DOI: 10.22620/agrisci.2022.35.007

EFFICIENCY OF USING ENVIRONMENTALLY HARMFUL INPUTS IN FIELD CROP PRODUCTION IN BULGARIA

Yordanka Y. Mitseva

Agricultural University – Plovdiv, Bulgaria
Email: danymiz1981@gmail.com

Abstract

There is a long-standing issue relating environmental to economic goals of agricultural production systems. An attempt to examine all possible aspects of this relationship is highly challenging and beyond the scope of the study. To gain insights into simultaneously improving the economic and ecological performance of the field crop farms, the research is focused on measuring the efficiency of using production inputs that have a large environmental impact. The paper investigates different field crop production regions in Bulgaria from 2014 to 2020 in an attempt to identify regional disparities. Such an investigation could help in consolidating policy measures addressing agro-environmental issues. By employing a mathematical programming approach (DEA method) on public data from the Farm Accounting Data Network and applying a non-parametric Kruskal–Wallis test over the obtained scores, no significant difference in the efficiency of using environmentally harmful inputs between six field crop production regions in Bulgaria is found. Regarding this finding and the Common Agricultural Policy strategies, recommendations for further research are proposed.

Keywords: eco-efficiency, input eco-efficiency, DEA method, regional disparity

INTRODUCTION

Agriculture must meet the needs of present and future generations for its products and services while ensuring profitability, environmental health, and social and economic equity in order to be sustainable. (FAO, 2014)

Sustainable agriculture is economically viable, ecologically sustainable, and socially responsible (Bachev et al., 2016). These desirable features of agriculture outline the three aspects of the agricultural sustainability model: economic viability, ecological sustainability, and social responsibility.

Environmental sustainability is regarded as critical to human survival, and as such, it is given equal weight in the agricultural sustainability model. The environment's relationship with farmers' management is two-sided: on the one hand, the supporting ecosystem services provide the basis for the provision of food (harvested production, biomass, energy), and on the other, the practices in the holding have an impact on ecosystem services (Todorova, 2022).

Common current agricultural practices have many negative impacts, the main of which are the loss of biodiversity (Maxwell et al., 2016) and carbon emissions. The negative impact on the environment comes mainly from the farming systems and practices: soil tillage, overwatering, and overusing fertilizers and pesticides. Since the farming practices that improve fertilizer use, plant protection management, and resource efficiency are all paths to economic viability and environmental sustainability (Atanasov, 2015; Beluhova-Uzunova & Dunchev, 2019; Mitova, 2021), more research into their relationship with nature (Mohammadi et al., 2022) and sufficient public financial and educational support (Beluhova-Uzunova & Dunchev, 2019) are required to adopt these systems and meet agriculture's commitment to environmental sustainability.

Farming practices that result in redundant input components, such as chemicals, not only endanger the environment and future productivity, but also place a significant current financial burden on farmers and reduce their earnings. Furthermore, as input consumption rises faster than plant yields, production efficiency falls significantly, jeopardizing farmers' competitiveness. As a result, excessive consumption of intermediate inputs and natural resources has negative economic and negative environmental consequences.

To mitigate such consequences and enable a fundamental shift to a sustainable food system, the European Green Deal (EC, The European Green Deal, 2019) is intended to promote some of the Sustainable Development Goals outlined in the United Nations resolution "Transforming our World: the 2030 Agenda for Sustainable Development" (UN, 2015).

The Green Deal sets several objectives through the Farm to Fork strategy (EC, A Farm to Fork Strategy, 2020) and the Biodiversity strategy (EC, Biodiversity Strategy, 2020) to put UN resolution into action:

- to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030;
- to reduce nutrient losses by at least 50% and reduce the use of fertilizers by at least 20% by 2030;
- at least 25% of the EU’s agricultural land must be organically farmed by 2030;
- at least 10% of the agricultural area should be under high-diversity landscape features.

Several indicators - "Use of more hazardous pesticides," "Primary energy consumption," "Final energy consumption," and "Consumption of chemicals by hazardousness - EU aggregate" - that track progress toward SDG2, SDG7, and SDG12, respectively, are directly affected by the excessive use of environmentally harmful inputs and natural resources in agricultural production systems.

Many SDG indicators are indirectly influenced by the use of environmentally hazardous inputs and natural resources in agricultural production systems, and the magnitude of their relationship is difficult to establish.

Locally, the Member States seek to encourage farmers to maintain sustainable pesticide and fertilizer use and/or transition to organic farming by enacting the National Action Plans (NAP) in accordance with numerous legislative frameworks (Directive (EC 2009/128), Nitrates Directive (EEC 1991/676), Regulation (EC) No 1185/2009 of the European Parliament and of the Council).

A number of Agro-environmental indicators (AEIs) track progress toward the NAP's ecological goals. AEIs are intended to monitor the incorporation of environmental concerns into the Common Agricultural Policy (CAP) at the EU, national, and regional levels. Three AEIs list the environmentally damaging inputs used on a national scale: inorganic fertilizer consumption, pesticide consumption, and energy consumption.

AEIs indicators, as well as SDGs indicators, are unsuitable for farm sector analysis due to their inability to link the actual use of such inputs by farmers and growers to the associated production outcomes. The limitations are primarily due to the data collection methods and sources. This implies that additional work is required to improve and develop them as policy-making modeling tools in order to identify (i) shortcomings in current measures and (ii) the need for new policy initiatives to tailor the targeting of the measures to local conditions. Regarding Communication from the Commission to the Council and the European Parliament COM (2006) 508 final, a coherent system of agro-environmental indicators must be able to capture the main effects of agricultural production systems on the environment, and, at the same time, to indicate a need for amendment of the agro-ecological goals, reflecting regional differences in economic structures and natural conditions.

The agro-ecological goals are based on the assumption that farmers use far too many environmentally harmful substances and that there is room for reduction in their use. They also assume that effective alternative approaches (with comparable performance and cost) are available in agricultural production systems.

So far, there is little consensus regarding these assumptions, and the stakeholder opinions are strongly polarized. Farmers and some industry professionals argue that reducing chemical plant protection products leads to disease spread and decreased productivity and that a few alternatives are available at a reasonable cost (as cited in Popp et al., 2012; Shukadarova, 2022). Environmental organizations and researchers confirm in many studies the devastating effect of pesticides on the environment and human health and call for stronger action to reduce the application of chemicals in agricultural production (Baweja et al., 2020; Malik & Kumar, 2021; Terziev & Petkova-Georgieva, 2019).

The opposing viewpoints position the economic and ecological effects of the Green Deal's implications against each other. Is there a combined economic-ecological effect? Where is the limit of such an effect? The answers to these questions, obtained through data analysis from the previous program period (2014–2020), provide insight into the predisposition of the Bulgarian field crop sector to improve its economic-ecological performance given existing technological practices.

Concept of Input Eco-efficiency

The concept of economic-ecological efficiency, initially proposed by Schaltegger and Sturm (Picazo-Tadeo et al., 2011; Richterová et al., 2021; Suzigan et al., 2020) as a practical approach to sustainability, has been lately popularized by the World Business Council for Sustainable Development (WBCS) for simultaneously increasing the competitiveness and environmental responsibility of enterprises (Richterová et al., 2021). Emphasizing that the prefix “eco” refers to both “economics” and “ecology,” Schaltegger and Burritt (as cited in Gołaś et al., 2020) point out that ecological goals should not be in contradiction with economic goals.

According to the Organization for Economic Co-operation and Development—OECD (as cited in Gołaś et al., 2020; as cited in Puertas et al., 2022), the simplest way to present eco-efficiency is to relate the economic effect of the production of an enterprise (e.g., sector, or economy) to the production inputs that increase the environmental pressure generated by this enterprise.

Glavi et al. claim that eco-efficiency is based on the assumption that it is possible to produce more goods and services with the same or fewer resources while causing less pollution. (2012, as cited in Łącka & Brzezicki, 2022).

Eco-efficiency is generally defined as the ratio of a desirable output divided by a polluting input, where the output is the value of the products and services produced and the input is the environmental pressures generated by the firm. An increase in output for a given level of inputs or a decrease in input for a given level of outputs improves eco-efficiency. A decrease in output for a given level of inputs or an increase in input for a given level of outputs results in a decrease in eco-efficiency (Grzelak et al., 2019).

To focus the research solely on the ratio between production outcomes and environmentally dangerous inputs, the term “**input eco-efficiency**” is used to refer to the technical efficiency of using environmentally harmful intermediate inputs in the production process. In this sense, input eco-efficiency is considered a cross point between input efficiency and eco-efficiency.

The input eco-efficiency ratio compares

environmental pressure to economic activity volume. Measuring relative levels of environmental pressure to production reveals opportunities for improvement as well as limits to improvement in the direction of more sustainable production.

Purpose of The Study

According to a systematic literature review conducted by Velten et al. (2015), dividing the three dimensions (aspects) of agricultural sustainability (economic viability, social responsibility, and ecological sustainability) into numerous primary objectives frequently results in complementarities, conflicts, or even trade-offs. Further separating the primary objectives into their smallest components, on the other hand:

- aids in the discovery of links between various aspects of sustainability and enables interdisciplinary approaches that better reflect interlinkage between SDGs;
- promotes the proliferation of definitions of sustainability.

Farmers must be aware of the economic and ecological aspects of production in order to manage inputs responsibly. Farmers' perceptions and environmental awareness are critical prerequisites for environmental responsibility and important potential factors in the transition to sustainable agriculture (Svitacova, 2021). Policymakers must be aware of agricultural units' ability to improve input eco-efficiency performance in order to better target interventions.

This paper takes on the challenge of presenting an integrated approach and raising economic and environmental awareness among farmers, researchers, and policymakers by focusing on a specific problem - assessing the efficiency of using environmentally harmful inputs in the field crop sector in Bulgaria.

Problem of the Study

Because of the vast amount of land used in the production process, the field crop sector influences and is influenced greatly by the natural environment. Territory unity of climatic and soil areas forms the so-called "ecological complexes" that characterize agricultural regions (Mikova, 2020).

Differentiation in ecological complexes is one of the factors influencing input eco-efficiency and shaping the agricultural structure of European countries (Bianchi et al., 2020).

If the country is input eco-efficient in comparison to other countries, it does not mean that all regions inside the country are also input eco-efficient. Different natural resource endowments may lead to disparities in agricultural input eco-efficiency between regions, and this should be reflected in agro-environmental measures.

In order to investigate the economic-ecological performance of the field crop production in Bulgaria during 2014–2020, the study aims to answer the following **research questions:**

Q_1**:** To what extent can agricultural units reduce their usage of environmentally harmful inputs without sacrificing productivity?

Q_2: Is there an obvious regional disparity in the efficiency of using environmentally harmful inputs?

For the purpose of the research, the following **hypotheses** are stated:

H_0: The means of the ranks of input eco-efficiency scores of the six regions are equal.

H_a: At least two of the means of the ranks of input eco-efficiency scores of the six regions are not equal.

The hypotheses are tested seven times—once for each year from 2014 through 2020. When the probability of obtaining a sample mean is less than 5%, it is concluded that the sample selected is too unlikely and the null hypothesis is rejected.

MATERIALS AND METHODS

Method for Input Eco-efficiency Estimation

To quantify input eco-efficiency, a mathematical programming approach is adopted using the data envelopment analysis (DEA) because, contrary to the single ratio indicators, it enables the integration of many inputs and outputs in one measure.

In the data envelopment analysis, the decision-making units (DMUs) like farms, regions, or countries that have the best relations of inputs to outputs obtain a score of 1 and form a frontier of efficiency. That's why DEA is also called the "frontier approach." The remaining DMUs, evaluated in comparison to the best ones, obtain a score under 1. The difference between a particular DMU's input eco-efficiency score and one (the score of a fully efficient DMUs) shows a possible range of improvement.

In order to cover the period 2014–2020 of the input eco-efficiency performance of the Bulgarian field crop agricultural sector, seven technological frontiers are estimated by solving mathematical models of the type (Model 1):

$$\min \theta$$

st.

$$\begin{aligned} &\sum_{j=1}^{n} \lambda_j x_{ij} \leqslant \theta x_{ij_0} && i = 1,2,\ldots\ldots,m \\ &\sum_{j=1}^{n} \lambda_j y_{rj} \geqslant y_{rj_0} && r = 1,2,\ldots\ldots,s \qquad \mathbf{(1)} \\ &\sum_{j=1}^{n} \lambda_j = 1 && \\ &\lambda_j \geq 0 && j = 1,2,\ldots\ldots,n \end{aligned}$$

The first model proposed by Charnes, Cooper, and Rhodes (1978) for evaluating efficiency, known as the CCR model, assumes constant returns to scale. The model used in the research assumes variable returns to scale, as it is proposed in the model by Banker, Charnes, and Cooper (1984), because groups of farms under investigation may not operate at their optimal scale. The approach is input-oriented since a farmer makes decisions mainly about inputs (controlled variables), whereas outputs are uncontrolled ones. The calculations are conducted with OpenSolver 2.9.3 optimizer according to Mason's guidelines (2012).

Data for Input Eco-efficiency Assessment

The research is based on representative data from the Farm Accountancy Data Network at the farm economic size level for six regions in Bulgaria. The time range for the research is 2014–2020. All variables are expressed in financial measures (€/ha).

As inputs (m = 3) for the model, three variables reflecting environmentally harmful resource consumptions are used, which are additionally calculated per hectare:

1. Fertilisers(SE295)/Arable land(SE026)
2. Crop protection (SE300)/Arable land(SE026)
3. Energy (SE345)/Arable land(SE026)

As output (s = 1) for the model is used measure of production:

1. Total crop output (SE136).

The number of DMUs varies during the years: 2014 (n = 24), 2015 (n = 29), 2016 (n = 27), 2017 (n = 30), 2018 (n = 32), 2019 (n = 32), and 2020 (n = 31).

Statistical Method

Kruskal–Wallis tests are applied in the search for statistical significance for the regional disparity in input eco-efficiency of the field crop production. The tests are employed in a set of six independent samples that represent different regions in Bulgaria. Although less powerful than the parametric (F) test, the non-parametric (H) test is chosen for the research because of the small (in some groups, under five), unequal sample sizes, and no assumption of normality.

Limitations of the research

Due to the methodology of FADN surveying, sampling, and aggregating data, the research is not free from limitations. Although using aggregated data mitigates the effect of outliers over the frontier model, it decreases the precision of the research. Moreover, the FADN sample does not cover all agricultural holdings, but only those that are considered commercial.

DEA scores should be adequately interpreted. They are relative efficiency scores that (i) allow us to identify which observed DMU units are efficient and which are not only relative to the fully efficient ones from the technology set and (ii) do not allow us to analyze dynamic changes in input eco-efficiency over time (only within-year comparison of DEA scores is appropriate due to the different technology frontier estimated for each particular year in this research).

To sum up, if other functional units, inputs, outputs, and calculation methods were adopted, the input eco-efficiency assessment might produce different results. This fact makes a direct comparison between research results found in the literature almost impossible.

RESULTS AND DISCUSSION

Within-year analysis

For better visualization of regional input eco-efficiency performance, the estimated scores are presented in boxplots (Figures 1-7). Abbreviations used: NW - North-western; NC - North-central; NE - North-eastern; SW - South-western; SC - South-central; SE - South-eastern.

Examining the 2014 year (see Figure 1), a minimum input eco-efficiency score of 0.590 is observed for a group of farms in the north-central region. Farm groups from the north-western, south-western, south-central, and south-eastern regions, which have a maximum score of 1, form the technological frontier. The mean value for this year ranges between 0.67 and 0.90, which points to a 10% to 33% average inefficiency of using environmentally harmful inputs in the field crop sector in comparison to the most efficient farm groups in the same sector. There is a noticeable clustering of northern regions with lower mean scores and southern regions with higher mean scores, though it is not enough to conclude regional disparities. By applying the non-parametric Kruskal–Wallis test, no statistical difference is found in at least two of the means of the ranks of the input eco-efficiency scores of the six regions (H(5) = 5.38, p = 0.372). As a result, the first null hypothesis cannot be rejected.

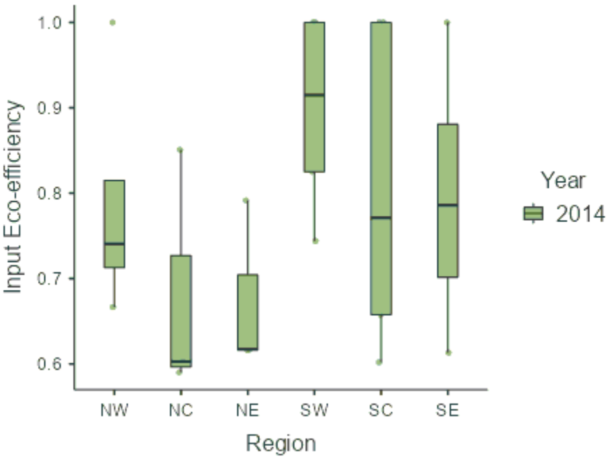

Figure 1. Boxplots of input eco-efficiency scores in 2014

Source: Own study based on FADN data.

In 2015 (see Figure 2), the most efficient farm groups are from all the regions except the North-western. This, however, is not an obstacle for most of the farm groups in this region to perform higher than average (M = 0.840, SD = 0.147) for this year. The definite overlapping of boxplots indicates convergence of the performance, which is proved by the result from the statistical test (H(5) = 2.77, p = 0.735). So the second null hypothesis cannot be rejected.

Examining the year 2016 (see Figure 3), only the South-western and South-eastern regions do not have fully efficient farm groups. These regions are also indicative of their narrow range of input eco-efficiency performance: South-western (0.592–0.729) and South-eastern (0.602–0.896). On the other hand, the South-central region is characterized by the widest range, spreading from the highest

(1.00) to the lowest (0.467) value obtained by the farm groups in the year. The big overlapping, visible in Figure 3, and the result from the statistical test (H(5) = 1.69, p = 0.890) lead again to no rejection of the third null hypothesis.

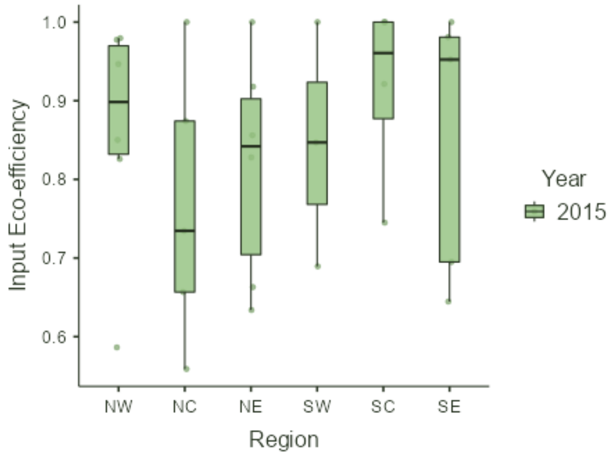

Figure 2. Boxplots of input eco-efficiency scores in 2015
Source: Own study based on FADN data.

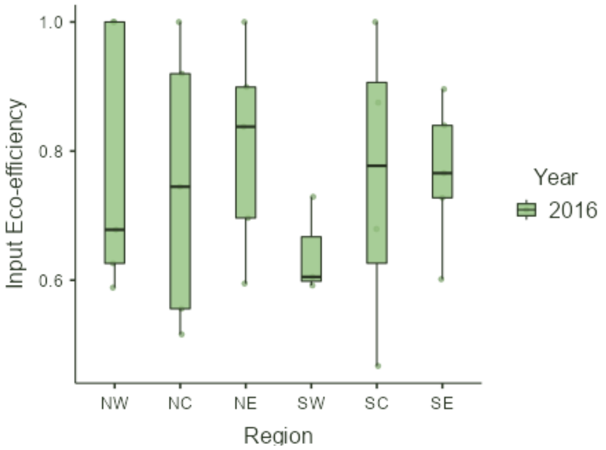

Figure 3. Boxplots of input eco-efficiency scores in 2016
Source: Own study based on FADN data.

Looking at the year 2017 (see Figure 4), the biggest convergence of the average efficiency of using environmentally harmful inputs in the field crop sector is observed. The range of the input eco-efficiency is almost equal, with small exceptions for the South-central and North-eastern regions. The regional mean values are very close to each other (with a range of 0.787–0.869) and to the average value for the year (M = 0.832, SD = 0.145). So, as expected, and from the result of the statistical test (H(5) = 0.88, p = 0.972), the probability of obtaining a sample mean is very high, and the fourth null hypothesis definitely cannot be rejected.

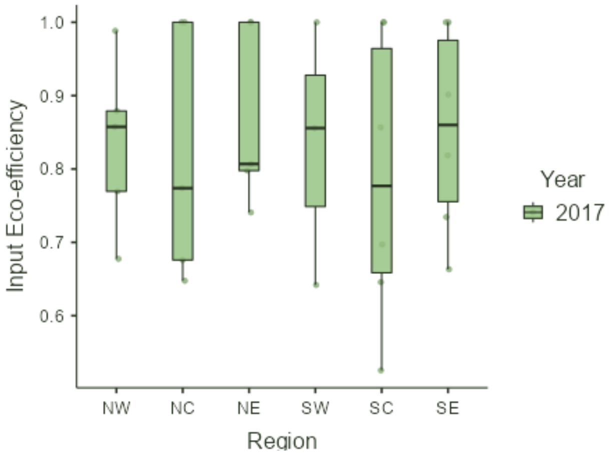

Figure 4. Boxplots of input eco-efficiency scores in 2017
Source: Own study based on FADN data.

In 2018 (see Figure 5), the least input eco-efficient farm group (with a score of 0.525) is from the South-central region. This region doesn't have any farm groups (from the ones observed) that are part of the technological frontier for the year. Moreover, it is indicative of the lowest mean score (M = 0.690, SD = 0.155) of input eco-efficiency. This year, the range of regional means (0.690–0.880) is wider than the previous year (0.787–0.869). The emerging distancing between the regional mean values is still not a sign of regional disparity. Given the result from the Kruskal–Wallis test (H(5) = 6.2, p = 0.287), no statistically significant difference in at least two of the means of the ranks of input eco-efficiency scores can be found, and inevitably, the fifth null hypothesis cannot be rejected.

In 2019 (see Figure 6), the emerging trend of distancing North-central and South-central from the rest of the regions is more apparent. As a whole, their average performance is lower, though the standard deviation of the scores in the South-central region (M = 0.629, SD = 0.204) is more than doubled in comparison with that in the North-central region (M = 0.588, SD = 0.098). Furthermore, the p-value obtained from the statistical test (H(5) = 10.1, p = 0.072) would be enough to reject the null hypothesis if other decision criteria were set (e.g., α = 0.10). However, according to the criteria set for this study (α = 0.05), the sixth null hypothesis cannot be rejected.

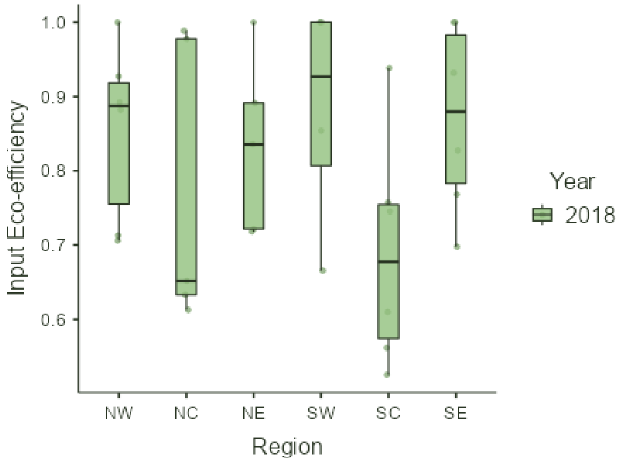

Figure 5. Boxplots of input eco-efficiency scores in 2018

Source: Own study based on FADN data.

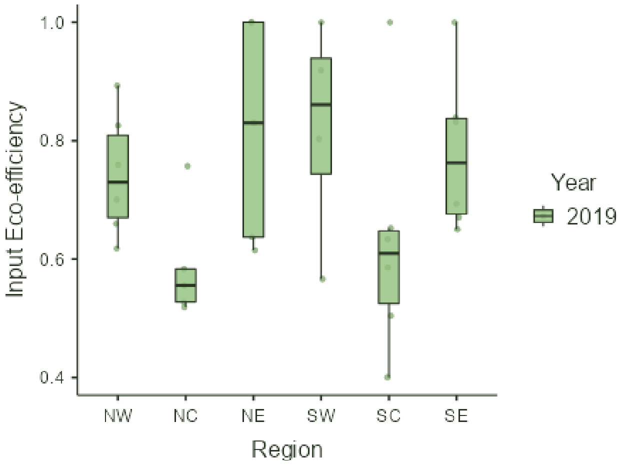

Figure 6. Boxplots of input eco-efficiency scores in 2019

Source: Own study based on FADN data.

In 2020 (see Figure 7), the central regions confirm their tendency toward low performance. The most input eco-inefficient farm groups for this particular year are mainly from these regions. It should be acknowledged that not rejecting the seventh null hypothesis is justified by almost marginal values of statistical significance (H(5) = 10.4, p = 0.066).

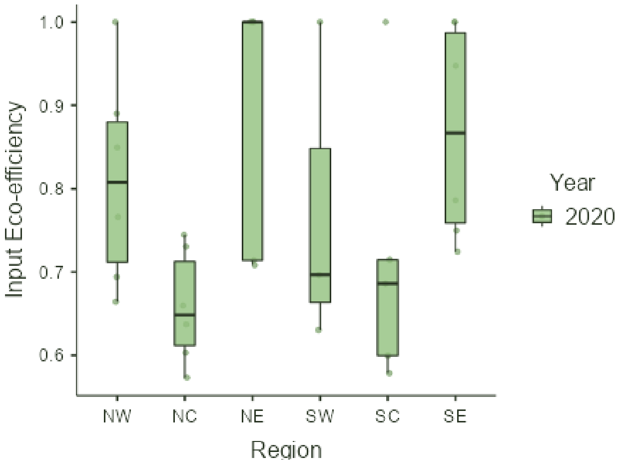

Figure 7. Boxplots of input eco-efficiency scores in 2020

Source: Own study based on FADN data.

Between-year analysis

A between-year comparison of the input eco-efficiency performance is appropriate only for the position (rank) of the regions. For this purpose, a color-coded table (Table 1) is used to present the regional mean values of such performances. The sample sizes of the groups are unequal. The standard deviation is given in parentheses. A heatmap is integrated into the table with conditional comparisons only within years. The dark green color indicates the highest mean value of input eco-efficiency in the particular year. The light green color indicates the lowest mean value of input eco-efficiency. The same logic is used for standard deviations: the highest values within a particular year are coded with a dark yellow color, and the lower values are coded with a light yellow color.

The overall mean value (the mean of the regional means of a particular year) of the input eco-efficiency indicator during 2014–2020 ranged between 0.73 and 0.84. This indicates that on average, the farm groups in the field crop sector could reduce their environmentally harmful inputs by almost one-quarter without reducing their production.

Table 1. Average Input Eco-efficiency performance for different regions

Year	**NW**	**NC**	**NE**	**SW**	**SC**	**SE**
2014	0,787	0,681	0,675	0,897	0,806	0,796
	(0,147)	(0,147)	(0,101)	(0,112)	(0,187)	(0,165)
2015	0,861	0,765	0,816	0,845	0,917	0,855
	(0,149)	(0,175)	(0,143)	(0,155)	(0,120)	(0,170)
2016	0,779	0,747	0,806	0,642	0,755	0,766
	(0,205)	(0,214)	(0,161)	(0,076)	(0,233)	(0,113)
2017	0,834	0,819	0,869	0,833	0,787	0,853
	(0,117)	(0,171)	(0,122)	(0,180)	(0,196)	(0,139)
2018	0,853	0,773	0,833	0,880	0,690	0,871
	(0,119)	(0,193)	(0,119)	(0,159)	(0,155)	(0,126)
2019	0,743	0,588	0,816	0,822	0,629	0,781
	(0,104)	(0,098)	(0,187)	(0,189)	(0,204)	(0,135)
2020	0,811	0,658	0,884	0,776	0,716	0,868
	(0,127)	(0,068)	(0,158)	(0,197)	(0,169)	(0,128)

Note. Own study based on FADN data. Abbreviations used: NW - North-western; NC - North-central; NE - North-eastern; SW - South-western; SC - South-central; SE - South-eastern.

The North-western and South-eastern regions are approximately stable in their average input eco-efficiency performance (the mean values are in the dark green spectrum) in comparison to other regions in the time period 2014–2020. These regions are also characterized by relatively small standard deviations of scores obtained during the second half of the period. In general, the other four regions (North-eastern, North-western, South-eastern, and South-western) show a very mixed performance, with a clear tendency for the central regions to lag behind other regions in the last two years of the observed period.

From the results of the seven non-parametric Kruskal–Wallis one-way analyses of the variance by ranks tests summarized in table 2, it can be concluded that there is no statistically significant difference between input eco-efficiency in at least two of the six regions (North-western, North-central, North-eastern, South-western, South-central, and South-eastern) in either of the years. The time period is characterized by noticeable convergence in the performance in the middle part (2015, 2016, and 2017) and a tendency of divergence in the last two years (2019 and 2020).

Table 2. Statistical significance of differences in input eco-efficiency between regions

Year	χ^2	Df	P
2014	5.38	5	0.372
2015	2.77	5	0.735
2016	1.69	5	0.890
2017	0.88	5	0.972
2018	6.2	5	0.287
2019	10.1	5	0.072
2020	10.4	5	0.066

Source. Own study based on FADN data.

Overall, there is no simplistic explanation for the results. The reason for the findings, apart from the small sample sizes and aggregated data, might be that each region is not a unique, uniform ecological complex or that other factors have a greater impact on the input eco-efficiency performance than regionality. For instance, farmers' expectations that reducing inputs will decrease crop production outputs may lead to the adoption of more input-intensive practices and excess consumption of chemical fertilizers and pesticides (Wang et al., 2022). This willingness of the farmers to secure their income narrows the gap in input eco-efficiency between regions.

All these suggestions would be a good starting point for further research into the potential determinants of input eco-efficiency.

CONCLUSION

According to this study, the following general conclusions can be drawn:

1. When considering agricultural sustainability as a "direction" of development, input eco-efficiency is an effective integrated approach for assessing some of the economic and ecological aspects of sustainability. Measuring relative levels of environmental pressure reveals opportunities for improvement in the direction of a more sustainable production and progress toward SDG2, SDG7, and SDG12. A fully input eco-efficient unit is not guaranteed to be ecologically sustainable in the absolute term. Improving input eco-efficiency is just one step toward sustainability.
2. On average, the investigated agricultural units in the time period 2014–2020 could reduce their usage of environmentally harmful inputs by approximately 16–27 % without decreasing their production. This conclusion confirms the opinions that the Green Deal's goals (reducing the overall use of chemical and hazardous pesticides by 50% by 2030) are very ambitious given the technological predisposition of the field crop sector in Bulgaria. Therefore, reaching the goals is possible through the adoption of innovative technologies and practices or the remuneration of the farmers when reducing chemical pesticides, fertilizers, and energy use lead to sacrificed productivity. This finding should not be misinterpreted. Firstly, it does not apply to individual farms. Secondly, averaging the scores indicates that the "average proportional reduction" of the environmentally harmful inputs is an unreachable target for some farm units given the established technological practices, while for others, such a reduction could be even greater.
3. There is no statistically significant disparity in the efficiency of using environmentally harmful inputs in different field crop production regions in Bulgaria during 2014–2020.
4. Considering the focus of the current Common Agricultural Policy on reducing resource use and negative environmental impacts, better implications for developing policy strategies will be provided by further research into:
   - the driving forces behind widening and narrowing regional input eco-efficiency disparities;
   - the farm-level input eco-efficiency performance;
   - the capacity of moving the farm-level input eco-efficiency frontier up by adopting input-saving practices like crop rotation, reduced tillage, integrated pest management, and precision agriculture.

REFERENCES

Atanasov, D. (2015). Perspectives for economic viability and sustainable development of Bulgarian agriculture in the new programming period 2014 - 2020. *Trakia Journal of Science, 13*(Suppl.1), 155–161. https://doi.org/10.15547/tjs.2015.s.01.026

Bachev H., B.Ivanov, D.Toteva, E.Sokolova (2016): Agrarian Sustainability and its Governance – Understanding, Evaluation, Improvement, Journal of Environmental Management and Tourism, Vol. 7, 4 (16), 639-663. https://www.researchgate.net/publication/318787024_Agrarian_sustainability_and_its_governance_-_understanding_evaluation_improvement

Banker, R. D., Charnes, A., & Cooper, W. W. (1984, September). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment

Analysis. *Management Science*, *30*(9), 1078–1092. https://doi.org/10.1287/mnsc.30.9.1078

Baweja, P., Kumar, S., & Kumar, G. (2020). Fertilizers and pesticides: their impact on soil health and environment. In B. Giri & A. Varma (eds.), *Soil Health*, (pp. 265-285). Springer. Retrieved from https://www.researchgate.net/profile/Adekiya-Aruna-Olasekan/publication/341666671_Contribution_of_Biochar_in_Improving_Soil_Health/links/5ed3c1c592851c9c5e6c3d29/Contribution-of-Biochar-in-Improving-Soil-Health.pdf#page=274

Beluhova-Uzunova, R. P., & Dunchev, D. M. (2019). Precision farming–concepts and perspectives. *Zagadnienia Ekonomiki Rolnej/Problems of Agricultural Economics*, (3). DOI: 10.30858/zer/112132

Bianchi, M., Valle, I. D., & Tapia, C. (2020, December). Measuring eco-efficiency in European regions: Evidence from a territorial perspective. *Journal of Cleaner Production*, *276*, 123246. https://doi.org/10.1016/j.jclepro.2020.123246

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429–444. https://doi.org/10.1016/0377-2217(78)90138-8

Communication from the Commission to the Council and the European Parliament Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy COM(2006) 508 final. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0508:FIN:EN:PDF

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU Biodiversity Strategy for 2030 Bringing nature back into our lives COM(2020) 380 final https://eur-lex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system COM/2020/381 final https://eur-lex.europa.eu/resource.html?uri=cellar:ea0f9f73-9ab2-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions The European Green Deal COM(2019) 640 final https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). *Official Journal of the European Communities L 375/1*, 31 December 1991,1-8. http://data.europa.eu/eli/dir/1991/676/oj

Directive 2009/128/EC of the European Parliament and of the Council as regards of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. *Official Journal of the European Union, L 309*/71. http://data.europa.eu/eli/dir/2009/128/oj

FAO (2014). Building a Common Vision for Sustainable Food and Agriculture. Principles and Approaches. FAO, Rome https://www.fao.org/3/i3940e/i3940e.pdf

Gołaś, M., Sulewski, P., Wąs, A., Kłoczko-Gajewska, A., & Pogodzińska, K. (2020, September 27). On the Way to Sustainable Agriculture—Eco-Efficiency of Polish Commercial Farms. *Agriculture*, *10*(10), 438. https://doi.org/10.3390/agriculture10100438

Grzelak, A., Guth, M., Matuszczak, A., Czyżewski, B., & Brelik, A. (2019). Approaching the environmental sustainable value in agriculture: How factor endowments foster the eco-efficiency. *Journal of Cleaner Production*, *241*, 118304. https://doi.org/10.1016/j.jclepro.2019.118304

Łącka, I., & Brzezicki, Ł. (2022). Joint analysis of national eco-efficiency, eco-inovation and SDGs in Europe: DEA approach. *Technological and Economic Development of Economy*, *28*(6), 1739–1767. https://doi.org/10.3846/tede.2022.17702

Malik, A., & Kumar, G. (2021). An overview of chemical pesticides and its impact on environment and human health. *International Journal of Modern Agriculture*, *10*(2), 2045-2052. http://www.modern-journals.com/index.php/ijma/article/view/959

Mason, A. J. (2012). OpenSolver - An Open Source Add-in to Solve Linear and Integer Programs in Excel. *Operations Research Proceedings*, 401–406. https://doi.org/10.1007/978-3-642-29210-1_64

Maxwell, S. L., Fuller, R. A., Brooks, T. M., & Watson, J. E. M. (2016, August). Biodiversity: The ravages of guns, nets, and bulldozers. *Nature*, *536*(7615), 143–145. https://doi.org/10.1038/536143a

Mikova, R. (2020). Agro-Ecological Conditions and Regional Features in the Production of Wheat and Sunflower. *Ikonomika I Upravlenie Na Selskoto Stopanstvo*, *65*(4), 50–57. Retrieved from https://journal.jaem.info

Mitova, D. (2021). Environmental sustainability of Bulgarian agriculture. *Bulgarian Journal of Agricultural Science*, *27*(1), 72-79 https://agrojournal.org/27/01-09.pdf

Mohammadi, A., Venkatesh, G., Eskandari, S., & Rafiee, S. (2022). Eco-Efficiency Analysis to Improve Environmental Performance of Wheat Production. *Agriculture*, *12*(7), 1031. https://doi.org/10.3390/agriculture12071031

Picazo-Tadeo, A. J., Gómez-Limón, J. A., & Reig-Martínez, E. (2011, April). Assessing farming eco-efficiency: A Data Envelopment Analysis approach. *Journal of Environmental Management*, *92*(4), 1154–1164. https://doi.org/10.1016/j.jenvman.2010.11.025

Popp, J., Pető, K., & Nagy, J. (2012). Pesticide productivity and food security. A review. *Agronomy for Sustainable Development*, *33*(1), 243–255. https://link.springer.com/article/10.1007/s13593-012-0105-x

Puertas, R., Guaita-Martinez, J. M., Carracedo, P., & Ribeiro-Soriano, D. (2022). Analysis of European environmental policies: Improving decision making through eco-efficiency. *Technology in Society*, *70*, 102053. https://doi.org/10.1016/j.techsoc.2022.102053

Regulation (EC) No. 1185/2009 of the European Parliament and of the Council concerning statistics on pesticides.

Official Journal of the European Union L 324/1, 10 December 2009, 1-22. http://data.europa.eu/eli/reg/2009/1185/oj

Richterová, E., Richter, M., & Sojková, Z. (2021, September 30). Regional eco-efficiency of the agricultural sector in V4 regions, its dynamics in time and decomposition on the technological and pure technical eco-efficiency change. *Equilibrium*, *16*(3), 553–576. https://doi.org/10.24136/eq.2021.020

Shukadarova, N. (2022). The Green Deal possible impact on cereal and oilseed sectors and the CAP "green architecture" in Bulgaria. *Agricultural Sciences*, *14(33)*, 27-35. DOI: 10.22620/agrisci.2022.33.004

Suzigan, L. H., Peña, C. R., & Guarnieri, P. (2020, June 15). Eco-efficiency Assessment in Agriculture: A Literature Review Focused on Methods and Indicators. *Journal of Agricultural Science*, *12*(7), 118-134. https://doi.org/10.5539/jas.v12n7p118

Svitacova, E. P. (2021). Environmental responsibility in sustainable agriculture. Bulgarian Journal of Agricultural Science, 27(5), 880-886. https://agrojournal.org/27/05-08.pdf

Terziev, V., & Petkova-Georgieva, S. (2019). The pesticides toxic impact on the human health condition and the ecosystem. *IJASOS-International E-journal of Advances in Social Sciences*, *5*(15), 1314-1320. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3477254

Todorova, K. (2022). Eco-innovation for provision of ecosystem services – a survey among farmers. Ikonomika i upravlenie na selskoto stopanstvo, 67(1), 43-51 (Bg). https://journal.jaem.info/page/en/details.php?article_id=551

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What Is Sustainable Agriculture? A Systematic Review. *Sustainability*, *7*(6), 7833–7865. https://doi.org/10.3390/su7067833

Wang, G., Shi, R., Mi, L., & Hu, J. (2022, January 18). Agricultural Eco-Efficiency: Challenges and Progress. *Sustainability*, *14*(3), 1051. https://doi.org/10.3390/su14031051