental effects and economic efficiency, mainly using three aggregated groups of a wide range of observed indicators (environmental, economic and social).

Finally, Alaoui, Barão, Ferreira and Hessel (2022) also compare six mutually competing frameworks for assessing the overall sustainability of agricultural holdings in their attempt to summarize sustainability criteria and identify available frameworks for assessing agricultural sustainability. The authors conclude that only the Sustainability Monitoring and Assessment RouTine (SMART) framework simultaneously considers the ecological, socio-cultural and economic dimensions of sustainability in a balanced way, while the other considered frameworks rather focus on only one of these dimensions. While the observed frameworks differ from each other according to the information receivers they are actually intended for, they cover the main ideas and concepts from the environmental, economic and socio-cultural dimensions, concluding that future frameworks should also include the climatic, technological and social dimensions.

This article uses agricultural value added as a dependent variable, bearing in mind that it is a key indicator for measuring the growth of primary sector output and, in general, of national and local rural economic development patterns (Ru et al., 2022; Ceylan, Özkan, 2013). In addition, the agricultural value added is also used as a good indicator of the achieved evolutionary progress in the agricultural sector performance, based on which detailed information could be obtained about the need to change agricultural policies or investment decisions (Olubode-Awosola et al., 2008).

Used data and applied research methodology

Based on the analyzed articles from the Literature Review, the purpose of this article is to assess the impact of some environmental, economic and social sustainability factors on the agricultural development in the observed SEE countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, Moldova, North Macedonia, Romania and Serbia). All data for analysis comes from the World Bank database, which ensured their full comparability. The sample initially consisted of N=10 cross sections, that is, countries and T=10 time units, that is, years, which made 100 observations of a balanced panel. Preliminary analyzes indicated that there was no possible risk of multicollinearity given that the Pearson correlation coefficients between the regressors ranged up to |0.36|, indicating the absence of multicollinearity. It was also observed that the Agricultural methane emissions indicator had the highest positive and statistically significant correlation with the dependent variable ($\rho = 0.9122$, $p = 0.0000 < 0.05$). The variables used in the analysis are shown in more detail in the following *Table 1*.

Table 1. Indicators used in the analysis

Variable	Variable description	Variable code	Source of data
Agricultural development	Agriculture, forestry and fishing value added (in constant 2015 billion US$)	AGRI	World Bank
Agricultural methane emissions	Agricultural methane emissions (in thousand metric tons of CO_2 equivalent)	METH	World Bank
Renewable energy	Renewable energy consumption (as a % of total final energy consumption)	RENWEN	World Bank
Cereal yields	Cereal yields (in kg per hectare)	CEREAL	World Bank
Unemployment rate	Total unemployment rate (as a % of total labor force)	UNEMPL	World Bank
Education	Total government expenditure on education (as a % of GDP)	EDU	World Bank

Source: Authors

The article applies panel regression analysis in its intention to discover and describe the relationships between the dependent variable Agricultural development and the observed explanatory variables presented in *Table 1*. To this end, the article uses panel data Cross-section Fixed Effects Model (FEM) to identify the mentioned links. The most general and simplest form of the FEM model can be written as follows (Gujarati, 2012):

$$y_{it} = \alpha_i + \beta_i X_{it} + u_{it} \quad (1)$$

where y_{it} represents the dependent variable that is evaluated for each cross-sectional unit i, α_i is the intercept, X_{it} is the matrix of regression variables, β_i is the matrix of coefficients of explanatory variables, while u_{it} is the error term of the regression.

Taking into account *Formula 1* and the variable codes from *Table 1*, the considered research model took the following form:

$$AGRI = \alpha_i + \beta_1 \times METH_{it} + \beta_2 \times RENWEN_{it} + \beta_3 \times CEREAL_{it} + \beta_4 \times UNEMPL_{it} + \beta_5 \times EDU_{it} + u_{it} \quad (2)$$

In this article, the statistical software package Eviews 9 was used for panel data processing.

Results and discussion

Estimation of the entire sample

Initial analyses of the sample data also suggested that all included variables were stationary at their levels. For this purpose, the polled Levin, Lin and Chu (LLC) test was employed, which is suitable for panels of moderate size and provides exceptional estimator consistency compared to its separate unit root test counterparts (Barbieri, 2009). Considering their short length, as well as the detected stationarity, the used variables remained at their levels. Due to the imposed limitations on the length of the article, data on correlation coefficients between the regressors and the results of the conducted LLC test are available upon request from the Authors. The original intention of the authors was to include the variable Gender equality in the analysis, but as it turned out that it was not stationary even in its logarithmic form, it had to be excluded from further analysis.

In the next step, the article approached data diagnostics with the aim of selecting the best panel data regression model. The results of the Likelihood Ratio (LR), i.e. the Chow Test indicated that in the choice between the Pooled OLS model and the Fixed Effects Model, it was necessary to choose the FEM (Cross-section Chi-square = 245.0128, $p = 0.0000 < 0.05$). On the other hand, the results of the performed Hausman test indicated that the FEM emerged as a preferred solution in relation to the Random Effects Model (REM) (Chi-square = 19.7176, $p = 0.0014 < 0.05$). The Pesaran CD test also indicated that there was no cross-sectional dependence in the residuals (Pesaran, 2004), which also supported the argument in favor of applying the LLC test of stationarity of the considered variables. Given the observed statistical significance of the cross-sectional effects, but also the heteroscedasticity present in the panel data set, GLS Cross-section weights that allow heteroscedasticity in the cross-sectional dimension (Eviews Halp, 2024) were used, together with White's robust standard errors that correct heteroskedasticity and potential serial correlation. In the continuation of the article, an overview of all three mutually competitive models is presented in order to show the advantages of the selected FEM model in relation to the other two alternatives.

Table 2. Summary overview of three competing models

Variables	Pooled OLS	Random Effects Model	Fixed Effects Model
C	-2.4762* (0.469338)	0.0376 (0.817152)	3.1942* (0.328681)
METH	0.0012* (2.40E-05)	0.0007* (0.000170)	-0.0003* (0.000112)
RENWEN	-0.0092** (0.005227)	-0.0203** (0.011505)	-0.0070 (0.003753)
CEREAL	9.73E-05* (3.70E-05)	0.0004* (6.11E-05)	0.0002* (2.93E-05)
UNEMPL	0.0397* (0.006700)	-0.0067 (0.011198)	0.0003 (0.003654)
EDU	0.4094* (0.059195)	0.0297 (0.094380)	-0.0057 (0.021877)
R-squared	0.8499	0.3768	0.9919
Adjusted R-squared	0.8489	0.3437	0.9906
S.E. of regression	1.0659	0.3637	0.2509
F-statistic	786.1738*	11.3674*	747.2480*
Prob.(F-statistic)	0.0000	0.0000	0.0000

Note: * denotes statistical significance at the level of 0.05, while ** denotes statistical significance at the level of 010; standard errors in parentheses

Source: Authors' calculations

Off all the observed mutually competing models, the proposed Cross-section FEM model also showed the highest Adjusted coefficient of determination (R^2), indicating that it explained as much as 99.06% of the variation in the dependent variable. In addition, this model was characterized by the smallest regression error term (S.E. = 0.2509), while all variables collectively contributed to explaining the dependent variable (F-statistic = 747.2480, p = 0.0000 < 0.05). All of the above indicated that it was a well-fitted and correctly selected model.

The results of the analysis of the proposed Cross-section FEM model unequivocally indicated that the variables Agricultural methane emissions and Cereal yields gave a statistically significant contribution to agricultural development in the countries of Southeast Europe, which was in line with expectations. However, while an increase in Cereal yields by 1 kilogram per hectare leads to an increase in Agricultural value added by 0.0002 billion US$, an increase in Agricultural methane emissions in the amount of one thousand metric tons of CO_2 equivalent causes a decrease in Agricultural value added by 0.0003 billion US$. These findings point to the conclusion that from the perspective of harmful greenhouse gases (GHG) emissions, the development of agriculture in SEE countries is not sustainable. In addition, the growth in the use of renewable energy sources leads to a decrease in agricultural output, suggesting that even from environmental aspect agricultural development in the region is not sustainable. Finally, the negative impact of Total government expenditure on education on the development of agriculture is observable, which probably occurs as a result of the fact that the agricultural production of SEE countries is characterized by weak human capital (Kopsidis, Ivanov, 2017), but also that state allocations for education are likely to be directed towards some other productive sectors.

Estimation of sub-samples

In the next phase of the research, the initial sample was divided into two sub-samples, the first one, which refers to the EU membership candidate countries, and the second one, which consisted of EU member states. By following an almost identical FEM econometric procedure with all previously satisfied conditions, the authors conducted separate analysis on both sub-samples, noting that the sub-sample of EU membership candidates showed significant cross-section effects, while the sub-sample of EU members showed significant time effects. The results of the performed analysis of these two mutually comparative models are shown in the following *Table 3*.

Table 3. Results of sub-samples' Fixed Effects Models

Variables	Cross-section FEM (EU membership candidate countries sub-sample)	Period FEM (EU member states sub-sample)
C	1.8400* (0.285982)	-1.6172* (0.702027)
METH	-0.0003 (0.000188)	0.0012* (0.001190)
RENWEN	-0.0083* (0.002486)	-0.1106* (0.009537)
CEREAL	0.0001* (2.06E-05)	0.0004* (0.000123)
UNEMPL	0.0005 (0.003544)	0.1955* (0.007916)
EDU	-0.0895* (0.027788)	0.0421 (0.176494)
R-squared	0.9921	0.9965
Adjusted R-squared	0.9905	0.9946
S.E. of regression	0.0805	0.4778
F-statistic	618.7757*	510.3594*
Prob.(F-statistic)	0.0000	0.0000

Note: * denotes statistical significance at the level of 0.05

Source: Authors' calculations

Interesting enough, from this comparative overview, arises the first conclusion that emissions of harmful agricultural methane are negatively correlated with agricultural production in EU membership candidates, while they are positively correlated in EU members. This further suggests that agricultural production in the EU candidates is not sufficiently developed, nor sustainable in terms of methane emissions, while it is sustainable and certainly more developed in EU members. When it comes to renewable energy sources, in both groups of countries a statistically significant negative relationship with agricultural output is observed, indicating the environmental unsustainability of agricultural production, as well as the need for their greater use and more significant investments and employment in this area. As regards the Cereal yields variable, the expected significant positive relationship appeared in both groups of countries, indicating economic viability of their agricultural systems. Finally, it follows from the analysis that allocations for education have positive effects on agricultural development in the EU member states, while this is not the case with the EU membership candidate countries.

Conclusions

This article is dedicated to the research of the influence of some environmental, economic and social factors of sustainable agricultural development management of the countries of Southeast Europe in the period from 2011 to 2020. The research covered ten SEE countries, both official candidates for EU membership (Albania, Bosnia and Herzegovina, Montenegro, Moldova, North Macedonia and Serbia), and EU members (Bulgaria, Croatia, Greece and Romania) with the aim of evaluation the sustainability of their agricultural development. For that purpose, the Cross-section panel data Fixed Effect Model was applied to the aggregate sample, which indicated economic sustainability, but also environmental and social unsustainability of agricultural development in all observed countries. While there is a positive relationship of the economic variables Cereal yields and Unemployment rate with agricultural development, there is also a worrying negative relationship between agricultural methane emissions, the use of renewable energy sources and educational expenditure, on one, and agricultural output on other hand.

After dividing the common sample into two separate sub-samples, the analysis pointed to significant differences between EU membership candidate countries and EU members. Unlike the candidate countries, which again demonstrated the environmental and social unsustainability of their agricultural systems, the situation is completely different in EU members. In EU member states, agricultural development is sustainable from the aspect of harmful methane emissions, cereal yields and allocations for education, while it is unsustainable only from the aspect of using renewable energy sources. This further means that the candidates for EU membership have a long way to go towards consolidating their agricultural sectors, including the greening of their economies and certainly greater and more focused allocations for education purposes. In addition, both groups of countries should focus more intensively on managing the use of renewable energy sources in agricultural production, such as wind, solar and biomass energy, in order to contribute to the promotion of their efficient, sovereign and sustainable agricultural growth. The evidence-based information and findings of this article are useful and informative for researchers, practitioners, decision makers and agricultural policy makers, but also for the wider public concerned with these important issues. The indicators used in this paper can provide useful hints for subsequent research, while further streams of research could be aimed at expanding the scope of the analysis to the countries of Central Europe.

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Conflict of interests

The authors declare no conflict of interest.

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Appendix

Table 1. Indicators for agricultural sustainability assessment

Sets of indicators	Smith & MacDonald (1998)	Rao & Rogers (2006)	Yu & Mu (2022)	Alaoui et al. (2022)
Set 1	**Biophysical** (Land and water quality and Productivity)	**Environmental** (Soil loss, Farm size, Water quality, Carbon emissions, Average rainfall, Groundwater use, Soil quality, Livestock etc.)	**Environmental** (Pollution, Acidification, GHG emissions, Energy use efficiency, Healthy agricultural area etc.)	**Environmental** (Water use, quality and pollution, soil quality and land degradation, Air quality, Climate, Plants and fertility, Biodiversity, Energy use, Animal welfare etc.)
Set 2	**Economic environment** (Income, Profitability, Production costs, Consumption, Poverty indices etc.)	**Socio-economic** (National income, Poverty level, Land availability and Food consumption per capita, Debt-service ratio, Labor productivity, Literacy rate, Ownership rights, Household income, Credits and assets etc.)	**Economic** (Agricultural income, Income of farmers, Economic yields, Farm management costs, Agricultural contribution to GDP, Productivity of labor, land and capital, Agricultural productivity, Investment in R&D etc.)	**Economic** (Profitability, Vulnerability, Accountability, Investment, Local economy indicators, Economic risks etc.)

Sets of indicators	Smith & MacDonald (1998)	Rao & Rogers (2006)	Yu & Mu (2022)	Alaoui et al. (2022)
Set 3	**Social environment** (Social justice and equity, Participation, Democratic institutions, Overall policy environment, Access to resources and outputs, Attitudes, Knowledge, Social values etc.)	**Science and technology capacity** (High yielding varieties, Change in fertilizer and water use efficiency, Change in livestock productivity etc.)	**Social** (Agricultural employment and land, Rural development, Education level, Agricultural and environmental subsidies, Income distribution and social inequalities, Agricultural labor intensity, Diversity of products etc.)	**Socio-cultural** (Employment contracts, Workload, Wages, Health safety, Job satisfaction, Decent livelihood, Gender equality, Cultural diversity, Investment in local communities, Employment, Consumer safety, Transparency etc.)
Set 4		**Institutional capacity** (Capacity building, Access to information, financial resources, community services and markets, Infrastructure, Insurance, Financial and agricultural institutions)		

Source: Authors' research