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# ASSESSMENT OF SELECTED ECONOMIC AND ENVIRONMENTAL ASPECTS IN AGRICULTURE IN EU COUNTRIES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT: Sustainable development includes activities that reduce losses and waste in the production process, taking into account the rationalisation of consumption and using innovative technological solutions that enable an increase in the economic efficiency of natural resources. The aim of the study was to assess the level of selected economic and environmental indicators in agriculture in the EU member states. The study used Perkala synthetic indicators of economic and environmental results, as well as the quartile range method. On this basis, country rankings were created and grouped into four subgroups. The conducted research shows that in many EU countries, there are discrepancies in the economic and environmental results of agriculture. The study fills the cognitive gap in terms of current data and a comprehensive assessment of the economic and environmental results obtained in agriculture. Multi-criteria assessment can support decision-makers in creating effective strategies aimed at the optimal allocation of resources in a pro-environmental context.

KEYWORDS: sustainable development of agriculture, assessment of efficiency in agriculture, Perkal index

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## Introduction

Sustainable development in agriculture is aimed at optimising production based on natural conditions, i.e. soil fertility, but also at effective management of assets in order to obtain safe food and at the same time protect the environment, ensuring financial stability for agricultural producers. Sustainable development essentially includes three dimensions, i.e. ecological, economic and social, which in practice should be expressed in actions reducing losses and waste in the product life cycle, taking into account rationalisation of consumption and using innovative technological solutions enabling increased efficiency of natural resources. The Common Agricultural Policy (CAP) supports sustainable development of agriculture in projects concerning small farms, redistributive payments or investments beneficial for environmental protection (Mikuła, 2014; Yadav et al., 2017; Hajian & Kashani, 2021; Petrunenko et al., 2021; Abobatta & Fouad, 2024).

The CAP assumptions in individual EU countries may be characterised by varying degrees of advancement, and also have a different impact on environmental protection and the effectiveness of agri-environmental programs in a given region. This may result from, among others, different structures of agricultural production or the adopted model of the agricultural production system in EU countries, local opportunities resulting from natural conditions, and diversified financial support for agricultural production in different EU countries. Hence, various economic and environmental reasons for the lack of agricultural efficiency can be observed (Domagała, 2021). Consequently, this may also be reflected in the degree of advancement of the implementation of sustainable development assumptions in individual EU countries. In the literature on the subject, many studies assess the impact of agriculture on the environment using agri-environmental indicators (e.g. Foguesatto et al., 2020; Laurett et al., 2021; Sekuła et al., 2022; Marcinkowski & Haręża, 2025). However, a certain information deficiency has led to an attempt to combine the economic results and the impact of the sector on the environment.

The aim of the study was to assess the level of selected economic and environmental indicators in agriculture in EU member states in the context of sustainable development. A comprehensive assessment of adaptation processes that meet the assumptions of sustainable development could contribute to determining the level of advancement of the processes, which would be helpful in comparative analysis in EU countries.

The study fills the cognitive gap in the scope of current data and the application of a comprehensive approach to assessing the results obtained in agricultural production supplemented with economic indicators. For this purpose, the multi-criteria Perkal index was used, which included agri-environmental and economic indicators in its formula. Recognising the cause-and-effect relationship and assessing it using a multi-criteria measure can help decision-makers in creating effective strategies at the EU level, as well as the region. Moreover, this concept can support agricultural production managers in the decision-making process aimed at the optimal allocation of resources in a pro-environmental context at the macro-, meso- or micro-level.

## An overview of the literature

The essence of sustainable development of agriculture and rural areas is "..ensuring a lasting improvement in the quality of life of contemporary and future generations by shaping the right proportions between three types of capital: economic, human and natural..." (Żmija, 2014). As the aforementioned author notes, there is a relationship between the development of agriculture and the sustainable development of rural areas, which reflects the improvement of the living conditions of the population, as well as conducting business activities with respect for the natural environment, rural landscape and cultural heritage. It is about reconciling environmental and economic requirements, in a compromise approach covering both natural, social and economic aspects. The implementation of the concept of sustainable development of agriculture is difficult for many reasons, including social, economic, intellectual, organisational, administrative and ethical ones (Łuczka, 2023). It seems that what is also important is the fact that this concept tries to reconcile often contradictory goals, e.g. profitability of agricultural production in an ecological production system (conditioned by high

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production costs resulting, among others, from increased labour intensity compared to the conventional agricultural production system), nutritional safety of agricultural products produced under intensive agriculture (Grzybowska – Brzezińska et al., 2023).

The effects of implementing the assumptions of agricultural sustainability on a meso- or macro-scale are the result of "…agroecological, economic and social activities and agricultural practices used in individual farms…" (Janowska-Biernat, 2013). It is obvious that "…regional differences in the level of agricultural sustainability do not exclude the possibility of achieving environmental and economic goals at the level of both farms and the entire sector…" (Kowalczyk & Zolotnytska, 2024). Maximising economic effects does not have to mean over-exploitation and/or pollution of the natural environment, and organic farming does not necessarily have to be identified with low income. Research conducted by Kowalczyk and Zolotnytska (2024) proves that under certain conditions it is possible to combine economic and environmental goals, an example of which is "… the relationship between the growth of income of larger farms and their growing tendency to implement more environmentally friendly production techniques, such as EU programs concerning the environment and agriculture, multidirectional agricultural production and more moderate use of chemicals in agriculture…". However, many studies indicate that the development of organic farming is influenced more by economic and organisational factors than by natural factors. In a situation where there are no programs compensating for the high production costs in organic farming, farmers wanting to support their families will start looking for ways to change this situation. This was visible in agriculture in Austria and Germany in 2022, where organic farms began to switch to conventional agriculture (Miyake & Kohsaka, 2020; Ziętara & Mirkowska, 2021; Novytska et al., 2021; Miecznikowska-Jerzak, 2022; Chen et al., 2022; Chrobocińska & Lotkowska, 2023).

The implementation of the assumptions of sustainable development of agriculture and rural areas, as well as multifunctional development of rural areas, may be associated with a reduction in agricultural production, and the environmental consequences may be both positive and negative. (Kociszewski, 2018). In the production of food and/or raw materials, intensive farming methods may be used; in particular, this applies to large agricultural enterprises characterised by high commerciality, which may also pollute the natural environment. In turn, the assumptions of organic farming, which can be implemented on smaller farms, ensure, among others, biodiversity and the most beneficial practices for the environment, or the protection of natural resources. However, it turns out that organic farming is not economically competitive in comparison to production conducted in a conventional way, despite the use of, among others, subsidies or eco-premiums (Głuszek, 2023). Perhaps a compromise in such a situation is multifunctional agriculture, which should be based on environmental requirements, which is close to sustainable agriculture. However, all subsidies for agricultural production should be dependent on compliance with environmental standards, which should be reflected in properly targeted and effectively implemented aid programmes under the CAP (Kociszewski, 2018).

In the context of sustainable development, it is worth mentioning the public goods provided by farmers (Maciejczak, 2009). They are characterised by the fact that they are used by society, while their consumption is not related to the necessity of paying for them by the people who use them. In a situation where public goods are provided by an agricultural producer, as compensation, he receives CAP subsidies both for the implementation of production functions and for the provision of public goods, i.e. biodiversity, protection of the natural environment and landscape, and improvement of water conditions. It would also be necessary to take into account subsidies for set-aside, as well as agri-environmental subsidies and subsidies for areas with unfavourable farming conditions (ONW) and other subsidies. As Czyżewski and Smędzik-Ambroży (2017) point out, each of the above-mentioned subsidies falls within the criteria of subsidies for public goods, which means that "...the consumption of the spatial and natural environment of rural areas created by activities financially supported by these subsidies is inclusive in nature, and there is no need to pay fees for using them..." Mikuła (2014) adds that, however, the provision of public goods by agriculture is becoming a competitive activity in relation to the intensification and concentration of production. And the increase in the intensification of agricultural production may contribute to the decrease in the supply of environmental public goods.

Agri-environmental indicators are currently used to assess the progress of sustainable agriculture development and the use of agricultural potential in EU countries. However, the ideal method is

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still being sought, encompassing substantive and methodological aspects, enabling a full and comprehensive assessment. It turns out that the presented statistical data covering agri-environmental indicators available, for example, in Eurostat documents, present the results of individual dimensions separately. In some cases, this is an undoubted advantage. However, in order to make a comprehensive assessment, for example, of the implementation of CAP aid programs, a procedure covering a number of indicators creating a single, standardised, multi-criteria measure would be useful, for example, as in the case of the Regional Competitiveness Index – RCI. Many studies have attempted to use a number of methods to integrate individual indicators and "…determine one final sustainable development result that could be a significant support for decision-makers in assessing scenarios compared at the interpretation stage…" (Marcinkowski & Haręża, 2025). In addition, the aforementioned authors mention that the disadvantages of the method are procedures that "…often assume arbitrarily established importance weights for aggregating environmental, economic and social results, which may be controversial…". Therefore, there is a methodological gap that allows focusing only on environmental aspects. However, resource management is evidenced by the economic effects obtained from the activity, and therefore, there is a need to develop a comprehensive approach to agri-environmental and economic aspects in a multi-criteria measure that would facilitate the assessment of progress and the level of activities carried out in rural areas as part of programs that include the principles of sustainable agriculture.

The assumptions of sustainable agriculture, implemented in practice, should be monitored and evaluated. This is possible thanks to the available agri-environmental indicators, which constitute a wide range of instruments enabling the verification of postulated ideals in practice (Streimikis, & Baležentis, 2021). It seems that the proposed instruments do not fully reflect the effectiveness and efficiency of management in agriculture. The specific formula somewhat limits their role and importance in the management of sustainable agriculture and in shaping agri-environmental policy. In principle, their main goal is to identify and analyse the relationships between agricultural activity and the state of the environment, which allows for taking actions aimed at minimising the negative impact of agriculture on the natural environment. However, the assessment of the use of agroecological potential based solely on agro-environmental indicators is depleted of the economic and social aspects of managing an agricultural enterprise or agriculture on a national scale. As a consequence, this limits the practical use of agro-environmental indicators at the level of an agricultural enterprise, commune or voivodeship. In the literature on the subject, many studies indicate attempts to integrate individual indicators and interpretations that would be useful in the decision-making process, enabling the creation of effective development scenarios. It seems that no consensus has yet been found in this respect (Moldan et al. 2012; Petala et al. 2010, Foguesatto et al. 2020; Laurett et al. 2021; Marcinkowski & Haręża, 2025).

## Research methods

To assess the activity of the agricultural sector, an integrated approach was used, based on various indicators that complement each other and allow for a more comprehensive diagnosis. By performing a substantive analysis, the availability of source data and statistical verification, a set of variables was created that described the economic results of agriculture and the impact of this sector on the environment. The first group included:

$X_1$ – Gross value added (mln euro),
$X_2$ – Gross value added per 1 AWU (mln euro/AWU),
$X_3$ – Gross value added per 1 euro of capital inputs (euro/euro),
$X_4$ – Gross value added per ha (euro/ha),
$X_5$ – Agricultural land area per AWU (ha/AWU),
$X_6$ – Value of capital inputs per 1 ha (thousand euro/ha),
$X_7$ – Value of capital inputs per AWU (thousand euro/ha).

In the second group, the following variables were used:

$X_8$ – Final energy consumption by agriculture per hectare (tonne of oil equivalent per ha),
$X_9$ – Share of area under organic farming (%),
$X_{10}$ – Sales of pesticides by type of pesticide per ha (kg/ha),

$X_{11}$ – Greenhouse gas emissions from agriculture (%),
$X_{12}$ – Ammonia emissions from agriculture – % of total emissions (%),
$X_{13}$ – Energy productivity (purchasing power standard – PPS per kilogram of oil equivalent).
$X_{14}$ – Share of agriculture in production of renewable energy (%).

The study collected data for the 27 EU member states. The source of the materials was EUROSTAT. The analysis concerned the results from 2018-2021.

However, using only one-dimensional variables is insufficient to obtain a full assessment of the multidimensional image (Łukiewska, 2019). For this reason, synthetic measures were used, which integrated the information contained in partial variables. In the study, the synthetic Perkal index was calculated, which is the arithmetic mean of normalised partial features:

$$P_i = \frac{1}{m}\sum_{j=1}^{m} z_{ij}, \quad (1)$$

where:
$P_i$ – Perkal's indicator,
$z_{ij}$ – standardised value of the j-th variable in the i-th object after the conversion of destimulators into stimulators,
$m$ – number of objects.

The standardisation procedure was used to normalise the variables, according to the formula:

$$z_{ij} = \frac{x_{ij}-\overline{x_j}}{s_j}, \quad (2)$$

$z_{ij}$ – value of the normalised variable j in voivodeship i,
$x_{ij}$ – the value of variable j for voivodeship i,
$x_j$ – arithmetic mean of variable j,
$s_j$ – standard deviation of variable j.

In the study, the Perkala synthetic index of economic results was calculated, as well as the Perkala synthetic index of environmental results. In the first case, all variables were stimulants, in the second, the stimulants included the indicators $X_9$, $X_{13}$, $X_{14}$ and the destimulants $X_8$, $X_{10}$, $X_{11}$, $X_{12}$. In both cases, the quartile range method was used, which allowed the grouping of the obtained results into four groups of EU countries. Then, Pearson's linear correlation coefficient was used to calculate the correlation between economic and environmental indicators. The Statistica program was used for the calculations.

## Results of the research

The analyses show that the highest value added in agriculture in the EU was achieved by Italy, France, Spain and Germany (Table 1). The Netherlands, Poland and Romania were also relatively large producers of food products. The highest labour productivity measured by gross value added per 1 AWU was noted in the Netherlands, followed by Denmark, Germany, Belgium and France. It was 2-3 times higher than the EU average. In this respect, the disproportions concerned mainly the "new" and "old" EU countries. Relatively small differentiation between countries occurred in the case of gross value added per 1 ha. The best results in this respect were recorded in Italy, Spain and Croatia (0.9 euro/euro), and the lowest in Estonia, Luxembourg and Belgium (0.3 euro/euro). In terms of value added per 1 ha, the Netherlands and Malta dominated (5.1-6.1 thousand euros/ha). The largest land resources per 1 AWU were noted in Slovakia, Estonia and Denmark (62.1-73.9 ha/AWU). This was more than twice the EU average. In terms of the value of capital inputs per ha, the Netherlands stood out clearly (EUR 14 thousand/ha). The next positions were occupied by Malta and Belgium (EUR 6.0-7.6 thousand/ha). The highest value of capital inputs per AWU was noted in the countries of the "old" EU, such as Denmark, the Netherlands, Belgium, Luxembourg, Germany and Sweden (EUR 104.0-196.3 thousand/ha). Results above the EU average in this respect were also noted in France, Estonia and Austria (EUR 60.6-83.2 thousand/ha).

Table 1. Level of selected economic indicators in agriculture in EU countries in 2018-2021

| Country | Gross value added | Gross value added per 1 AWU | Gross value added per 1 euro of capital inputs | Gross value added per ha | Agricultural land area per AWU | Value of capital Inputs per 1 ha | Value of capital inputs per AWU |
|---|---|---|---|---|---|---|---|
| | mln euro | thousand euro/AWU | euro/euro | euro/ha | ha/AWU | thousand euro/ha | thousand euro/ha |
| Austria | 3499.4 | 28.9 | 0.5 | 729.3 | 39.6 | 1.5 | 60.6 |
| Belgium | 2511.3 | 47.7 | 0.3 | 1804.7 | 26.4 | 6.0 | 158.9 |
| Bulgaria | 2187.1 | 11.9 | 0.7 | 445.8 | 26.8 | 0.7 | 17.5 |
| Croatia | 1310.0 | 7.6 | 0.9 | 795.2 | 9.5 | 0.9 | 8.8 |
| Cyprus | 342.1 | 18.1 | 0.8 | 2338.7 | 7.7 | 3.1 | 23.6 |
| Czechia | 2062.5 | 21.0 | 0.4 | 419.0 | 50.2 | 1.0 | 52.1 |
| Denmark | 3114.1 | 61.3 | 0.3 | 988.1 | 62.1 | 3.2 | 196.3 |
| Estonia | 300.9 | 16.7 | 0.3 | 248.6 | 67.0 | 0.9 | 60.8 |
| Finland | 1438.8 | 21.7 | 0.3 | 271.2 | 80.1 | 0.9 | 69.9 |
| France | 33651.0 | 46.4 | 0.6 | 1141.0 | 40.7 | 2.0 | 83.2 |
| Germany | 23682.8 | 50.5 | 0.5 | 1293.1 | 39.0 | 2.7 | 105.0 |
| Greece | 5975.2 | 16.8 | 0.7 | 1469.7 | 11.5 | 2.0 | 23.2 |
| Hungary | 3533.7 | 10.5 | 0.5 | 548.8 | 19.1 | 1.1 | 20.3 |
| Ireland | 3588.4 | 22.8 | 0.5 | 688.1 | 33.1 | 1.4 | 46.9 |
| Italy | 34250.7 | 30.9 | 0.9 | 2080.6 | 14.8 | 2.3 | 33.3 |
| Latvia | 589.9 | 8.9 | 0.4 | 208.4 | 42.7 | 0.5 | 22.4 |
| Lithuania | 1459.4 | 11.4 | 0.5 | 472.9 | 24.1 | 0.9 | 22.6 |
| Luxembourg | 137.4 | 39.6 | 0.3 | 992.4 | 39.9 | 3.4 | 136.4 |
| Malta | 54.2 | 9.9 | 0.7 | 5147.8 | 1.9 | 7.6 | 14.6 |
| Netherlands | 11852.9 | 73.7 | 0.4 | 6087.4 | 12.1 | 14.0 | 169.0 |
| Poland | 10587.6 | 6.9 | 0.5 | 635.4 | 10.9 | 1.2 | 12.8 |
| Portugal | 3321.4 | 14.4 | 0.5 | 648.5 | 22.1 | 1.3 | 29.1 |
| Romania | 9089.0 | 7.5 | 0.8 | 659.2 | 11.4 | 0.9 | 9.8 |
| Slovakia | 659.1 | 16.1 | 0.3 | 218.5 | 73.9 | 0.7 | 48.3 |
| Slovenia | 542.5 | 7.2 | 0.5 | 598.4 | 12.1 | 1.3 | 15.4 |
| Spain | 28839.4 | 32.6 | 0.9 | 996.9 | 32.7 | 1.1 | 35.3 |
| Sweden | 1963.3 | 34.3 | 0.3 | 303.1 | 113.2 | 0.9 | 104.0 |

Source: authors' work based on Eurostat [10-03-2025].

Next, selected indicators illustrating the impact of agriculture on the environment in EU countries were analysed (Table 2). By far the largest relative amount of energy was used in the agricultural sector of the Netherlands (2054.9 tonnes/ha). Energy consumption was relatively high (above the EU average) also in Malta, Belgium, Cyprus and Finland (324.8–1128.1 tonnes/ha), and the lowest in Bulgaria, Lithuania and Romania (37.6–42.1 tonnes/ha). The EU goal is to allocate at least 25% of agricultural land in the EU to organic farming by 2030 (Chrobocińska, Łukiewska 2024). The only country that exceeded the recommended level in the analysed period was Austria (25.0%). A relatively high share of organic land was recorded in Estonia (22.4%) and Sweden (20.2%). In countries such as the Netherlands, Romania, Poland, Bulgaria, Ireland and Malta, this share did not exceed 5%.

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In terms of pesticide sales per hectare of agricultural land, Malta and Cyprus were the leaders (97.8-10.0 kg/ha), probably due to intensive agricultural production in a limited area. Relative pesticide sales more than twice the EU average were recorded in the Netherlands and Belgium (4.1-4.8 kg/ha). In turn, the lowest pesticide turnover per hectare (below 0.8 kg/ha) was recorded in Sweden, Ireland, Latvia, Estonia, Romania and Slovakia. The impact of agricultural activity on the environment is also related to the emission of greenhouse gases that are unfavourable to the environment. The highest level of emissions was recorded in Ireland (35.1%), followed by Denmark (25.6%) and Lithuania (21.0%), and the lowest in Malta, Slovakia and Cyprus (3.4-5.5%). Agriculture also contributes to ammonia emissions. The differences between countries in this respect were relatively small. The highest share in total emissions occurred in Ireland, followed by Poland and Cyprus, and the lowest in Germany and Croatia. In the period under review, the leaders in energy productivity in agriculture were countries such as Estonia, the Czech Republic, Portugal, and Lithuania. The lowest efficiency in this respect was characteristic of Sweden, Hungary, and Slovakia. In terms of the share of agriculture in the production of renewable energy, the Netherlands was clearly the leader. A relatively large share was also recorded in Germany, followed by Belgium, the Czech Republic and Slovakia. Agriculture had the smallest share in the creation of renewable energy in Estonia, Slovenia and Sweden.

Table 2. Level of selected environmental indicators in agriculture in EU countries in 2018-2021

| Country | Final energy consumption by agriculture ha | Share of under organic farming | Sales of pesticides per ha | Greenhouse gas emissions from agriculture | Ammonia emissions from agriculture – % of total emissions | Energy productivity | Share of agriculture in production of renewable energy |
|---|---|---|---|---|---|---|---|
| | tonne of oil equivalent per ha | % | kg/ha | % | % | PPS per kg of oil equivalent | % |
| Austria | 200.8 | 25.0 | 1.2 | 9.3 | 93.1 | 8.6 | 5.3 |
| Belgium | 621.6 | 7.2 | 4.1 | 8.1 | 91.1 | 6.4 | 16.3 |
| Bulgaria | 37.6 | 2.2 | 0.9 | 11.0 | 88.8 | 7.4 | 7.4 |
| Croatia | 154.4 | 7.7 | 1.0 | 10.1 | 82.9 | 11.9 | 3.1 |
| Cyprus | 348.0 | 5.4 | 7.8 | 5.5 | 96.1 | 9.1 | 5.8 |
| Czechia | 178.6 | 15.4 | 1.0 | 6.8 | 92.6 | 14.1 | 15.6 |
| Denmark | 218.6 | 11.1 | 0.9 | 25.6 | 85.6 | 10.8 | 10.1 |
| Estonia | 107.7 | 22.4 | 0.6 | 11.0 | 91.9 | 22.8 | 0.4 |
| Finland | 324.8 | 14.0 | 0.8 | 12.1 | 87.6 | 8.0 | 3.5 |
| France | 147.1 | 8.7 | 2.3 | 15.8 | 93.0 | 10.2 | 11.2 |
| Germany | 214.3 | 8.8 | 2.6 | 7.0 | 82.8 | 6.9 | 22.8 |
| Greece | 52.9 | 11.7 | 1.2 | 9.7 | 90.2 | 10.2 | 6.3 |
| Hungary | 127.6 | 5.6 | 1.3 | 10.7 | 91.2 | 5.6 | 15.8 |
| Ireland | 55.4 | 1.8 | 0.6 | 35.1 | 99.1 | 9.2 | 3.9 |
| Italy | 217.8 | 16.3 | 3.1 | 7.8 | 91.6 | 9.5 | 9.5 |
| Latvia | 99.1 | 15.1 | 0.6 | 19.9 | 85.0 | 9.9 | 5.7 |
| Lithuania | 39.5 | 8.5 | 0.9 | 21.0 | 95.3 | 12.5 | 10.3 |
| Luxembourg | 203.0 | 5.0 | 1.0 | 6.1 | 88.0 | 8.7 | 8.0 |
| Malta | 1128.1 | 0.6 | 10.0 | 3.4 | 91.9 | 8.7 | 4.1 |
| Netherlands | 2054.9 | 4.0 | 4.8 | 10.2 | 86.1 | 10.6 | 33.8 |
| Poland | 258.3 | 3.6 | 1.5 | 8.6 | 96.2 | 10.9 | 9.0 |
| Portugal | 102.3 | 12.0 | 1.8 | 11.4 | 85.0 | 13.4 | 4.9 |
| Romania | 42.1 | 3.7 | 0.7 | 16.5 | 88.7 | 9.0 | 3.8 |

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| Country | Final energy consumption by agriculture ha | Share of under organic farming | Sales of pesticides per ha | Greenhouse gas emissions from agriculture | Ammonia emissions from agriculture – % of total emissions | Energy productivity | Share of agriculture in production of renewable energy |
|---|---|---|---|---|---|---|---|
| | tonne of oil equivalent per ha | % | kg/ha | % | % | PPS per kg of oil equivalent | % |
| Slovakia | 68.7 | 11.8 | 0.8 | 5.2 | 89.7 | 5.8 | 14.3 |
| Slovenia | 153.0 | 10.5 | 1.1 | 10.6 | 92.3 | 7.4 | 2.0 |
| Spain | 107.9 | 10.1 | 2.5 | 11.1 | 95.7 | 9.4 | 10.5 |
| Sweden | 201.9 | 20.2 | 0.3 | 13.0 | 86.6 | 2.2 | 2.5 |

Source: authors' work based on Eurostat [10-03-2025].

Then, the discussed data were compared by calculating the synthetic indicator of economic results and the synthetic equivalent of environmental results (Fig. 1-2). The clear leader in terms of economic results was the Netherlands. This country stood out with the highest level of gross value added per 1 AWU, gross value added per ha, value of capital inputs per 1 ha in the EU scale, as well as a high level of gross value added. At the same time, agriculture in this country has recorded a high share of agriculture in the production of renewable energy and unfavourable other environmental results, mainly in terms of final energy consumption, pesticide sales per ha and a small share of ecological land. High economic results were also characteristic of other countries of the "old" EU, such as: Denmark, France, Italy, Germany, Spain and Belgium. Denmark stood out with the highest level of value of capital inputs per AWU and gross value added per 1 AWU (2nd position). France and Germany recorded high gross value added and gross value added per 1 AWU, Italy and Spain high gross value added and gross value added per 1 euro of capital input, and Belgium high value of capital inputs per 1 ha, value of capital inputs per AWU and gross value added per 1 AWU. The only country that achieved a high level of the synthetic indicator of environmental performance (above the third quartile) was Germany. In this country, a high level of share of agriculture in the production of renewable energy (2nd place) and a low level of ammonia emissions from agriculture (1st place) were noted. Relatively good environmental results were also achieved in Italy (10th place in the ranking). Italy was characterised by a fairly high share of area under organic farming (above 16%). The next positions in the environmental performance ranking were taken by Denmark (14th place), then Spain and France (18th and 19th place). Belgium came out worst in this respect, taking only 24th place.

Estonia was the leader in terms of environmental performance in agriculture, which stood out primarily for its relatively high energy productivity, large share of ecological land and low sales of pesticides per ha. However, this country was characterised by a low share of agriculture in the production of renewable energy. However, the positive impact of agriculture on the environment was associated with low land productivity (25th place) and capital productivity (27th place). In terms of the synthetic index of economic results, this country was only in 19th place. The group of countries with the best environmental results also included the Czech Republic, Germany, Portugal, Slovakia, Austria and Croatia. The Czech Republic was distinguished by a high level of energy productivity and a relatively large share of ecological land, Portugal by low ammonia emissions and high energy productivity, Slovakia by a low level of Greenhouse gas emissions from agriculture, Austria by the highest share of ecological land in the EU, and Croatia by low ammonia emissions and high energy productivity. As mentioned earlier, of these countries, only Germany achieved high economic results (synthetic indicator below the third quartile). The synthetic indicator of economic results between the first and third quartiles was noted for Austria (12th position), as well as the Czech Republic (16th position) and Slovakia (17th position). These countries were characterised by average results in most of the analysed partial indicators. Croatia took only 20th place, Portugal 22nd place and Latvia 26th place in terms of the synthetic economic index. In all these countries, particularly unfavourable results were recorded in terms of labour productivity, and in Croatia, also in terms of the level of agricultural land per AWU.

Then, a group of countries was distinguished in which both synthetic indicators were within the interquartile range, i.e. between the first and third quartiles. This group included Greece, Luxembourg, Finland, Sweden and Romania. It can be assumed that in these countries, the adopted agricultural model is characterised by average economic and environmental results and is sustainable.

In addition, it was observed that in countries such as Malta, Cyprus and Ireland, the economic results were average (synthetic indicator in the interquartile range), and the environmental results were low (synthetic indicator below the first quartile). In Bulgaria, Hungary, Lithuania and Slovenia, economic performance was low (below the first quartile), and environmental performance was average (in the interquartile range). The situation was the least favourable in Poland, where both economic and environmental performance were low (below the first quartile).

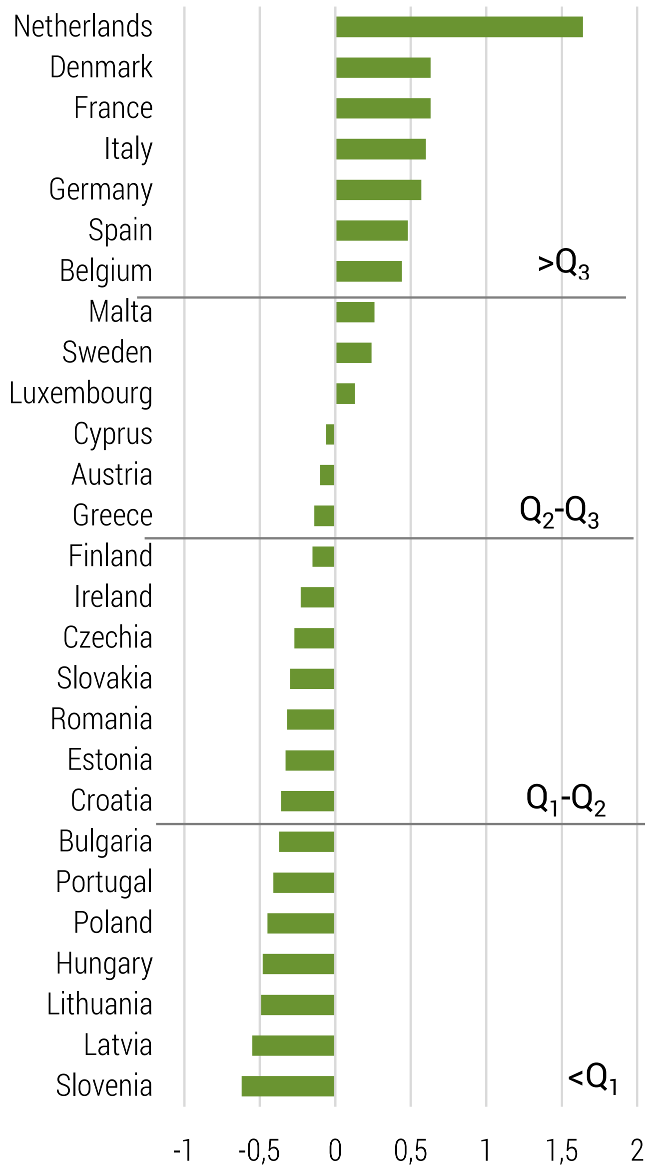


Figure 1. Perkal synthetic index of economic performance in EU member states

Source: authors' work based on Eurostat [10-03-2025].

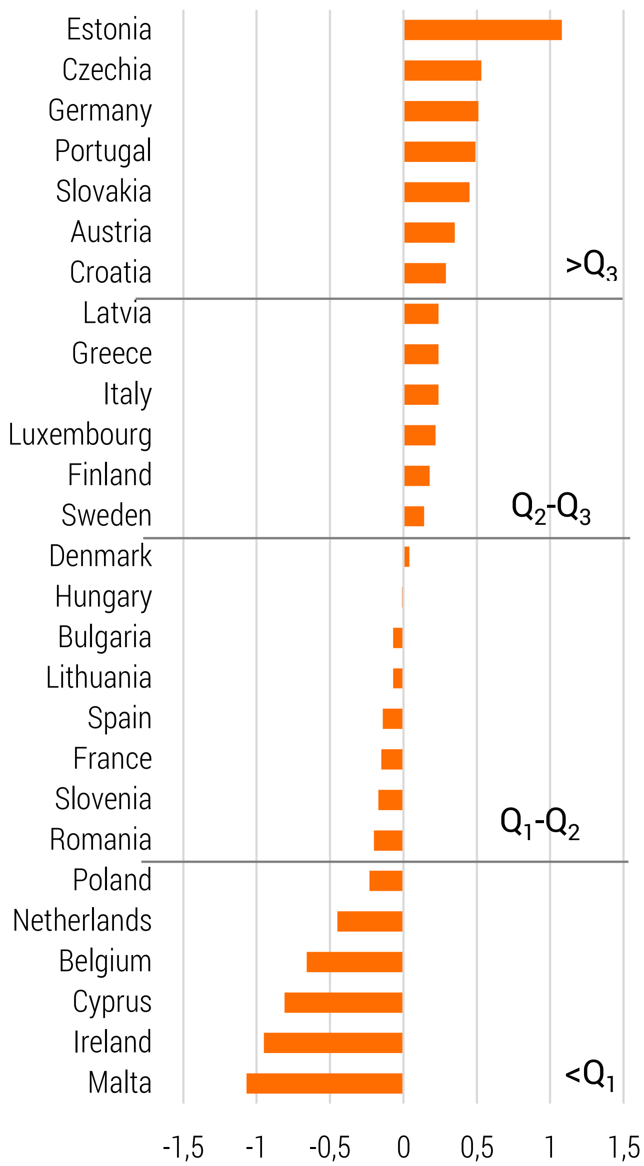


Figure 2. Perkal synthetic index of environmental performance in EU member states

Source: authors' work based on Eurostat [10-03-2025].

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Based on Pearson's linear correlation coefficients, it was observed that there are relationships between some of the analysed environmental and economic indicators in the agriculture of EU member states (Table 3). Final energy consumption by agriculture is positively correlated with productivity indicators (gross value added per 1 AWU and gross value added per ha) and value of capital inputs per 1 ha and value of capital inputs per AWU. In addition, a positive correlation was observed between the area under organic farming and gross value added per ha and the value of capital inputs per 1 ha. In countries with higher sales of pesticides per ha, a higher gross value added per ha, a higher value of capital inputs per 1 ha and a lower agricultural land area per AWU (and vice versa) were observed. Share of agriculture in production of renewable energy is, in turn, significantly related to gross value added per 1 AWU, gross value added per ha, value of capital inputs per 1 ha, and value of capital inputs per AWU. Environmental indicators such as greenhouse gas emissions from agriculture, ammonia emissions from agriculture – % of total emissions and energy productivity are not correlated with any of the analysed economic indicators, and the Perkal synthetic index of environmental performance is only correlated with gross value added per ha and agricultural land area per AWU.

Table 3. Pearson linear correlation coefficients between economic and environmental indicators in agriculture in EU countries in 2018-2021

| Indicator | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $P_{environmental}$ |
|---|---|---|---|---|---|---|---|---|
| $X_8$ | 0.01 | 0.00 | 0.09 | -0.05 | 0.10 | -0.04 | 0.33 | 0.05 |
| $X_9$ | 0.50* | 0.04 | 0.14 | 0.07 | -0.25 | -0.12 | 0.65* | 0.04 |
| X10 | -0.08 | -0.28 | 0.31 | -0.14 | 0.21 | -0.03 | -0.13 | -0.27 |
| X11 | 0.91* | -0.39 | 0.81* | -0.28 | -0.03 | -0.04 | 0.48* | -0.49* |
| $X_{12}$ | -0.24 | 0.59 | -0.46* | 0.16 | -0.23 | -0.11 | -0.12 | 0.42* |
| $X_{13}$ | 0.96* | -0.35 | 0.64* | -0.20 | -0.14 | -0.04 | 0.63* | -0.37 |
| $X_{14}$ | 0.43* | 0.08 | 0.02 | 0.10 | -0.33 | -0.10 | 0.50* | 0.10 |
| Peconomic | 0.68* | -0.09 | 0.42* | -0.09 | -0.19 | -0.14 | 0.64* | -0.14 |

*correlation coefficient significant at the level 0.05

Source: authors' work based on Eurostat [10-03-2025].

## Discusion

Sustainable development of agriculture in the literature covers a wide range of issues, but a precise, universally accepted definition has not been developed so far. However, some studies attempt to define practical actions that would bring benefits from both an ecological and economic point of view. Studies conducted by other authors (e.g. Harasim et al., 2014; Czudec et al., 2018) indicate that there is regional differentiation in the sustainability of agriculture and rural areas, which is consistent with the observations in the presented study. It turned out that in a comparative analysis at the regional level in Poland and Ukraine, the vast majority of regions in terms of environmental and economic sustainability of agriculture and rural areas overlapped in groups with the highest and lowest sustainability, respectively. This applied to both voivodeships in Poland and oblasts in Ukraine (Kowalczyk & Zolotnytska, 2024).

In the literature on the subject, one can find various studies taking into account only agri-environmental indicators, which allow the results to be presented in various perspectives in order to understand the directions of changes taking place in agriculture in the context of considerations concerning sustainable development. The development or/and regression of organic farming can be determined based on changes in indicators over time, e.g. related to greenhouse gas emissions (Štreimikienė et al., 2024). As a consequence, recommendations can be formulated regarding restrictions related to excessive pollution or related, for example, to subsidising soil reclamation. The selection, verification and analysis over time of individual groups of agro-environmental indicators in a specific

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area can play a key role in improving sustainable development in a specific scope, e.g. indicators characterising the potential of renewable energy are used to promote sustainable practices in land use (Streimikis & Baležentis, 2024; Hou et al., 2020; Heyl et al., 2021; Salvan et al., 2022).

It is worth agreeing with Zieliński and Jadczyszyn (2022) that "...In the EU, protecting the natural environment and providing public goods to society is not possible without ensuring the good condition of areas with high natural value...". Farmers who want to apply the principles of sustainable development in practice or implement the principles of organic farming often encounter many problems, including difficult conditions of agricultural production or increased labour intensity in organic farming, which consequently increases production costs. The opportunity for the development of organic farming may be EU ecological payments, granted depending on the area of crops grown using organic methods, as well as professional agricultural advice, the creation and support of operating companies purchasing and processing organic agricultural products, or the development of groups of organic producers creating a stronger negotiating position of organic producers with discount chains and large-scale stores (Zieliński et al., 2022). However, this would involve consumers accepting a higher price, which, given the current wealth of the average consumer's wallet, in the face of rising inflation and lower prices of traditional food, seems difficult to implement (Ziętara, & Mirkowska, 2021; Chrobocińska, & Łukiewska, 2024).

In practice, farmers receive CAP subsidies as remuneration for conducting agricultural production and, at the same time, as part of their activities, for providing public goods. Area payments are not directly related to agricultural production and generating added value in the economic context. However, the indirect impact of various factors on the formation of the level of added value is noticeable. This concerns, among others, maintaining small and medium-sized farms thanks to area payments, which allow for relative stabilisation of production and maintaining continuity of supplies, which also allows for the implementation of the "From farm to fork" strategy and shortening the supply chain. Implementation of innovative solutions, thanks to, for example, horizontal integration and product diversification, can also support the increase in added value (Kania & Musiał, 2018). In addition, area payments can contribute to initiating the investment process, which can increase the efficiency of agricultural production and generate greater added value. In addition, investments, for example, in agritourism, can also translate into a possible increase in added value in the local environment (Kosiński & Szymańska, 2024).

It should be added that in practice, researchers encounter certain difficulties regarding the availability of data on agri-environmental indicators. Assessment at the regional or higher level is possible, but there is a lack of data in public regional statistics, e.g. at the municipal level or at the micro level (Bockstaller et al., 2008; Salvan et al., 2022). This is burdensome when trying to collect adequate and compatible data for the assessment of a specific case study. This means that further discussion is needed regarding the assessment, standardisation, and comparability of environmental and, at the same time, economic results in sustainable agriculture.

## Conclusions

The assumptions of sustainable development are implemented in the EU countries, but there is diversity in this respect. In macro terms, at the level of EU countries, the implementation of environmental and economic goals in agriculture is difficult to reconcile, which was visible in our own research. Differences in the implementation of economic and environmental goals can be found in many EU countries. The only country that achieved both high economic and environmental performance was Germany. Countries such as Denmark, France, Italy, Spain and Belgium recorded high economic performance but average or low environmental performance. In addition, the research made it possible to identify a group of countries with the best environmental performance, which, in addition to Germany, included Estonia, the Czech Republic, Portugal, Slovakia, Austria and Croatia. Economic performance in these countries was at an average or low level. Such a discrepancy between the levels of economic and environmental results obtained proves that the assumptions of sustainable development in agriculture have not been fully implemented in the above-mentioned countries. There are many reasons for this state of affairs, including the different structures and intensification of agricultural production in the EU countries. In addition, there is insufficient institutional support

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to sufficiently compensate for the increased production costs during the transition from conventional agriculture to more sustainable agriculture..

It should be added that the research results allowed us to distinguish a group of countries in which the agricultural model was characterised by average economic and environmental results, which indicates that the development of agriculture was sustainable. This group included countries such as Greece, Luxembourg, Finland, Sweden and Romania.. The least favourable situation was in Poland, where both low economic and environmental results were recorded.

Considering the connections between the analysed environmental and economic indicators, it was found on the basis of the research that there is a correlation between some of them. The synthetic environmental indicator was positively correlated with agricultural land area per AWU and negatively correlated with gross value added per ha. This may mean that intensive production characterised by high specialisation (as well as intensive chemicalisation, and consequently greater use of plant protection products and artificial fertilisers) may contribute to the burden on the environment (in extreme cases to soil degradation and groundwater pollution). High specialisation is the opposite of biodiversity, and therefore, in countries where agriculture is characterised by intensive production, it may not meet the requirements of sustainable agriculture. The research results indicate a certain exception to the rule – Germany, where a high level of involvement of RES was observed, which may indicate an increase in a certain pro-environmental awareness. On the other hand, extensive production, which is characterised by relatively low labour (and capital) inputs per unit area, promotes natural processes and biodiversity, which is in line with the assumptions of sustainable development.

The issue of the relationship between economic and environmental efficiency is important from the perspective of sustainable development of agriculture. It seems that economic efficiency in agricultural production is only possible in large-scale production, which also results from the intensification of processes. On the other hand, ecological production is burdened with high labour costs, which unfortunately contribute to the fact that, in such a situation, it is not competitive in comparison to conventional production. Therefore, the idea of sustainable agriculture requires appropriate legal and financial instruments that would support niche agricultural production.

The conducted research is burdened with certain limitations. They result, among others, from the difficulty of selecting indicators that could fully reflect the issues described. This problem is complicated not only due to the availability of statistical data, but also the existing cause-and-effect relationships and correlations between the available agri-environmental indicators. In future research, it would also be worthwhile to examine the environmental and economic trends in agriculture in the EU member states over a longer time horizon.

## The contribution of the authors

Conceptualisation, K.Ł. and K.Ch.; literature review, K.Ch.; methodology, K.Ł.; formal analysis, K.Ł. and K.Ch; writing, K.Ł. and K.Ch; conclusions and discussion, K.Ł. and K.Ch.

The authors have read and agreed to the published version of the manuscript.

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# OCENA WYBRANYCH ASPEKTÓW EKONOMICZNYCH I ŚRODOWISKOWYCH W ROLNICTWIE KRAJÓW UE W KONTEKŚCIE ZRÓWNOWAŻONEGO ROZWOJU

STRESZCZENIE: Zrównoważony rozwój obejmuje działania zmniejszające straty i marnotrawstwo w procesie produkcyjnym, uwzględniające racjonalizację konsumpcji oraz wykorzystujące innowacyjne rozwiązania technologiczne umożliwiające wzrost ekonomicznej efektywności zasobów naturalnych. Celem opracowania była ocena poziomu wybranych wskaźników ekonomicznych i środowiskowych w rolnictwie w krajach członkowskich UE. W opracowaniu zastosowano wskaźniki syntetyczne Perkala wyników ekonomicznych oraz wyników środowiskowych, a także metodę przedziałów kwartylowych. Na ich podstawie stworzono rankingi krajów i pogrupowane je na cztery podgrupy. Z przeprowadzonych badań wynika, że w wielu krajach UE występują rozbieżności w wynikach ekonomicznych i środowiskowych rolnictwa. Opracowanie wypełnia lukę poznawczą w zakresie aktualnych danych i kompleksowej oceny uzyskiwanych wyników ekonomicznych i środowiskowych w rolnictwie. Wielokryterialna ocena może wspomóc decydentów w kreowaniu skutecznych strategii ukierunkowanych na optymalną alokację zasobów w kontekście prośrodowiskowym.

SŁOWA KLUCZOWE: zrównoważony rozwój rolnictwa, ocena efektywności w rolnictwie, wskaźnik Perkala

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