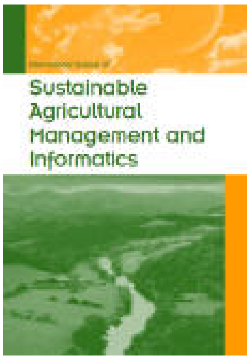

International Journal of Sustainable Agricultural Management and Informatics

ISSN online: 2054-5827 - ISSN print: 2054-5819
https://www.inderscience.com/ijsami

A non-compensatory approach to the creation of composite indices of agricultural sustainability of the European Union countries

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DOI: 10.1504/IJSAMI.2022.10050899

Article History:

Received:	19 July 2022
Accepted:	29 August 2022
Published online:	07 December 2022

A non-compensatory approach to the creation of composite indices of agricultural sustainability of the European Union countries

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Abstract: The paper aims to calculate and evaluate the degree of achieved agricultural sustainability in the countries of the European Union. Agriculture is a specific activity that, on the one hand, must provide sufficient amounts of food for the population, while on the other hand, it can have a significant negative impact on the environment. The assessment of agricultural sustainability was made by selecting ten relevant indicators from the Eurostat and OECD databases, and by creating a composite index using the Mazziotta-Pareto method. The research results show that the Northern Europe countries (Sweden, Finland and Denmark) achieve the highest level of agricultural sustainability, mainly due to the high participation of organic agricultural production, as well as the low level of soil erosion, considering all European countries. On the contrary, countries with high agricultural economic performance show significantly worse results in terms of sustainability (such as Italy, Spain and France).

Keywords: agriculture; environment; sustainable development; sustainability assessment; non-compensatory methods; composite indices; Mazziotta-Pareto Index; MPI; European Union.

Reference to this paper should be made as follows: Marković, M., Stanković, J.J., Marjanović, I. and Tsaples, G. (2023) 'A non-compensatory approach to the creation of composite indices of agricultural sustainability of the European Union countries', *Int. J. Sustainable Agricultural Management and Informatics*, Vol. 9, No. 1, pp.1–18.

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1 Introduction

The issues of agriculture and sustainable development are inseparable because the greater part of agricultural production is carried out in open space using land that is subject to degradation of various types. Agriculture fulfils its basic role by producing food, but at the same time affects rural development, food safety and soil quality (Ristić et al., 2020). The concept of sustainable agriculture implies the application of agricultural practices in a sustainable way. Specifically, sustainable agriculture means enabling the food and fibre needs of current generations to be met, without compromising the ability of future generations to meet their own needs (Brodt et al., 2011). The ability to understand the capacity of the ecosystem is the basis for realising the sustainability of agriculture. The role of ecosystems in supporting agriculture is significant and is reflected in the provision of conditions for agricultural production. However, agricultural activities in the previous period threatened regenerative capacities and led to ecosystem degradation primarily through unsustainable soil and water treatment practices that led to significant changes in soil quality, and caused surface and underground water pollution as well as soil erosion (Falkenmark et al., 2007). Ecosystem degradation has a direct impact on reducing the capability of future generations to meet their needs. There are views that the degradation of the ecosystem caused by unsustainable agricultural practices was one of the basic patterns of the downfall of some ancient civilisations (Lal, 2009).

The concept of sustainable agriculture can be defined as an integrated system of agricultural practices that enable the long-term satisfaction of people's need for food, the improvement of the quality of life, the preservation of the quality of the environment, the sustainability of natural resources, while at the same time ensuring sustainable socio-economic development (Gold, 1999). Some authors emphasise that agricultural sustainability is an integral and inseparable part of sustainable socio-economic development (Marković and Marjanović, 2022). The term agricultural sustainability was created with the aim of defining agricultural production principles that do not degrade natural resources, and ensure the satisfaction of people's needs for food and fibre in the long term. The increase in environmental awareness and the development of the concept of ecological sustainability in the middle of the last century led to an increase in interest in agricultural sustainability. Agricultural sustainability aims to conserve natural resources and improve the resilience of rural areas by encouraging profitable agricultural and community-friendly methods (Spânu et al., 2022). The aspiration of sustainable agricultural production is to reduce negative anthropogenic impacts on the environment through adequate practices of using and preserving the quality of natural resources. The increase in the number of inhabitants that characterised the previous century and that continued in this century indicated the need for increased food production (Abusin and Mandikiana, 2020). Since agricultural production inevitably has an impact on the environment, in order to meet the needs of the growing human population, it is necessary to focus on sustainable agricultural practices (Skaf et al., 2019) that will enable the preservation of the quality of the environment. However, when analysing agricultural sustainability, the fact that agriculture has twofold externalities is particularly important. On the one hand, agriculture generates negative externalities, such as water, air, and soil pollution, while simultaneously, agriculture provides public goods such as food security. Therefore, a measurement system capable of capturing the conflicting dimensions of agricultural sustainability needs to be developed.

One of the prerequisites for achieving a satisfactory level of agricultural sustainability is the establishment of an adequate measurement and monitoring system in order to facilitate the transition to sustainable agricultural practices. However, on the international level, there is still no universal measure of the sustainability of agriculture (Sharma et al., 2020). The multidimensional nature of agricultural sustainability makes it difficult to measure the achieved sustainability levels. Bearing in mind numerous indicators that evaluate different, often conflicting aspects of sustainability, it is necessary to establish a methodological framework that will enable the integration of diverse indicators. The creation of a composite index of agricultural sustainability enables obtaining a unique assessment of the achieved level of agricultural sustainability, measured by one synthetic indicator, which facilitates strategic decision-making related to the transition of conventional agricultural activities to sustainable agricultural practices. Bearing in mind the role of agricultural sustainability in achieving environmental sustainability and preserving biodiversity, the aim of this paper is to propose a methodological framework for creating composite indexes of agricultural sustainability.

The rest of the paper is structured as follows: Section 2 specifies the theoretical considerations of agricultural sustainability and approaches to measuring agricultural sustainability, Section 3 provides an overview of the data and research methodology, while Section 4 presents the research results and discussions. The final considerations are given in the conclusion.

2 Theoretical framework

2.1 Sustainable agriculture as a means for achieving sustainable development

Sustainable agriculture implies the integration of three dimensions of sustainability: economic, environmental and social, thus directing its goals towards the achievement of social and economic equality, economic profitability and environmental preservation (FAO, 2022).

The economic aspect of agricultural sustainability focuses on improving economic equity and achieving profitability and competitiveness through abandoning conventional agricultural practices that cause land degradation and through reducing risks that threaten production (Van der Ploeg et al., 2019). Economic sustainability is one of the foundations of sustainability. Economic sustainability does not only mean making a profit, but it means making a profit in a sustainable way, while preserving the resource base in such a way as not to jeopardise the ability of future generations to generate profit. The environmental aspect of agricultural sustainability involves encouraging a transition towards reducing the unsustainable use of scarce resources, using renewable resources, reducing pollution and abandoning activities that cause environmental degradation, thereby enabling the preservation of the biodiversity. The social aspect of agricultural sustainability is reflected in the development of the local community and the improvement of the quality of life not only of residents in the rural environment, but also of the entire population through the provision of healthy and high-quality agricultural products. Furthermore, the social dimension addresses issues related to ensuring adequate conditions for living and working in rural areas, as well as preventing the depopulation of rural areas (Đokić, 2019). Therefore, a sustainable agricultural system represents a balance between the need to ensure food security, achieve economic viability, preserve the natural environment, and reach social well-being in the long term (Cruz et al., 2018).

Achieving agricultural sustainability implies the adoption of agricultural practices and technologies that are aimed at preserving the environment, that are efficient and accessible, that lead to improved productivity and that have positive externalities on the environment (Pretty, 2008). Sustainable agricultural practices imply production planning in such a way that the biological potential of soil, water and other resources is not exceeded, thereby enabling their regeneration. Agricultural sustainability includes the concepts of both resilience and persistence; resilience in the sense of the ability of agricultural systems to absorb shocks and persistence in the sense of the long-term viability of the agricultural systems (Pretty, 2008). It is integrated into numerous national and international development goals aimed at developing and improving agricultural principles and technologies that are environmentally friendly and that contribute to food security, poverty alleviation and climate change mitigation (Spânu et al., 2022). Sustainable agriculture implies:

1 agricultural practices that increase the productivity and efficiency of land use

2 rational and balanced use of external resources (fertilisers, pesticides, irrigation water)

3 improving the capacity of agricultural land

4 profitable and efficient agricultural production

5 application of knowledge and innovative technologies for resource conservation (Zhen and Routray, 2003).

Bearing in mind that agricultural land accounts for 38.2% of the total land area of the European Union (Agriculture, Forestry and Fishery Statistics, 2020), it is particularly important to analyse the impact of agricultural activities on the environment. Nevertheless, the increase in the human population has caused a greater demand for food, which has contributed to additional pressures on agriculture, which is one of the sectors with the greatest impact on the environment. With the purpose of increasing the production per hectare agricultural practices were directed towards the intensification and mechanisation. Above all, the focus of agricultural practices was on the increase of agricultural areas, intensive irrigation, genetic modification of crops, small crop rotation and intensive monoculture (Agovino et al., 2019). Specifically, to meet the increased needs of the population, conventional agricultural practices have been focused on intensive agricultural production, which implies greater use of fertilisers and chemicals that end up polluting natural resources and the atmosphere causing substantial environmental problems (Lin, 2011). Excessive use of chemicals, primarily pesticides, in addition to harming biodiversity, also endangers human health. The harmfulness of pesticides to human health can be seen through the frequency of acute poisonings caused by contact with pesticides. According to the data of the World Health Organization, about 1,000,000 people are affected by acute poisoning, while the death rate between 0.4% and 1.9% is documented every year (Hassaan and El Nemr, 2020). Intensive conventional agricultural practices contribute to water and soil pollution, depletion of natural resources and loss of biodiversity (Trigo et al., 2021).

Another consequence of conventional agricultural methods is the increase in greenhouse gas emissions which are considered as one of the causes of climate change. Climate change can be the cause of poor agricultural performance, but also the consequence of inadequate farm management. Greenhouse gas emissions from arable land are one of the leading factors contributing to global warming (Shakoor et al., 2021). The agricultural sector generates greenhouse gas emissions through several channels: methane production by ruminants, nitrous oxide emissions from the soil, fertiliser application, as well as, indirectly, through deforestation and land clearing (Agovino et al., 2019). Agriculture is responsible for about 10% of greenhouse gas emissions in the European Union (Mielcarek-Bocheńska and Rzeźnik, 2021). According to the European Green Deal, Europe should become climate neutral by 2050, which will be achieved primarily by reducing greenhouse gas emissions. The declarations of the European Commission (EU Effort Sharing Decision and Effort Sharing Regulation) set goals for the reduction of greenhouse gas emissions. In order to mitigate the consequences of climate change, it is necessary to work intensively on reducing greenhouse gas emissions from all sectors, including agriculture. With that in mind, the pro-environmental orientation of the Common Agricultural Policy aligned with the goals of the European Green Deal has been emphasised recently (Czyżewski et al., 2018). Sustainable development of agriculture is one of the main goals of the European Common Agricultural Policy (Grzelak et al., 2019). All reforms of the Common Agricultural Policy went in the direction of establishing sustainable production practices of farmers with the aim of achieving sustainable management of natural resources and sustainability of rural areas. Therefore, increased negative externalities resulting from conventional agricultural practices impose the need to reorient to sustainable agricultural models, with the aim of reducing the negative impact on the environment.

2.2 Agricultural sustainability evaluation techniques

Ensuring appropriate legal regulations and making adequate decisions in the field of agricultural development with the aim of achieving sustainable agricultural production implies the existence of a quantitative measure of agricultural sustainability (Senanayake, 1991). Yet, when it comes to measuring agricultural sustainability there are certain theoretical and empirical difficulties (Sidhoum, 2018).

Although initially there were views that due to the specificity of agricultural production in each country, it is necessary to develop a set of individual country-specific indicators that would monitor the path to the realisation of agricultural sustainability, during the last decades it has been proposed to establish a set of common metrics with the aim of ensuring relevance and comparability (Gennari and Navarro, 2019). The system of indicators enables the quantification and systematisation of information on the basis of which it is possible to assess the current situation, monitor progress, estimate future trends and make a comparative analysis, both spatially and over time. A wide range of ecological and socio-economic indicators have been developed to measure agricultural sustainability (Spânu et al., 2022).

One of the first comprehensive systems for measuring agricultural sustainability was proposed by the Organization for Economic Cooperation and Development under the name pressure-state-response (PSR) model (OECD, 1991). According to the PSR model, a set of environmental indicators is used to assess the effects of the pressures of anthropogenic activities on the state of the environment, on the basis of which corrective policies are proposed. Based on the PSR model, other models for assessing agricultural sustainability have been developed, such as the driver-pressure-state-impact-response (DPSIR) framework (Martins et al., 2012). However, over time it has been shown that there is a certain ambiguity and inadequacy of PSR model indicators for managing different dimensions of sustainability (Levrel et al., 2009).

The system of indicators must adequately reflect the interconnection between the economic, ecological and social dimensions of agricultural sustainability in order to enable the achievement of economic goals without harming the environment and quality of life. Measuring the performance of agricultural systems is a way to determine the development paths of agricultural production in a broader sense (Yli-Viikari et al., 2007). The system of agricultural indicators is a way of assessing the impact of agricultural practices on the agroecosystem (Fernandes and Woodhouse, 2008). An adequate methodological framework that can provide a comprehensive assessment of agricultural sustainability is a synthetic indicator, that is, a composite index (Burja and Burja, 2016). Measuring agricultural sustainability is a multi-attribute issue that is often characterised by the interconnectedness of diverse indicators (Galdeano-Gómez et al., 2017) and which can be adequately addressed by composite index creation.

Numerous studies have addressed the issue of quantifying agricultural sustainability, both at the macro and micro levels (Taylor et al., 1993; Rigby et al., 2001; Bachev, 2005; Van Cauwenbergh et al., 2007; Chand et al., 2015; Terano et al., 2015; Sabiha et al., 2016; Galdeano-Gómez et al., 2017; Talukder et al., 2017; Grzelak et al., 2019; Mukherjee, 2021; Tsaples and Papathanasiou, 2021; Valizadeh and Hayati, 2021; Grzelak et al., 2022). Nevertheless, no generally accepted indicator system or composite index for measuring agricultural sustainability has yet been established. According to Czyżewski et al. (2018) indicators related to agricultural sustainability should encompass soil and water quality, land conservation, greenhouse gas emissions and biodiversity. In addition, in order to encompass the economic and social dimensions of agricultural sustainability, it is necessary to include certain socio-economic indicators such as indicators related to profitability, productivity or quality of life. It can be concluded that the assessment of agricultural sustainability is a multidimensional issue. The quantification of multidimensional phenomena has become an important issue in the world scientific community in recent years, where it is accepted that such phenomena cannot be measured by a single descriptive indicator, and that it is necessary to develop a multidimensional measure (Mazziotta and Pareto, 2017). In order to measure multidimensional phenomena, it is necessary to perform a combination of diverse dimensions, which are viewed as integral components of a complex phenomenon (Mazziotta and Pareto, 2013). The methodological framework that enables the integration of different dimensions of a multidimensional phenomenon is the creation of composite indices. Bearing in mind the above, the aim of this paper is to propose a methodology for creating a composite index of agricultural sustainability of the countries of the European Union.

3 Methodology and data

The advantage of composite indices is that they significantly simplify a multidimensional problem and facilitate decision-making. However, the construction of composite indicators is a complex process consisting of several steps, where the creator of the index is required to make several methodological decisions. Starting from the construction of the conceptual framework and the selection of indicators, the decisions that the creator of the composite index must make, which affect the quality of the index itself, are related to the normalisation method, the weighting method, as well as the aggregation method.

There are various methods of weighting and aggregation, none of which can be singled out as recommended and the most appropriate (Alaimo and Maggino, 2020). Depending on the nature of the phenomenon being examined, the creators of the index must also make choices of methodology. However, when it comes to quantifying sustainability, certain aggregation procedures, such as linear aggregation, have disadvantages that are reflected in allowing full substitutability of indicators (Fernandez and Martos, 2020). Specifically, the substitutability of indicators implies that when aggregating, poor performance in one indicator can be compensated by good performance in another indicator, which in the case of measuring agricultural sustainability would mean that, for example, soil pollution can be compensated by high rates of profitability. Therefore, it can be concluded that it is preferable to apply non-compensatory aggregation methods in sustainability studies. One of the non-compensatory aggregation techniques is the Mazziotta-Pareto Index (MPI), characterised by the non-substitutability of dimensions, which are given equal importance (Ivaldi et al., 2017). The MPI creation procedure uses a nonlinear function to normalise values around the mean, excluding units of measurement and the effect of variability, while penalising observations that are relatively far from the mean (Agovino et al., 2018). It can be concluded that the MPI penalises substitutability among indicators through a methodological approach that, in addition to the average performance of the unit, also takes into account consistency of indicators (Greco et al., 2019).

The main advantage of the proposed methodology is that it is based on the irreplaceability of indicators (De Muro et al., 2011), so it does not allow compensation between indicator values. In addition to the property of non-compensation, another reason for choosing the MPI methodology is the fact that it does not requires information on the weighting coefficients of the indicators, that is, it uses equal weights. Sustainability studies concern a large number of stakeholders, both policy makers, the academic community and the general public. The inclusion of all interested parties in the process of evaluating the importance of individual indicators would be a time-consuming and extensive job. Bearing in mind that Hagerty and Land (2007) showed that where data on the subjective weights of certain indicators are not available, the methodology that results in the lowest level of disagreement is the equal weights approach.

The basic steps in the construction of the MPI are the normalisation of individual indicators and the aggregation of standardised values using an arithmetic algorithm with a penalty function (Ivaldi et al., 2017). The penalty function represents the product of the coefficient of variation (CV) among indicators and the standard deviation of the unit (Greco et al., 2019), and provides penalty for the units with greater imbalance between the indicator values.

The algorithm for determining MPI consists of the following steps (Mazziotta and Pareto, 2016):

Step 1 Determination of the standardised matrix $Z = [z_{ij}]$ where:

$$z_{ij} = 100 \pm \frac{\left(x_{ij} - M_{x_j}\right)}{S_{x_j}} \cdot 10 \tag{1}$$

where M_{x_j} represent mean and S_{x_j} represents standard deviation of the j^{th} indicator.

In formula (1), the sign + is applied when it comes to the income type of the indicator, i.e., when a higher value of the indicator indicates positive changes in a multidimensional phenomenon, while the sign – is applied in situations where the cost type of the indicator is in question.

Step 2 Determination of mean M_{z_i} and standard deviation S_{z_i} of standardised values. In this step, the unit’s mean and standard deviation are calculated.

Step 3 Determination of the values of the composite indices using relation:

$$MPI_i^{+/-} = M_{z_i} \pm S_{z_i} \cdot cv_{z_i} \quad (2)$$

where cv_{z_i} represents the coefficient of the variation and is calculated as the quotient of the unit's standard deviation and its mean.

The sign in formula (2) depends on the type of multidimensional phenomenon that is the subject of evaluation. If it is a multidimensional phenomenon where a higher value of the composite index indicates a better performance of the unit (as in the case of agricultural sustainability), the MPI_i^- will be applied. On the other hand, in the case of multidimensional phenomena where a higher value indicates a worse performance, the MPI_i^+ is applied.

Table 1 Description of indicators

Indicator	*Description*	*Source*
Total greenhouse gas emissions from agriculture	Percentage of the greenhouse gas emissions (carbon dioxide, methane, nitrous oxide and fluorinated gases) from the country's agricultural sector	OECD (2022)
Ammonia emissions from agriculture	The amount of ammonia emissions as a result of agricultural production (kg per hectare)	Eurostat (2022)
Energy use	Final energy consumption covers the energy supplied to the final consumer for all energy uses. It is calculated as the sum of the final energy consumption of agricultural sector	Eurostat (2022)
Arable land and cropland	Percentage of total agricultural land area that is either arable or under permanent crops	OECD (2022)
Organic crop area	Percentage of total utilised agricultural area (arable land) fully converted and under conversion to organic farming	Eurostat (2022)
Total sales of agricultural pesticides	The annual sales of active substances contained in plant protection products placed on the market	Eurostat (2022)
Harmonised risk indicator 1	Harmonised risk indicator 1 is based on statistics on the quantity of active substances placed on the market in plant protection products	Eurostat (2022)
Estimated soil erosion by water	Percentage of land in the country affected by soil loss due to water erosion processes (rain splash, sheet wash and rills)	Eurostat (2022)
Net entrepreneurial income of agriculture	The income derived from agricultural activities that can be used for the remuneration of own production factors	Eurostat (2022)
Government support to agricultural research and development	Percentage of government budget directed to agriculture	Eurostat (2022)

In order to assess the agricultural sustainability of the countries of the European Union, data were collected from various sources covering the economic, environmental and social dimensions of agricultural sustainability (Table 1). Data were collected for the last available year (2019), except for the indicator Estimated soil erosion by water, for which the last available data is from 2016.

The selection of indicators was made on the basis of previous research, taking into account the availability of data. Bearing in mind the influence that greenhouse gas emissions have on the climate, in order to mitigate the effects of climate change, it is necessary to strive to reduce the emission of these gases, and those countries with a lower level of emissions have a higher degree of agricultural sustainability. The agriculture sector is responsible for greenhouse gas emissions from livestock and crop activities, as well as from the conversion of natural ecosystems to agricultural land (FAO, 2020). When it comes to ammonia emissions, increased ammonia emissions may cause increased acid deposition and disproportionate levels of nutrients in soil and water, causing destruction to the ecosystem (EEA, 2019).

In addition to reducing the greenhouse effect and ammonia emissions, the leading question of modern agriculture is how to reduce energy consumption. After all, the total energy consumption must be reduced because the European Union is a significant importer, which makes it sensitive to political and economic factors (Šikić, 2020). With the development of agriculture, as well as any other economic activity, there is an increase in energy consumption and the risk of environmental pollution (Jednak et al., 2020). The amount of fossil fuel consumption of the agricultural sector indicates the degree of commitment of a country to the creation of renewable energy sources. In particular, the process of energy transition requires reliance on agriculture as an energy source that can deliver, besides food, bioenergy to society to replace fossil fuels (Harchaoui and Chatzimpiros, 2018). Increasing the use of energy from renewable sources contributes to the preservation of the environment, and the achievement of agricultural sustainability. The conversion of agricultural land into arable land has certain negative consequences for the environment. Numerous studies point to a decline in biodiversity on arable land caused by habitat loss and reduced food availability (Critchley et al., 2004). Mitigating the consequences of conventional agricultural practices can be performed by converting arable land into organic farming.

Organic production is the most obvious example of sustainable agriculture. The advantages of organic farming are reflected in the improvement of environmental protection, the promotion of sustainable land use and the improvement of animal welfare and product quality (Cruz et al., 2018). Reducing the use of pesticides also contributes to achieving agricultural sustainability. Countries with less pesticide use and stricter regulation of pesticide use are on the way to moving away from conventional agricultural practices and towards achieving sustainable land use and agricultural production. In particular, sustainable agricultural practices involve limited or no use of pesticides, as opposed to conventional agricultural activities where the focus is on applying pesticides to protect crops (Benbrook et al., 2021).

Another obstacle to the realisation of sustainable agriculture is reflected in soil erosion, which occurs due to changes in land use and unsustainable agricultural activities, which over time can result in a decrease in agricultural potential and deterioration of soil quality (Montgomery, 2007).

In addition to the environmental dimension, achieving agricultural sustainability requires taking into account both the economic and social dimensions. Ensuring economic and social sustainability implies the achievement of an appropriate income, therefore countries with a higher level of net entrepreneurial income from agriculture show greater tendencies towards the achievement of sustainable agricultural production. Nevertheless, achieving agricultural sustainability also requires certain investments in research and development in order to identify and establish sustainable agricultural principles.

Descriptive statistics of the indicators that comprise composite index of agricultural sustainability are presented in Table 2. A large variability of the data can be observed, especially regarding indicators Total sales of agricultural pesticides, energy use and estimated soil erosion by water with the value of the CV is greater than 1. The large dispersion of indicators shows the existence of significant differences between the member states of the European Union when it comes to the sustainability of agriculture.

Table 2 Descriptive statistics of indicators

	Minimum	*Maximum*	*Mean*	*Std. deviation*	*CV*
Total greenhouse gas emissions from agriculture	3.00	32.40	11.3643	6.27961	0.55257
Ammonia emissions from agriculture	7.00	105.00	25.1071	20.50355	0.81664
Energy use	6.50	4,169.73	1,043.5403	1,357.02086	1.30040
Arable land and cropland	6.20	60.50	26.9071	12.78517	0.47516
Organic crop area	0.10	15.87	4.4054	4.20448	0.95439
Total sales of agricultural pesticides	56.80	75,190.40	12,494.3321	19,254.37908	1.54105
Harmonised risk indicator 1	38.00	149.00	82.5714	28.38809	0.34380
Estimated soil erosion by water	0.00	24.93	4.9161	6.23217	1.26771
Net entrepreneurial income of agriculture	73.86	730.00	124.1750	120.01568	0.96650
Government support to agricultural research and development	0.30	19.70	5.9179	4.42016	0.74691

4 Results and discussion

By applying the methodology for determining the MPI index based on ten indicators representing dimensions of agricultural sustainability, the values of the composite index were obtained on a sample of the European Union countries (Table 3). The obtained results are in accordance with the outcomes of the Food Sustainability Index, where for the year 2021, the countries of Northern Europe are at the top of the sample of 78 countries for the sustainable agriculture sub-pillar (FSI, 2021). It is interesting that France, as one of the countries with the largest share of arable land in the total agricultural land, is at the bottom of the list, which is also the case with the sustainable agriculture sub-pillar (of the same report), where France is at the bottom of the list when looking at the countries of the European Union.

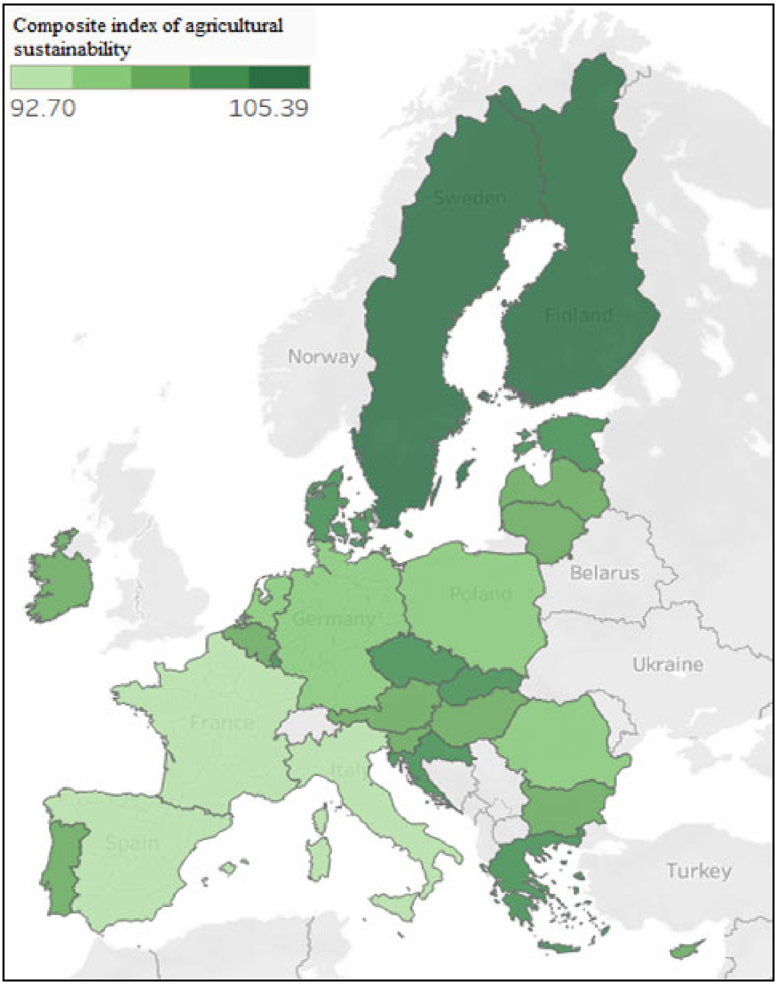
The state of agricultural sustainability in the Southern Europe countries may be a consequence of the low participation of organic agriculture, which is considered a sign of sustainability, and whose participation in the mentioned countries is marginal. Unlike the countries of Southern Europe, the Northern European countries have a significantly higher percentage share of organic agriculture, with the percentage of arable land fully converted and under conversion to organic farming ranging from 9.17% in Denmark to 15.87% in Finland.

Table 3 Values of composite indices of agricultural sustainability

Country	*Composite index*
Sweden	105.388
Finland	104.178
Denmark	102.687
Estonia	101.940
Croatia	101.873
Czech Republic	101.787
Slovak Republic	101.618
Greece	101.589
Luxembourg	100.647
Portugal	100.223
Belgium	100.131
Latvia	99.884
Lithuania	99.419
Ireland	99.385
Bulgaria	99.285
Austria	99.071
Cyprus	98.388
Hungary	98.352
Slovenia	98.059
Romania	97.772
Germany	96.472
Netherlands	96.383
Poland	95.924
France	94.061
Malta	93.804
Spain	93.276
Italy	92.696

The results indicate relative geographical homogeneity when it comes to the achieved level of agricultural sustainability in the European Union countries (Figure 1). The countries of Northern Europe record the highest level of agricultural sustainability, although traditionally they do not have significant arable land. Therefore, it can be point out that precisely due to the fact that arable land is a limited resource in the countries of Northern Europe, there is a need to apply sustainable agricultural value practices in order to preserve and possibly improve the productive capacity of arable land for future generations. On the other hand, the countries of Southern Europe (with the exception of Greece and Portugal) achieve the lowest levels of agricultural sustainability.

Figure 1 Graphical presentation of agricultural sustainability composite index (see online version for colours)



5 Conclusions

Agricultural sustainability represents a multidimensional phenomenon, during the evaluation of which it is necessary to take into account not only environmental, but also other dimensions of sustainability. This is especially important from the point of view of policy makers, who often neglect the social and environmental dimensions of sustainability, with the aim of achieving economic progress and sustainability. Therefore, in order to achieve agricultural sustainability, all three dimensions are equally significant and essential. The creation of composite indices contributes to a greater degree of mutual understanding between policy makers, the scientific community and the general public, since composite indices are easy to interpret and understand, and can adequately quantify multidimensional phenomena. A consistent evaluation of progress towards achieving agricultural sustainability through composite indices represents an adequate way of obtaining information about the achieved level of agricultural sustainability of a country and a reliable guideline for creating corrective actions. Improving the sustainability of agriculture must be defined as the main development goal that can be realised by appropriate policy measures and initiatives, with the aim of achieving the well-being of both current and future generations.

The composite index created in this paper includes all three dimensions of agricultural sustainability and provides an adequate basis for making development decisions of policy makers on the way to achieving the sustainability of agricultural production. The contribution of the paper is twofold. From a theoretical point of view, the paper contributes to the existing literature by providing a theoretical overview of the harmful effects of conventional agricultural practices and the necessity of conversion to sustainable agricultural practices. From an empirical point of view, the paper contributes to agricultural sustainability research by proposing a composite index of agricultural sustainability of the European Union countries, based on a non-compensatory approach that is suitable for sustainability evaluations.

The study showed that the predominantly agricultural countries of the European Union that have a high percentage of arable land have the lowest values of the agricultural sustainability index (Italy, Spain and France). They achieve a low share of organic production in the total agricultural production, so in the future they must increase the area under organic production, which is the best representative of good agricultural practice that also takes care of the environment. Agrarian policy makers must focus on the increase of areas under organic production, as the best way to adopt adequate agricultural principles to achieve the sustainability of agriculture in every sense – economic, ecological and social. The best agricultural practices that emphasise respect for the principles of sustainable development are achieved by Sweden, Finland and Denmark, regardless of the modest opportunities for agricultural development. These countries are particularly successful in preventing soil erosion caused by water.

The paper faces with certain limitations. Although the selection of indicators was carried out in accordance with previous research, there is a possibility that certain indicators were omitted, primarily due to their unavailability in the analysed time period. In addition, the MPI methodology assumes equal importance of the indicators in the composite index, which is not always the case, and the inclusion of weights might lead to different results. Further research in this area can be directed to the analysis of the trend of achieved agricultural sustainability through the inclusion of several time periods, on the basis of which progress or lag on the road to achieving agricultural sustainability can be better assessed.

Acknowledgements

This research was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contracts No. 451-03-68/2022-14/200371 and No. 451-03-68/2022-14/200100).

The paper is a part of the research done within the international project: 'Enhancing skills for sustainable and eco friendly tourism' (No. 2021-1-RS01-KA220-VET-000028060) under the ERASMUS+ program, co-funded by the EU. Usual disclaimers apply.

The paper is a part of the research done within the international project: 'Advanced data analytics in business' (No. 598829-EPP-1-2018-1-RS-EPPKA2-CBHE-JP) under the ERASMUS+ program, co-funded by the EU. Usual disclaimers apply.

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