Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Assessment of the environmental and economic efficiency of crop producers

Anastasia S. Babanskaya, Elena S. Kolomeeva*, Natalya F. Zaruk, Maria V. Kagirova, Rishat A. Migunov, Yulia N. Romantseva

Russian State Agrarian University, Moscow Timiryazev Agricultural Academy, 49 Timiryazevskaya St., Moscow, 127434, Russian Federation

* *Corresponding author's Email*: *kolomeeva@rgau-msha.ru*

ABSTRACT
The article is devoted to developing a methodological approach to analyzing the efficiency and competitiveness of crop producers, taking into account ecological parameters to ensure the development of organic production. The authors propose a system of quantitative and qualitative indicators for a comprehensive assessment of crop producers' environmental and economic efficiency. The object of the study was 65 producers of organic and non-organic crop production of grain and mixed specialization. For comparative analysis, comparability of indicators in terms of conditions was ensured through sampling and the scientifically based sampling method, i.e., stratified sampling. The initial database contains enterprise reporting indicators and aggregated data by territories in the form of categorical data and time series. The study used the sampling method, statistical grouping, comparative analysis, and approaches to identifying trends in the time series. The study resulted in the information-analytical model for assessing the efficiency and competitiveness of enterprises in order to determine the development trends of ecologically responsible and conventional crop producers. This study helps to increase attention to environmental issues in the crop production sector and to identify areas for improving the efficiency and competitiveness of organic crop producers.

Keywords: Competitiveness, Crop production, Ecologically responsible enterprises, Efficiency, Organic crop production, Statistical indicators.
Article type: Research Article.

INTRODUCTION
The concept of "Eco-efficiency" was originally developed in 1992 by the World Business Council for Sustainable Development (WBCSD) to ensure ecologically friendly and resource-efficient production. On April 21, 2004 the European Parliament and the Council of the European Union adopted the Directive No. 2004/35/CE "On Environmental Liability to Prevent Environmental Damage and Remedy its Consequences". It initiated the formation of new models of interaction between the state and companies on ecological damage prevention in the legislation of some EU member states. Low prices for natural resources and underdeveloped ecological legislation limited the application of this concept in Russia. A large share of the Russian Federation's subjects are located in the zone of risky agriculture. At the same time, the objective goals of ensuring the country's food independence and preserving the integrity of territories and their development from the interest of local authorities in creating legal and economic conditions. The solution to these problems requires developing a methodological approach to analyzing the efficiency and competitiveness of agribusiness enterprises. The scientific novelty of the research consists in forming a methodical approach to analyzing the efficiency and competitiveness of ecologically responsible crop producers based on the development of an information-analytical model for assessing economic and ecological parameters using open data. The peculiarity of the proposed methodological approach is:

A comprehensive approach (taking into account both the environmental rating of the regions and the economic and environmental efficiency of agribusiness enterprises);
Using available information (open statistical and financial reporting);
The flexibility of the multi-attribute model (it is possible to supplement the indicators and change the weighting coefficients of the indicators, taking into account the interests of the state, agribusiness enterprises, and investors).
According to WBCSD, the basic concept of ecological and economic efficiency is explained by an integrated index that measures the ecological impact accompanied by economic activity. This concept implies that the pursuit of economic growth cannot depend solely on the costs of ecological degradation (World Resources Institute 2001). There is a growing interest on the part of authorities to develop ecological ratings for enterprises. It is only logical that the problems of uniform assessment of the achieved economic and ecological efficiency results arise at the levels of states, regions, and individual economic entities. Due to the increased attention to ecological and economic efficiency, scientists offer various models and methods for assessing the effects of production activities on ecological systems, for example, data envelopment analysis (DEA; Trukhachev *et al.* 2016; Wu *et al.* 2016; Moutinho *et al.* 2017; Ghimire & Johnston 2017; Zhang *et al.* 2018). Some studies apply the SBM (Stochastic Block Model) approach, which consists in clustering objects based on random graph modeling, to assess ecological and economic efficiency (Wang & Feng 2015). For our study, however, such methods will not give proper results, as heterogeneous quantitative and qualitative indicators are used.The article by Xu *et al.* (2017) considers the DDFM model based on calculating the weighted sum of improved performance indicators as the target function. Köne Aylin (2012) reviewed the analytic hierarchy process method (AHP). However, this approach is not suitable for rural areas. Houssard *et al.* (2022) investigated a multidimensional model for assessing ecological performance in the agricultural sector at the meso level. Czyżewski *et al.* (2020) provided a system of indicators at the level of districts, characterizing environmental pollution, most of which we used in our analysis. Because the statistical record of the Russian regions is carried out according to a wider nomenclature of attributes, we carried out a more profound and detailed analysis of the ecological condition, taking into account the availability of data. The main problems with the models reviewed were the need for a comprehensive approach to assessing ecological and economic efficiency and using a limited number of characteristics. Many models have placed greater emphasis on economic performance at the expense of ecological performance. Schaible *et al.* (2015) noted that government conservation programs' ecological and economic efficiency improves when the heterogeneity of farms and the differences in farmers' motivation to invest in management and greening the business are more clearly taken into account in their implementation. This approach has necessitated research into the particular characteristics of ecological and economic efficiency at the enterprise level. Many researchers (Lopes *et al.* 2011; Gómez-Limón *et al.* 2012; Maia *et al.* 2016; Grzelak et al. 2019) have conducted a comprehensive comparative analysis of the ecological impacts of conventional and ecologically oriented agribusiness enterprises. Karelov (2013) calculated a composite indicator of ecological and economic production efficiency (EEPE) for agricultural enterprises. However, only ecological parameters were taken into account to a greater extent. According to Anfinogentova's methodology (Anfinogentova 2017), agricultural organizations' ecological responsibility level was assessed based on the Mandelbrot set basic formula and the Hurst statistical indicator. The limitations of the application of the described techniques are related to the fact that small and medium agribusiness enterprises do not fully account for the ecological characteristics of their activities, and in large agribusiness enterprises, deliberate and unintentional distortions of information about the level of ecological damage are allowed, so the application of this methodology is not transparent and informative enough. To assess ecological and economic efficiency, many authors (Dudin *et al.* 2016; Thompson 2017; Babanskaya *et al.* 2022; Migunov *et al.* 2021, 2023) include a combination of indicators of production profitability and pollution abatement efficiency. We share the authors' approach, introducing the indicator of overall profitability and emphasizing the feasibility of implementing economically unprofitable but ecologically effective projects (Babanskaya *et al.* 2023). By analogy with this assessment methodology, projects with a positive integral indicator of ecological and economic efficiency can be implemented in which the ecological benefits outweigh the insufficient level of economic efficiency. "It is clear that ecologically responsible behavior has become one of the main drivers of business development and competitiveness. International financial institutions take this into account when granting loans. In addition, several major international banks have adopted the so-called "Equator Principles" which take into account ecological aspects when lending to businesses" (Wittenberg 2010). In the Russian Federation, the problems of ecological responsibility have remained without due attention at the state level for a

long time. The notion and criteria of an ecologically responsible enterprise are not defined at the legislative and methodological levels.

MATERIALS AND METHODS

The methodological approach to analyzing the efficiency and competitiveness of crop producers, taking into account ecological parameters, includes seven stages presented in Fig. 1.

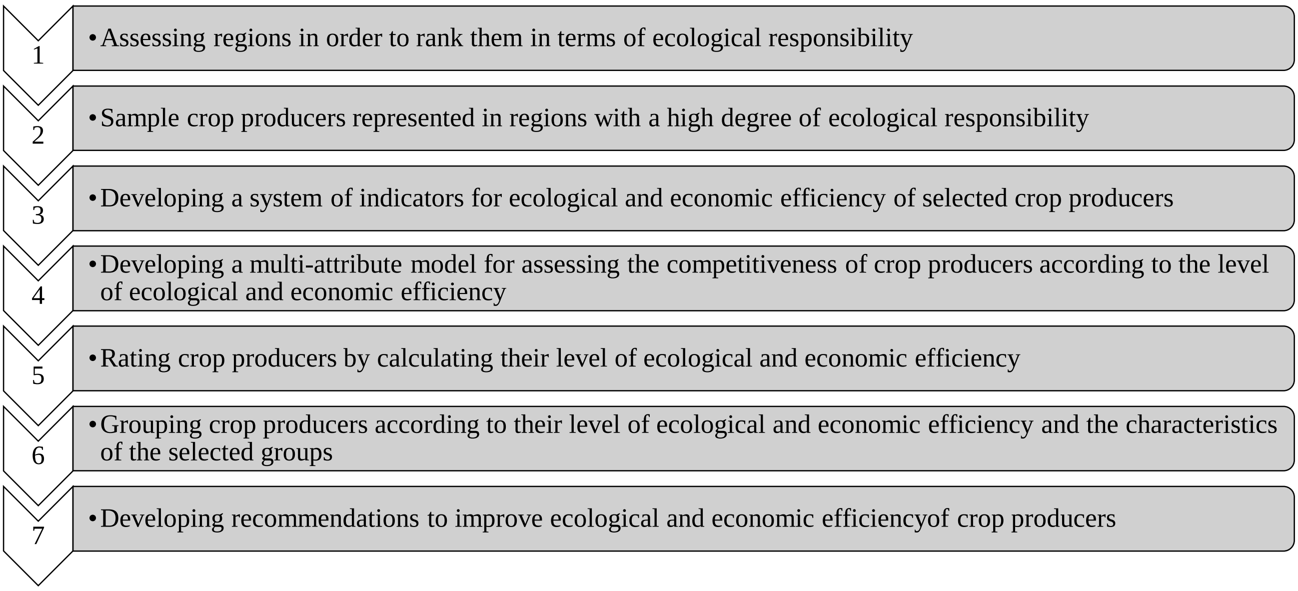

Fig. 1. Methodological approach of the study*; * developed by the authors.

The first stage assumes the analysis of the RF subjects. Its purpose is to provide the information base for developing the mechanism for supporting ecologically oriented management of the territories' development necessary for the production of environmentally friendly products in agriculture. The initial database contains generalized characteristics by regions in the form of categorical data and time series. Statistical indicators have been selected. They reflect the specifics of the territorial structure of the country as fully as possible – the significant length from south to north and from west to east, which leads to a high degree of differences in soil and climatic conditions, population density, the land endowment of the subjects of the Russian Federation. Ivanova E, Myronidis D and Arustamov EA have presented examples of studies of territories by ecological characteristics (Arustamov 2017; Ivanova & Myronidis 2022). An analysis of the Russian regions in terms of ecological responsibility was carried out using the following system of statistical indicators: atmospheric emissions per regional area; share of air pollutants captured and neutralized in the total amount of pollutants discharged from stationary sources; ecological protection expenditure per regional area; share of waste neutralized. Regions that were favorable for crop production and had a high rating for environmental responsibility were selected. The second stage involved the selection of enterprises. Sixty five grain and mixed specialization crop producers were selected as the object of the study. There are 227 certified organic producers registered in Russia, including 30 certified enterprises – organic producers in the regions selected in the first step. They are included in the general population. This ensures that all of the existing production facts under the principles of environmental responsibility are considered. This sample was supplemented by an alternative type of producers in comparable numbers – 35 leading non-organic crop producers from the same regions, confirming the sample's representativeness. The scale of operations of the enterprises noted differs considerably, so it is advisable to group them into three segments: large, medium, and small based on the indicator "Revenue" and assess ecological and economic efficiency separately for each segment (Kisseleva 2022). The main criteria for selecting enterprises for their ecological and economic assessment were the following: type of economic activity, the volume of production and sales, and the ecological responsibility rating of the Russian regions. In this study, an enterprise will be considered ecologically responsible if it maintains a balance between economic and ecological performance and operates not only within the framework of economic efficiency and competitiveness but also takes into account the principles of ecological thinking described by UNESCO. In the third stage, a system of indicators characterizing crop producers' ecological and economic efficiency (EEE) was offered. Like Moulogianni & Bournaris (2021), the study takes a holistic approach, using quantitative and qualitative indicators of local conditions, needs, and priorities for sustainable development. Traditionally, the indicators of economic efficiency are various types of profitability and business activity, calculated based on open official data of the enterprises' accounting financial statements. The indicators of ecological efficiency are those offered by the authors to assess the ecological responsibility of enterprises that are not a commercial secret and are simple to collect, analyze, and assess the key ecological components of business processes. Five groups of indicators were selected as basic characteristics of economic efficiency, characterizing separately different aspects of crop producers: the scale of operations, business efficiency in general, return on investment, efficiency of core activities (production and sales), and the structure of assets and liabilities (Table 1). Three groups of indicators have been developed to meet the criteria of ecological responsibility in the sphere of production, circulation, and administrative parameters to assess ecological efficiency (Table 2).

Table 1. Terms for assessing crop producers for economic efficiency.

Group	Characteristic	Calculation Details	Desired Value P_j^*	Normative Values (Threshold) P_j^{min}	Weight Factor K_i^j
Economic Efficiency ($G_i^{economy}$)					
Range Activity " (I_i^{RA})	Revenues, R (g_i^R)	Natural logarithm of inflation-adjusted revenues adjusted for inflation	1.155	1.101	0.055
	Cost of Assets, COA (g_i^{COA})	Natural logarithm of inflation-adjusted balance sheet total	1.310	1.140	0.045
Efficiency of Business	Return on Equity, ROE (g_i^{ROE})	Ratio of net profit to equity	20.000	12.276	0.067
	Return on Assets, ROA (g_i^{ROA})	Ratio of net profit to total assets of the enterprise	24.507	5.000	0.082
Efficiency of Investments (I_i^{EOI})	Return on Investment in Fixed Assets, ROI (g_i^{ROI})	Ratio of operating profit to operating costs [(revenue – cost of sales) / cost of sales]	35.000	7.000	0.041
	Return on Fixed Assets, ROFA (g_i^{ROFA})	Ratio of operating profit to cost of property, plant and equipment	25.000	10.000	0.034
Efficiency of Sales	Return on Sales, ROS (g_i^{ROS})	Ratio of profit on sales to revenue	15.000	5.000	0.069
	Asset Turnover, ATO (g_i^{ATO})	Ratio of revenue to total assets of the enterprise	0.500	0.300	0.056
Structure of Assets and	Capitalisation/Financial Leverage Ratio, LR (g_i^{LR})	Ratio of total assets to equity	1.500	0.500	0.028
	Current Ratio, CR (g_i^{CR})	Ratio of current assets to current liabilities	1.700	1.000	0.023

* developed by the authors based on the results of the analysis.

The source of information for assessing economic efficiency is the State Information Resource for Accounting (Financial) Reporting of the Russian Federation. The study period is from 2018 to 2021. The sources of information for assessing ecological efficiency are the survey results, data from the official websites of organizations and statistical reporting (Federal Service for Supervision of Natural Resources Management 2021). All input, intermediate, and output parameters have been considered based on available (open) data that are not commercially sensitive to crop producers for a comprehensive and accurate assessment of ecological and economic efficiency. Based on the ecological block of indicators, the criteria for differentiation of agribusiness enterprises according to the level of ecological responsibility was developed. When taking into account only the ecological indicators to assess the ecological responsibility of the enterprise, the authors offer to use the following system of differentiation: high level of ecological responsibility scores from 16 to 21 points, sufficient level of ecological responsibility – from 10 to 15 points and low level of ecological responsibility of enterprises – from 1 to 9 points. The fourth stage consists of constructing a multiattribute model of the competitiveness of crop producers according to the level of ecological and economic efficiency. The problem of comparing quantitative and qualitative indicators of ecological and economic efficiency, presented in Tables 1 and 2, will be solved by applying the method of unit utility, adapted by the authors for crop producers (Bashina *et al.* 2016.). According to this approach, the assessment is carried out using a multiattribute model characterized by three components:

the structure of the model, reflecting the relationship of macroattributes, microattributes, and indicators; weight factors; and the method of assessment. The formalization of requirements for crop producers in terms of ecological and economic efficiency in order to implement the principles of ecological responsibility is carried out in several stages:

The construction of a hierarchical multiattribute model of the competitiveness of enterprises (Fig. 2);

The construction of an additive model of the competitiveness of enterprises;

The calculation of ecological and economic efficiency of enterprises (using the unit utility calculation method).

Transforming the structure of the multiattribute model of a crop producer's competitiveness according to the level of ecological and economic efficiency allows for modification. With sufficient information, ecological costs, production performance, using ecologically friendly technologies, environmental conditions, bioclimatic potential, land quality, and other factors can be considered.

The authors of this paper offer to determine the ecological and economic efficiency of a crop producer in order to implement the principles of ecological responsibility, based on the macro attribute "Economic Efficiency" (Table 1) and the macro attribute "Ecological Efficiency" (Table 2).

To determine the weight factors of the hierarchical multi-attribute model for assessing the competitiveness of crop producers, we conducted a survey among 135 respondents to obtain a representative sample. The interviewees were agricultural university professors and crop producers' employees. The authors considered the compensatory method of assessment the most applicable for a multiattribute model for assessing the competitiveness of a crop producer according to the level of ecological and economic efficiency to implement the principles of ecological responsibility. In this method, the weaknesses of the enterprise can be compensated by strengths (Bashina *et al.* 2016). Estimated weight factors are defined as the product of the weight factor of the indicator itself, the weight factor of the microattribute, and the weight factor of the macroattribute in which the indicator is included. For example, for Return on Assets, the estimated weight factor would be:

$$K_i^{ROA} = a_i^{ROA} \times a_i^{EOB} \times a_i^{economy} = \quad 0.0825 \qquad \textbf{(1)}$$

Table 2. Terms for assessing crop producers for ecological efficiency

Group	Characteristic	Calculation Details	Desired Value P_j^*	Normative Values (Threshold) P_j^{min}	Weight Factor K_i^j
Ecological Efficiency ($G_i^{ecology}$).					
Sphere of Production " (J_i^{SOP})	Waste Management, WM (g_i^{WM})	One point for each of the indicators: "Recycling", "Waste management"	2	1	0.070
	Power Supply, PS (g_i^{PS})	One point for each of the indicators: "Hybrid energy systems", "Alternative energy sources (wind, water, solar)"	2	0	0.040
	Resource and Technological Potential, RATP (g_i^{RATP})	One point for each of the indicators: "Precision farming, breeding and genetic innovation", "Intensive closed-loop technology"	2	0	0.060
	Ecological Parameters of Products, EPOP (g_i^{EPOP})	One point for each of the indicators: "Organic, ecologically friendly products", "Several eco benefits (products made from recycled raw materials, natural composition, biodegradable, etc.)", "Eco-brand, eco-labelling of products"	3	1	0.030
Sphere of Treatment " (J_i^{SOT})	Transport and Logistics Parameters, TALP (g_i^{TALP})	One point for each of the indicators: "Sustainable transport (rail, sea, river)", "Alternative modes of transport (electric vehicles)", "Sustainable logistics (transport minimization)"	3	1	0.096
	Packaging and Storage, PAS (g_i^{PAS})	One point for each of the indicators: "Renewable packaging materials used", "Reusable packaging"	2	1	0.078
Administ rative Paramete	Ecological Management Parameters, EMP (g_i^{EMP})	One point for each of the indicators: "Ecological development programs of the enterprise", "Internal Ecological audit", "Basic Ecological documentation, waste disposal contracts"	3	1	0.044

Ecological Taxation and Payments, ETAP (g_i^{ETAP})	One point for each indicator: "Payment of Ecological taxes", "Ecological payments of non-tax nature (utilization fees, charges for negative impact and use of natural resources)	2	1	0.056
Ecological Reporting, ER (g_i^{ER})	One point for each of the indicators: "Reporting reflects general Ecological information", "Reporting reflects indicators that characterize the level of Ecological status"	2	1	0.025

* developed by the authors based on the results of the analysis.

Tables 1 and 2 present the justification of the desired and normative (threshold) values and the results of weight factor calculations. Achieving thresholds is the criterion for a crop producer's efficiency and competitiveness.
This paper uses a method for assessing the ecological and economic efficiency of an enterprise based on assessing the degree of proximity of the real values of ecological and economic efficiency indicators in the enterprise in question to the desired "ideal" value of these indicators. Efficiency is assumed to be higher in those enterprises where the real characteristics are least different from the desired ones in the system for assessing ecological and economic efficiency.

We will calculate the parametric indicators of proximity to the "ideal" enterprise using the formula:

$$g_i^j = \frac{P_i^j - P_j^{min}}{P_j^* - P_j^{min}}, \quad (2)$$

where P_i^j is the value of the indicator j for the enterprise i;
P_j^* is the value of the indicator j at which the criterion of efficiency, competitiveness (the desired value) is fully met;
P_j^{min} is the minimum value of the indicator j to be included in the system for assessing ecological and economic efficiency [regulatory (threshold) value].
The formula for calculating the integral indicator of an enterprise's ecological and economic efficiency can be represented as follow:

$$EEE_i = \sum_{j=1}^{n} K_i^j \times g_i^j, \quad (3)$$

where n is the number of indicators of the enterprise;
K_i^j is the weight factor of the microattribute j of the enterprise i;
g_i^j is a parametric proximity indicator of the microattribute j of the enterprise i.
The fifth stage of the methodological approach consists in rating crop producers according to the level of ecological and economic efficiency.
Two parameters are used as the basis for rating enterprises: the ecological and economic efficiency of the enterprise and the deviation value of the enterprise in question from the ideal one.
The higher the value of eco-efficiency, the higher the enterprise's competitiveness and investment attractiveness in the current market environment. However, the value of the integral indicator of EEУ according to the unit utility method does not show the degree of proximity of enterprises' characteristics to each other.
The deviation value of the enterprise i in question from the "ideal" enterprise can be determined by using the ratio:

$$l_i = \sqrt{\sum_{j=1}^{n} (g_j^0 - g_j^i)^2} \quad (4)$$

where n is the number of indicators of the enterprise;
g_j^0 is the value of a single parametric proximity indicator j for the "ideal" enterprise;
g_j^i is the value of a single parametric proximity indicator j for the enterprise i.
For the "ideal" enterprise the value P_j^0 of each indicator j is equal to the desired value of P_j^*, i.e. $P_j^0 = P_j^*$.
The introduced indicators are used as rating coordinates for enterprises. The ecological and economic efficiency (EEEi) that we have calculated determines the first rating indicator, and the second coordinate is the deviation

value l_i. At Stage 6, the rating results were used to identify groups of crop producers according to the degree of their ecological and economic efficiency: highly efficient, efficient, low-efficient, and inefficient. At the seventh stage, each group is characterized, and recommendations are offered to improve the crop producer's competitiveness and ecological and economic efficiency.

RESULTS AND DISCUSSION

Based on the developed methodological approach, the ecological responsibility rating of the Russian regions was calculated without the autonomous districts and federal cities of St. Petersburg, Moscow, and Sevastopol (Table 3). Since the study is based on an assessment of environmentally responsible business practices, the top region group is of the utmost interest.

Table 3. Grouping of the Russian regions by level of ecological responsibility.

Group	Intervals by Level of Ecological Responsibility, point	Number of Regions
lowest	up to 29	20
medium	30 to 49	33
top	over 50	26

* developed by the authors based on the results of the analysis.

The Moscow Region leads the rating, which is generally explained by the highest ecological expenditure, more than 20 times the national average, and a high level of waste management. The high level of ecological expenditure and a well-developed waste management system compensate even for the high level of air pollutant emissions from stationary sources, almost five times as high as the Russian average. The region is predominantly home to agricultural holdings and large agro-industrial producers but primarily processing companies with a high degree of ecological responsibility. There are organic producers, but their number is small. Overall, agriculture does not play a significant role in forming the gross regional product. However, regional enterprises should be primarily considered when analyzing large businesses (Fig. 3). The regions of the top group, by the degree of ecological responsibility, also include the subjects of the Russian Federation, which has a predominantly agricultural orientation. First of all, we should mention the regions with a developed crop-producing sector (the Kaluga, Lipetsk, Tula, Tambov, Voronezh, Belgorod, Bryansk and Rostov Regions, Stavropol and Krasnodar Territories). These regions of large and medium-scale high-intensity production also have significant ecological costs and high levels of air pollutant emissions with adequate waste management. The enterprises of these regions are most interested in analyzing medium- and large-scale crop producers, which makes it necessary to include them in the sample. Some of the regions in the top group of ecologically responsible ones can also be characterized as low-urbanized, mainly with extensive traditional agriculture (Karachai-Cherkess Republic, Republic of Crimea, Republic of Mari El, Chuvash Republic, Republic of Adygeya, Republic of North Ossetia-Alania). These regions are characterized by low emissions and low levels of waste, with relatively low ecological expenditure. Small businesses prevail in these regions. In general, the Russian region's ecological responsibility level is variable, and there are also significant differences in its development trends (both positive and negative dynamics, including the presence of structural shifts). This indicates that the agricultural development processes in the regional context are far from uniform and are largely due to the existing specifics of farming. Data on 65 crop producers (including 30 certified organic producers) from the regions at the top level of ecological responsibility were selected and analyzed for comparative economic analysis of organic and non-organic producers, which mainly had grain specialization. They were differentiated into six groups by the average annual volume of revenues and affiliation to organic agriculture (Fig. 4). The average values of economic indicators were calculated using the arithmetic mean weighted formula in the grouped distribution series. The weight factors were the number of units in the aggregate in the different groups. Fig. 4 shows that the range activity of the enterprises causes differences in efficiency and competitive strategies between organic and non-organic crop producers. In this situation, only large representatives of the organic business will be sufficiently efficient and competitive in the produce market. Meanwhile, medium-scale organic crop producers in Russia show low efficiency in many respects, and small-scale producers could be more profitable. Nevertheless, the medium-scale organic and non-organic crop producers form the largest group, being the engine of rural development and employers for almost 50% of the rural labor force. Significant differences in the economic efficiency of medium-scale organic and non-organic crop producers necessitated further comparative analysis of their ecological and economic efficiency levels. This will make it possible to assess differences in economic efficiency as well as ecological and economic efficiency and also to identify areas to improve crop producers' competitiveness. Using the developed methodological approach to the integral assessment of ecological and economic efficiency of organic and non-organic crop producers, a multiattribute model of competitiveness assessment was built, and the level of ecological and economic efficiency of medium-scale enterprises was calculated. The results of the rating of medium-scale crop producers in terms of ecological and economic efficiency are presented in Fig. 5. As the dots are grouped, this indicates that there are groups of crop producers qualitatively homogeneous in terms of the level of ecological and economic efficiency with marked differences between the groups. The developed rating of crop producers according to the level of ecological and economic efficiency are as follows: high-efficient – with an EEE value of 0.96 and above, efficient – from 0.5 to 0.96, low-efficient – from 0 to 0.5, and inefficient – less than 0.

ECOLOGICAL AND ECONOMIC EFFICIENCY (EEE)

Macroattribute **"Economic Efficiency"**

Weight factor $G_i^{economy}$=0.5

Microattribute **"Range Activity"**

weight factor

a^{RA} = 0.2

parametric indicators:

- "Revenues" (R), *a^{R} =0.55;*
- "Cost of Assets" (COA), *a^{COA}=0.45.*

Microattribute **"Efficiency of Business"**

weight factor

a^{EOB} = 0.33

parametric indicators:

- "Return on Equity" (ROE), *a^{ROE}=0.45;*
- "Return on Assets" (ROA), *a^{ROA}=0.55.*

Microattribute **"Efficiency of Sales"**

weight factor a^{EOS} = 0.25

parametric indicators:

- "Return on Sales" (ROS), *a^{ROS}=0.55;*
- "Asset Turnover" (ATO), *a^{ATO}=0.45*

Microattribute **"Efficiency of Investments"**

weight factor

a^{EOI}= 0.15

parametric indicators:

- "Return on Investment" (ROI), *a^{ROI}=0.55;*
- "Return on Fixed Assets" (ROFA), *a^{ROFA}=0.45*

Microattribute **"Structure of Assets and Liabilities"**

weight factor

a^{SOAL} = 0.1

parametric indicators:

- "Capitalisation/ Financial Leverage Ratio" (LR), *a^{LR}=0.55;*
- "Current Ratio" (CR), *a^{CR}=0.45*

Macroattribute **"Ecological Efficiency"**

Weight factor $G_i^{ecology}$=0.5

Microattribute **"Sphere of Production"**

weight factor a^{SOP}= 0.4

parametric indicators:

"Waste Management" (WM), *a^{WM} = 0.35;*

- "Power Supply" (PS), *a^{PS} =0.2;*
- "Resource and Technological Potential" (RATP), *a^{RATP}=0.3;*
- "Ecological Parameters of Products" (EPOP), *a^{EPOP}=0.15*

Microattribute **"Administrative Parameters"**

weight factor a^{AP}=0.25

parametric indicators:

- "Ecological Management Parameters" (EMP), *a^{EMP}=0.35;*
- "Ecological Taxation and Payments" (ETAP), *a^{ETAP}=0.45;*
- "Ecological reporting" (ER), *a^{ER} =0.2*

Microattribute **"Sphere of Treatment"**

weight factor a^{SOT} = 0.35

parametric indicators:

- "Transport and Logistics Parameters" (TALP), *a^{TALP} =0.55;*
- "Product Packaging and Storage" (PAS), *a^{RAS} =0.45*

Fig. 2. Structure of the multiattribute model for assessing the competitiveness of a crop producer according to the level of ecological and economic efficiency*; * developed by the authors.

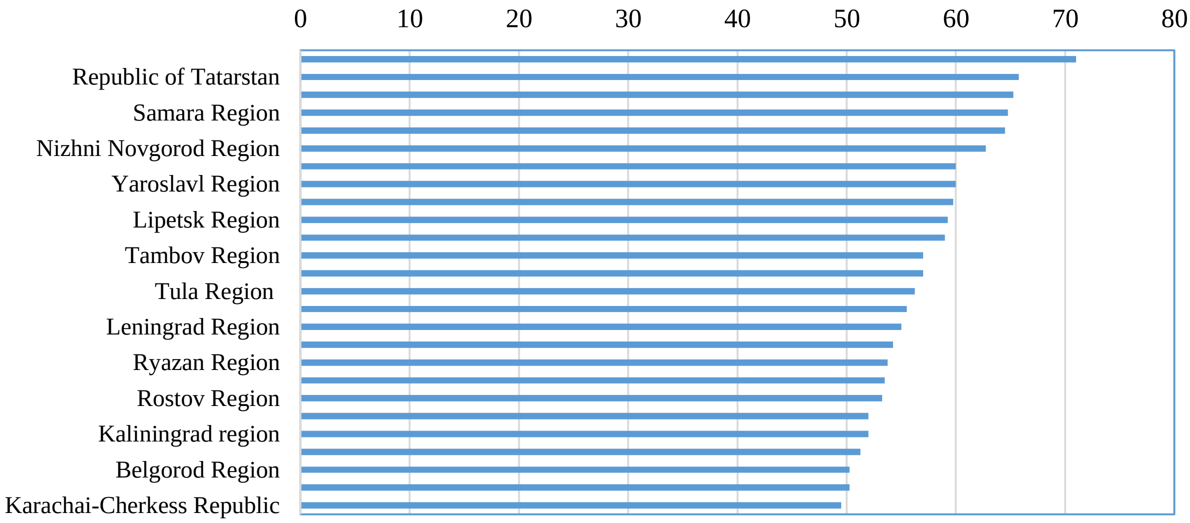

Fig. 3. Ecological responsibility rating of the top group of the Russian regions, 2021*; * compiled by the authors on the basis of calculations.

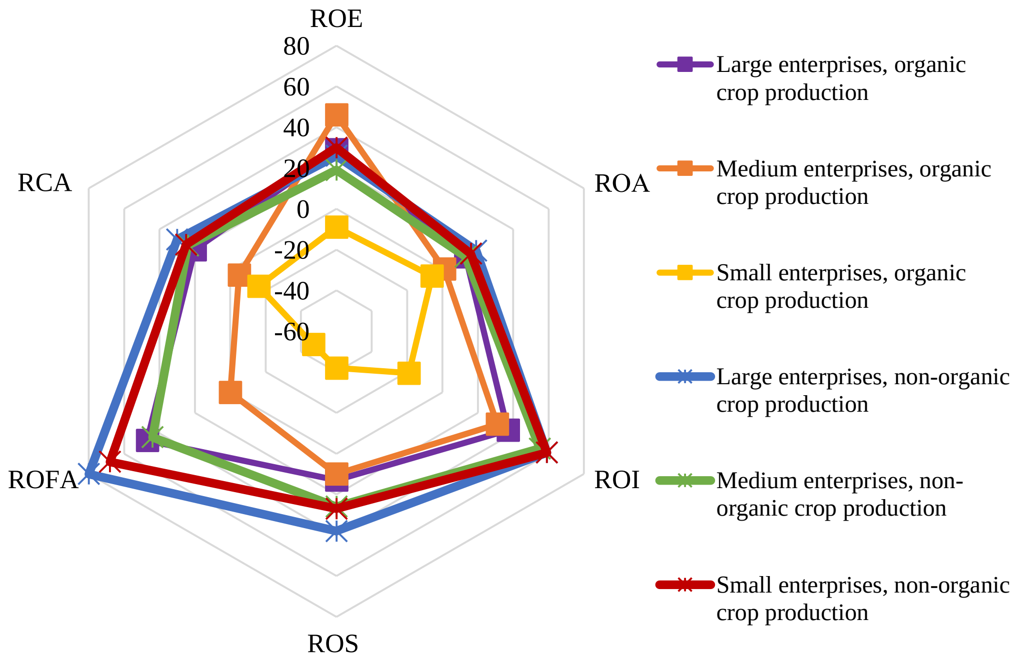

Fig. 4. Comparative analysis of economic efficiency of organic and non-organic crop producers in Russia, differentiated by revenues*, 2021*; * large – average annual revenues of more than 1,000,000 thousand rubles; medium – average annual revenue from 500,000 to 1,000,000 thousand rubles; small – average annual revenue less than 500, 000 thousand rubles; ** compiled by the authors based on the results of the analysis.

The first group of highly efficient enterprises includes highly profitable crop producers with increased or neutral ecological responsibility. These enterprises have one or more eco-benefits and a high turnover rate, which makes them highly potential for developing eco-oriented production. The second group of efficient enterprises includes moderately profitable crop producers with increased or high indicators of ecological responsibility. In this group, an ecologically responsible approach to crop production compensates for the lack of economic efficiency. These enterprises have several eco-benefits and, in most cases, differentiated activities by type of production (grain crop production is combined with different types of livestock production), allowing them to provide a closed production cycle and increased ecological effect. These enterprises are either already organic or have sufficient economic potential to develop organic crop production. The third group of low-efficient enterprises includes low-profit crop producers with neutral ecological responsibility indicators. These enterprises have one or more eco-advantages and, while they have a good return on sales, a very low return on equity, indicating management errors in organizing activities and managing resources. Such enterprises have underestimated economic potential and lack the financial resources to develop eco-oriented production.

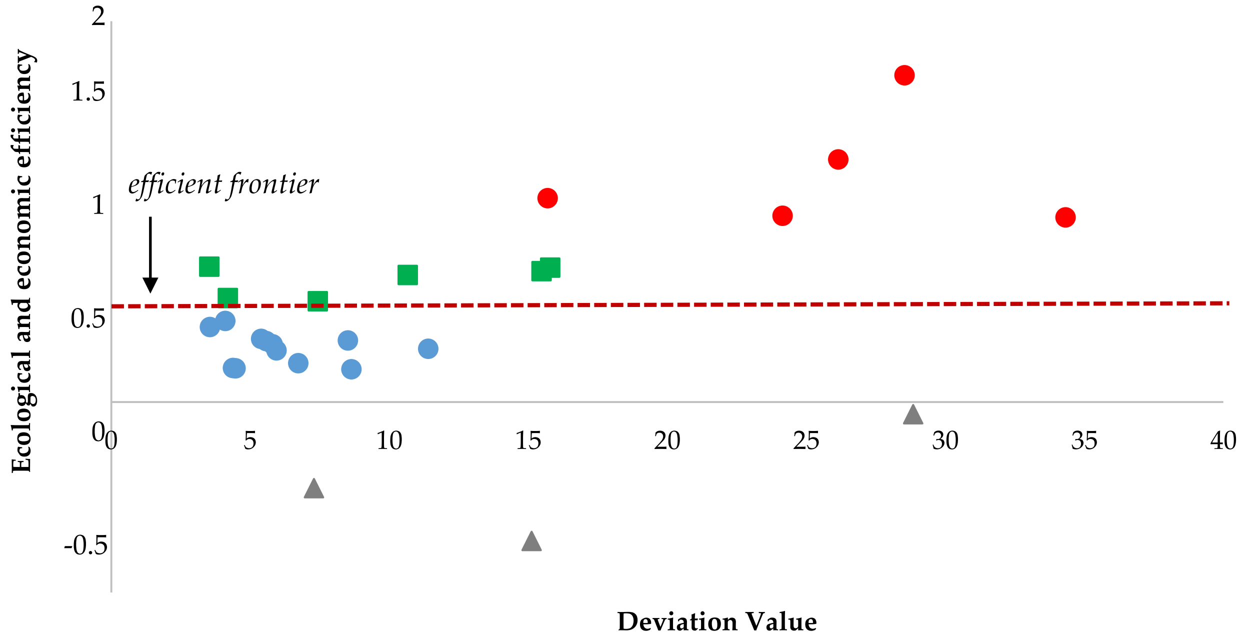

Fig. 5. Rating of crop producers by level of ecological and economic efficiency (EEE) *; * compiled by the authors based on the calculation results of the multiattribute EEE model.

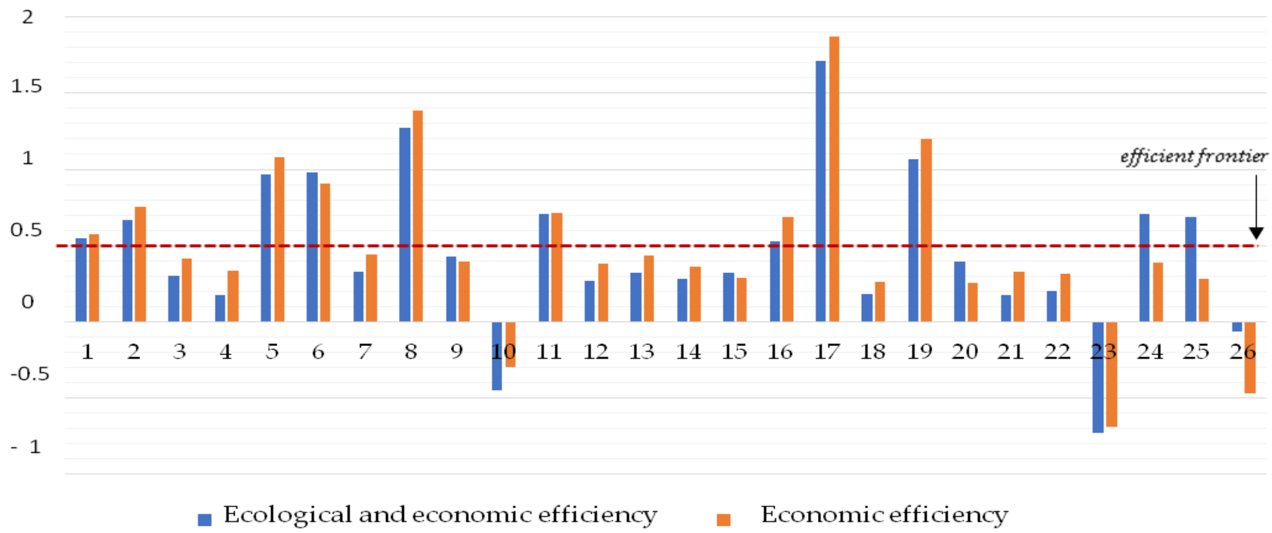

Fig. 6. Comparison of economic efficiency and ecological and economic efficiency of crop producers*; * compiled by the authors based on the calculation results of the multiattribute EEE model.

The fourth group of inefficient enterprises is characterized by unprofitable activities and the impossibility of financing ecological crop production. When comparing economic efficiency and ecological and economic efficiency (Fig. 6), the tendency to compensate weakened economic parameters with strong ecological ones is very noticeable. It is obvious for the most ecologically responsible crop producers No. 20, 24, 25, 26.

CONCLUSIONS

The shift in socio-economic formation requires resource-efficient rather than resource-conserving business models for agribusiness enterprises. This, in turn, means that enterprises must build their businesses ecologically responsible in the context of the "Green Economy" and responsible consumption paradigms. This necessitates a unified assessment of the quality of enterprises based on an integral indicator of ecological and economic efficiency. The methodological approach developed by the authors to determine the ecological and economic efficiency of crop producers of traditional and ecologically-oriented production has several advantages compared to similar studies conducted in Russia and abroad. The main advantage of this methodological approach is its universality, based on the use of exclusively official statistical information available to all users. The ecological efficiency indicators offered by the authors are the indicators to assess the ecological responsibility of enterprises, which are not a commercial secret and are easy to collect, analyze, and assess the key ecological characteristics. All characteristics included in the system of indicators comply with Russian and international statistical practices, as well as Russian and international financial reporting standards, which makes it possible to use the methodological approach not only for Russian but also for foreign companies. The methodological approach is highly flexible due to the possibility of managing weight factors and including additional characteristics corresponding to the research request. The methodological approach can be combined or individually to assess economic or ecological characteristics. Limitations are related to the difficulty of collecting data on the objects under analysis. In Russia, agribusiness enterprises have no legally established content or requirement to provide full information on the environmental costs. A more in-depth analysis of environmental and economic efficiency can be carried out using the example of other countries where full environmental reporting by agribusiness enterprises is generated. The next stage of the study will involve developing environmental reporting forms to improve the analytical capacity for assessing the level of environmental responsibility of agribusiness enterprises. The proposed approach has been developed for regions with low, medium, and high environmental responsibility ratings. The approach was tested on one of the types of regions with a high level of environmental performance. The greatest amount of environmental information is available for regions of this type. The selection of regions ensures the comparability of indicators when comparing objects. This methodological approach is further developed by providing the possibility to compare regions of different types by expanding the system of indicators to assess the rating of regions and refining the system of weight factors. The methodological approach for assessing ecological and economic efficiency has been developed, taking into account the 2030 Agenda for Sustainable Development (UN General Assembly Resolution 70/1), the "State Policy for Environmental Protection," and regional programs for the development of the "Green Economy."

The created database and the developed methodological approach can be used for:

developing ecological and economic ratings of enterprises when addressing state support for crop producers;

tracking progress in the indicators of ecological responsibility of enterprises and ecological protection;

strengthening the integration of enterprises interests of the state in the sectoral policy.

Based on the results of the comparative analysis and integral assessment of ecological and economic efficiency, recommendations for increasing the level of ecological responsibility and competitiveness of crop producers are offered:

Firstly, it is advisable to start developing ecologically responsible business with large crop producers by cascading their activities' transformation towards greening business processes and increasing their eco-benefits.

Secondly, further development of state support and subsidy programs is required to scale up the ecologically responsible approach in medium-scale crop producers and strengthen their competitive position in the market. Such programs are already being implemented in many Russian regions by providing subsidies, budget investments, and state and municipal guarantees for the obligations of small and medium-scale enterprises, introducing "green" standards and ecological management according to the International Organization for Standardization (ISO) of series 9000 and 14000. The offered integral assessment of ecological and economic efficiency can serve as the basis for making decisions on the allocation of budgetary resources and state support to enterprises, considering the parameters of ecological responsibility. Thirdly, the implementation of the state support mechanism will not significantly affect small-scale organic crop producers. This group should pay attention to the possibilities of cooperation to strengthen business processes and activities' efficiency. Fourthly, while rating enterprises, the methodological approach based on ecological and economic assessment increases the investment attractiveness of organic agriculture and ecologically responsible businesses, motivating owners to implement ecological development programs. Fifthly, the developed methodological approach will help the regions to strengthen the ecological orientation of crop producers and strengthen their competitive positions in the ecological responsibility rating of the Russian regions. The developed methodological approach makes it possible to create a reasonable system of economic incentives for waste recycling for federal and regional authorities and businesses through stimulating levels of environmental payments, tax preferences and preferential lending and to change the system of key performance indicators (KPI) by incorporating ecological parameters into it, which helps to stimulate environmentally responsible behavior related to improving the quality parameters of the environment and the waste recycling industry.

ACKNOWLEDGMENTS

This study was supported by Russian State Agrarian University – Moscow Timiryazev Agricultural Academy within the framework of the intra-university grant competition "Food Sovereignty", the project theme is "Study of the conceptual foundations for the analysis of efficiency and competitiveness of ecologically responsible agribusiness enterprises of the Russian Federation" №5 in the framework of the implementation of the program of university development "AgroBreakthroughs-2030" of the strategic leadership program "Priority-2030".

REFERENCES

Anfinogentova, AA, Dudin, MN, Lyasnikov, NV, Protsenko, OD 2017, Methodology for assessing the quality of agribusiness enterprises based on ecologically responsible approach. *Regional Economy,* 13: 579-590. http://dx.doi.org/10.17059/2017-2-22, [In Russian].

Arustamov, EA 2017, Ratings and criteria for assessing the ecological state of Russian cities and regions. *Internet Journal Naukovovedenie,* 9(4). URL: http://naukovedenie.ru/PDF/41EVN417.pdf, [In Russian]. Babanskaya, AS, Telegina, ZA, Kolomeeva, ES, Minaeva, VM, Tikunova, AS, Usanov, AY, Tryastsina, NY 2023, Analysis of the financial state and efficiency of activities of organic producers in Russia. *WSEAS Transactions on Business and Economics,* 20: 1916-1927, https://doi.org/10.37394/23207.2023.20.167.

Babanskaya A, Kolomeeva E, Migunov R, Telegina Z & Grudneva A 2022, Directions and prospects of sustainable development of the national accounting and analytical system of agricultural formations. *IOP Conference Series: Earth and Environmental Science*, p. 012002. DOI: 10.1088/1755-1315/949/1/012002. EDN WAEFGJ.

Bashina, OE, Komlev, EB, Mamaeva, NV 2016, Assessment of the firm's market position under price competition. Proceedings of Tula State University. Economic and Legal Sciences, 3: 66-75, URL: https://ideas.repec.org/a/scn/013908/16941546.html, [In Russian].

Czyżewski, B, Smędzik-Ambroży, K & Mrówczyńska-Kamińska, A 2020, Impact of environmental policy on eco-efficiency in country districts in Poland: How does the decreasing return to scale change perspectives? *Environmental Impact Assessment Review,* 84: 106431. https://doi.org/10.1016/j.eiar.2020.106431.

Dudin, MN, Frolova, EE, Artemieva, JA, Bezbah, VV & Kirsanov, AN 2016, Problems and Perspectives of BRICS Countries Transfer to “Green Economy” and Law-carbon Energy Industry. *International Journal of Energy Economics and Policy,* 6: 714-720, URL: https://dergipark.org.tr/en/download/article-file/361673.

Ghimire, SR, Johnston, JM 2017, A modified eco-efficiency framework and methodology for advancing the state of practice of sustainability analysis as applied to green infrastructure. Author manuscript; available in PMC 2018 Aug. 15, *Integrated Environmental Assessment and Management (IEAM),* 13: 821-831, https://doi.org/10.1002/ieam.1928.

Gómez-Limón, JA, Picazo-Tadeo, AJ & Reig-Martínez, E 2012, Eco-efficiency assessment of olive farms in Andalusia. *Land Use Policy,* 29: 395-406, https://doi.org/10.1016/j.landusepol.2011.08.004.

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, https://doi.org/10.1016/j.jclepro.2019.118304.

Houssard, C, Revéret, J-P, Maxime, D, Pouliot, Y, Margni, M 2022, Measuring shared value creation with eco-efficiency: Development of a multidimensional value framework for the dairy industry. *Journal of Cleaner Production,* 374. https://doi.org/10.1016/j.jclepro.2022.133840.

Ivanova, E, Myronidis, D 2022, Application of an integrated methodology for spatial classification of the environmental flow in the Bulgarian-Greek Rhodope Mountain Range. *International Journal of Sustainable Agricultural Management and Informatics,* 8: 84-103, https://doi.org/10.1504/IJSAMI.2022.123045.

Karelov, AC 2013, Estimation of ecological and economic efficiency of production (by the example of enterprises of copper industry). PhD (Ec) Dissertation, 08.00.05, Economics and management of national economy (economics of nature management). The Ural Federal University named after the first President of Russia BN, Yeltsin: Yekaterinburg. URL: https://www.dissercat.com/content/otsenka-ekologo-ekonomicheskoi-effektivnosti-proizvodstva, [In Russian].

Kisseleva, NA 2022, Peculiarities of functioning of small and medium-sized entrepreneurship at the modern stage of economic development. *Science & Technique,* 21: 436-443. https://doi.org/10.21122/2227-1031-2022-21-5-436-443.

Köne, AC 2012, The Analytic Hierarchy Process (AHP) approach for assessment of regional environmental sustainability. Conference: 2012 Berlin Conference of the Human Dimensions of Global Environmental Change on "Evidence for Sustainable Development", URL: https://www.researchgate.net/ publication/235639975.

Lopes, CM, Santos, TP, Monteiro, A, Rodrigues, ML, Costa, JM & Chaves, MM 2011, Combining cover cropping with deficit irrigation in a Mediterranean low vigor vineyard. *Scientia Horticulturae,* 129: 603-612. https://doi.org/10.1016/j.scienta.2011.04.033.

Maia, R, Silva, C, Costa, E 2016, Eco-efficiency assessment in the agricultural sector: the Monte Novo irrigation perimeter. *Journal of Cleaner Production*, 138: 217-228, https://doi.org/10.1016/j.jclepro.2016.04.019.

Migunov, R, Babanskaya A, Kolomeeva, E, Nifontofa, E & Brusenko, S 2021, Institutional changes and their impact on agricultural economics in Russia in 1952-2018. *The Challenge of Sustainability in Agricultural Systems,* DOI 10.1007/978-3-030-73097-0_69.

Migunov, R, Syutkina, A, Zaruk, N, Kolomeeva, E & Arzamastseva, N 2023, Global challenges and barriers to sustainable economic growth in the agribusiness sector. *WSEAS Transactions on Business and Economics*. DOI 10.37394/23207.2023.20.85.

Moulogianni, C & Bournaris, T 2021, Assessing the Impacts of Rural Development Plan Measures on the Sustainability of Agricultural Holdings Using a PMP Model. *Land*, 10: 446. https://doi.org/10.3390/ land10050446.

Moutinho, V, Madaleno, M & Robaina, M 2017, The economic and environmental efficiency assessment in EU cross-country: Evidence from DEA and quantile regression approach. *Ecological Indicators,* 78: 85-97. https://doi.org/10.1016/j.ecolind.2017.02.042.

Schaible, GD, Mishra, AK, Lambert, DM, Panterov, G 2015, Factors influencing environmental stewardship in U.S. agriculture: Conservation program participants vs. non-participants. *Land Use Policy,* 46: 125-141, http://dx.doi.org/10.1016/j.landusepol.2015.01.018.

The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard 2021, World Resources Institute: Washington, DC, USA, URL: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Thompson, PB 2017, The spirit of the soil: Agriculture and environmental ethics. London: Routledge, 208, http://doi.org/10.4324/9781315559971.

Trukhachev, VI, Sklyarov, IY, Sklyarova, JM, Latysheva, LA, *et al.* 2016, Contemporary state of resource potential of agriculture in South Russia. *International Journal of Economics and Financial Issues,* 6(S5): 33-41.

Wang, Z, Feng, C 2015, A performance evaluation of the energy, environmental, and economic efficiency and productivity in China: An application of global data envelopment analysis. *Applied Energy,* 147: 617-626. https://doi.org/10.1016/j.apenergy.2015.01.108.

Wittenberg, EJ 2010, Environmental Responsibility of Russian Business. *Russia and the Modern World*, 2: 31-48. URL: https://cyberleninka.ru/article/n/ekologicheskaya-otvetstvennost-rossiyskogo-biznesa/viewer, [In Russian].

Wu, J *et al.* 2016, Evaluating the environmental efficiency of a two-stage system with undesired outputs by a DEA approach: An interest preference perspective. *European Journal of Operational Research,* 3: 1047-1062, https://doi.org/10.1016/j.ejor.2016.04.034.

Xu, T, Gao, P, Yu, Q, Fang, D 2017, An Improved Eco-Efficiency Analysis Framework Based on Slacks-Based Measure Method, *Sustainability,* pp. 1-21, https://doi.org/10.3390/su9060952.

Zhang, B, Bi, J, Yuan, Z, Yuan, ZW, Ge, JJ 2018, Eco-efficiency analysis of industrial system in China: A data envelopment analysis approach. *Ecological Economics,* 1-2: 306-316, https://doi.org/10.1016/ j.ecolecon.2008.03.009.