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Environmental and socio-economic factors in the location of organic crop production

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ABSTRACT

The study aims to substantiate a methodological approach to the optimal location of organic crop production throughout the territory, considering soil-climatic, environmental, economic, and social conditions. The object of the study is territories located in different climatic zones. A system of statistical indicators has been developed to identify typical groups of territories for the possibility of producing organic products. The system includes 33 elements that characterize units in terms of condition and potential for economic development, level of agricultural production, climatic and environmental conditions, and demand potential for organic products. The technique is based on factor and cluster analysis. Factor analysis made it possible to identify five components underlying the grouping of territories. Using cluster analysis made it possible to identify with a high degree of accuracy seven groups with different conditions for agricultural production and potential for developing organic production, which, according to their characteristics, are suitable for producing certain agricultural products. Optimization of the location of organic production is explained by the requirements for the preservation of the environment, biodiversity, conditions for growing crops, and meeting the demand of consumers of environmentally friendly products

Keywords: Environmentally friendly, Crop production, Agricultural production, Organic products, Statistical indicators, Cluster analysis, Factor analysis.
Article type: Review Article.

INTRODUCTION

Climate change and increasing anthropogenic impact on the environment, leading to ecological problems, pose a threat to all countries and require the development of effective solutions in the organization of production processes, ensuring the application of resource-saving technologies, increasing production through the use of prosperous scientific advances in digitization, ecology, chemistry, breeding, etc. This is the focus of economic science research – the green economy, based on the fact that the economy is a dependent component of the natural environment within which it exists as its part. In the European countries and the USA, the noted areas of economic development are reflected in the document "A European Green Deal" (A European Green Deal. European Commission, Brussels, 11.12.2019 COM 2019) and others. Implementing their main provisions will ensure the absence of greenhouse gas emissions and economic growth unrelated to the uncontrolled use of resources. It will also form a resource-efficient and competitive economy. One of the main goals of the Green Deal is to improve human health and well-being. Agriculture plays the leading role in its achievement. It ensures the food security of each country and is responsible for the efficient use and preservation of natural resources that form the national wealth (Safiullin & Rylov 2020; Pivovarov *et al.* 2021; Kitsai *et al.* 2021; Thuan *et al.* 2023). The ideas of a healthy lifestyle and environmental protection have defined trends in consumer preferences in developed

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economies. These trends are aimed at the consumption of organic products. Between 1999 and 2019, global organic sales increased from $15.2 billion in 1999 to $106 billion in 2019, with an average annual growth of $4.6 billion. In Russia in 2021, organic sales amounted to €220 million. The Research Institute of Organic Agriculture (FiBL) predicts that by 2030, the market capacity will be around $300 billion. The growth of the global market for organic products forms a new niche for exporting products produced in Russia (Research Institute of Organic Agriculture FiBL & IFOAM, Organics International 2021; The World of Organic Agriculture Statistics and Emerging Trends 2021). The study aims to substantiate a universal methodological approach to the optimal location of organic crop production in the territories, considering soil-climatic, environmental, economic, and social characteristics. The goal is justified by the existing need for developing countries to construct effective mechanisms to support agriculture, which should be based on the rational location of production for the industry's sustainable development. This is especially true without an integrated approach to forming a location strategy. This problem has been solved by the authors based on the study of scientific research on the actually formed, existing location of organic production in developed and developing countries; identification of the most significant conditions that affect it; formation of a complex of factors that comprehensively characterize the state of the territories, taking into account the requirements for organic products; and development of a methodology for substantiating its location in the future (Svetlov 2017a,b). Different scientists from various countries have conducted many studies of the factors of organic production development and its effects on the economy. Thus, Sapbamrer & Thammachai (2021) found that an important condition for the development of organic agriculture was the interaction of producers in creating non-chemical resource-saving production. It forms a condition for the transition to new, more profitable forms of interaction between the participants of economic processes. Consumer interest in organic products is based on the idea of environmental protection, as well as on a sufficient level of income of the population, as production is mainly focused on the domestic market (Hansmann *et al*. 2020). The current level of development of Russian society, the level of income, and the available natural conditions for the implementation of organic agriculture with its optimal location across the country and by categories of producers can form the basis for strengthening the position of the agricultural sector in the economy of the country, as well as ensure the sustainability of agriculture. The optimal location of organic agriculture provides a synergistic effect in related industries, which positively affects the development of the agricultural sector and the region's economy (Wiśniewski *et al.* 2021). Various criteria are used to assess location efficiency, the most common ones being the indicator of the increase in the volume of organic production, the increase in sales to meet effective demand (Mpanga *et al.* 2021), and the expansion of cultivated areas under organic farming. There are various authors' methodological approaches to optimal locating agricultural production, which take into account demography, living standards of the population, food prices, production indicators of crop and livestock production, bioclimatic potential of the regions, etc. in the system of indicators, and use economic and mathematical models (Yevdokimova & Romanenko 2013; Truhachev *et al.* 2017; Svetlov 2017; Romanenko *et al.* 2018; Altukhov *et al.* 2020; Kolesnikov & Vasil'yeva 2021). However, there are few methodologies for the practical location of organic production on a territorial basis. This is because complex economic systems, such as organic production in the country, need more accurate mathematical descriptions. When building optimization models, it is necessary to consider their limitations due to using linear equations that only sometimes correctly reflect the existing interrelationships in economic, social, and natural phenomena. The efficiency, practicality, and accuracy of their final results are only useful for describing a single object. Their effectiveness will differ in adapting the model for other objects and optimizing complex systems. A.Yu. Yegorov's methodology (2014) determines the development potential of the agricultural organic food market at the regional level based on three main components: agro-industrial potential, ecological purity, and population living standards. In our opinion, this methodological approach does not consider all indicators corresponding to the optimal location of agricultural organic food production according to environmental and social characteristics. Ruschitskaya (2019) supplemented A.Yu. Egorov's methodology with several factors:

1. Sown areas of agricultural enterprises where mineral fertilizers have not been applied for the last five years;
2. Availability of material, technical, and labor resources in agricultural enterprises for organic food production;
3. The remoteness of sown areas from existing polluters by technogenic indicators (industrial centers, harmful industries, their waste disposal sites, highways, etc.)
4. Quality level of water sources;
5. Stability level of profitability of production and sales activities of agricultural enterprises.

In our opinion, this author's methodology uses the matrices "Production-Economy" and "Leadership-Perspective", as well as linear equations, which can distort the consequent efficient location of organic production across territories.

N.D. Avarskiy, V.V. Taran, A.G. Paptsov, and Zh.E. Sokolova (Federal Research Center of Agrarian Economy and Social Development of Rural Areas, All-Russian Research Institute of Agricultural Economics) proposed one of the well-known methodological approaches to identifying priority regions of Russia for creating and developing organic markets. They took into account the system of external environmental indicators (ecological, infrastructural, socio-economic, financial, economic, and demographic) and internal environmental ones (availability of production facilities and means of production, information, and advisory support, the level of development of organic agriculture and the extent of development of information and communication technologies; Paptsov & Avarsky 2020). The essence of this methodological approach was to obtain an integral indicator based on the point equivalent and the statistical method of calculating the multivariate mean. The region-wise development of organic markets is monitored based on the obtained results. However, this method does not consider the regions' optimal conditions of organic production. Methodologies for determining the possibility of achieving a particular criterion are based on studying the totality of production factors that form the existing location and substantiating the best combination for a particular territory. In this case, the researcher's task is to find the optimal method of analysis carried out as a whole for the totality and in the context of individual analytical groups of producers, as well as existing economic entities (municipalities, districts, regions, countries). However, most studies are aimed at identifying transparent cause-effect relationships, i.e., at finding specific mechanisms that are unified for any object, i.e., they do not take into account the impact of the specifics of the territory, economic entities, and conditions of their development (Darnhofer *et al.* 2020; Rudoy 2020). Many researchers in both developed and developing economies have analyzed the factors influencing the location of organic products. In this case, all factors are most often initially considered in the following groups: socio-economic, climatic, and soil factors (Malek *et al.* 2019). Croatian scientists (Blaće *et al.* 2020) provided an example of constructing a model (based on panel data by the municipality in the period 2004 – 2017) of the dependence of the area under organic production on two groups of variables: economic (average primary income, development index, average unemployment rate, distance to market centers) and demographic (population size, share of persons with higher education). One of the popular spatial analysis methods (hot spot analysis), expressed in Getis-Ord Gi statistics being used. The data published by the Ministry of Agriculture of the Republic of Croatia and the Agency for Agriculture, Fisheries and Rural Development was supplemented with the results of an online questionnaire (Blaće *et al.* 2020). Due to the small number of certified organic producers and consequently their small share in the total number of agricultural producers, questionnaires are an important way of collecting data about their activities (Pejnović *et al.* 2021; Alotaibi *et al.* 2021; Noor *et al.* 2022; Barnes *et al.* 2022). The authors do not consider the questionnaires a source of reliable and regular information that monitors farmers' opinions regarding the prospects for participation in the development of organic production. This is especially true for developing countries, where producers from small businesses are not ready to disclose most information about their activities. That is why this method of collecting information was not used when substantiating the proposed system of indicators. The authors took into account the full range of factors that allow regular monitoring of the conditions of the territories in terms of organic production based on officially published data that meets the requirements of reliability (as opposed to voluntary surveys, questionnaires), comparability across territories and over time. In many countries, such an analysis is often limited by the availability of information on organic production published by official statistics, so the proposed methodological approach is based on official statistics accessible to all users. In addition, this approach is suitable for small countries with relatively homogeneous farming conditions and agricultural production structures, as in this example, and for areas of considerable north-south and west-east extension. Most authors consider the environmental conditions of a territory to be fundamental to the location of organic production. In the example of Poland, when analyzing the efficiency of organic production location by the municipality, the territory was divided into four categories according to the level of the integrated environmental indicator in terms of its suitability for organic production: very favorable, favorable, favorable with limitations, unfavorable. Then, the relationship between the allocated funds in the Common Agricultural Policy was considered for each group based on correlation and spatial analysis (Wiśniewski *et al.* 2021). We agree with the authors that the area's ecological condition acts as the main condition for producing organic products. However, we also believe that in order to expand the area of organic crop production, the level of development of the region in general and the agrarian sphere, in particular, should be taken into account, as they determine the economic opportunities to support environmentally responsible producers and the development of scientific potential in order to expand production capacity. In addition, the standard of living determines the potential demand for more expensive organic products in the regions. An interesting study involving 112,724 certified farmers in 150 countries was conducted by Malek *et al.* (2019). The authors used econometric methods. They distinguished three groups of countries by the share of land under organic production (countries where organic farming is of national importance, countries that are major global producers, and countries where organic farming remains a niche activity). Using logistic regression, different factors' influence on organic agriculture's location was assessed, and the conclusion was formed that worldwide organic crop producers were located in territories with more favorable socio-economic, climatic, and soil conditions. The disadvantage of this methodology is that there is no analysis of the influence of a set of factors on the location of organic production; only the individual factors forming the concentration of producers in the country are taken into account. Mathematical methods impose higher requirements for source data (Delbridge *et al.* 2013). According to the FAO, there is no formal data collection system at the national level in the Russian Federation (FAO 2021). In many countries, there are difficulties in officially recording the number of enterprises, their production activities, and resources involved in organic production (Malek *et al.* 2019; Blaće *et al.* 2020). It is true not only for a region but also for the whole country. This fact requires improved statistical observation in agricultural censuses and current records carried out by ministries to obtain more reliable data. A common database on organic producers and the main indicators of their production and economic activities, to be developed by the certifying authority and national institutions, needs to be made publicly available. However, remote sensing is the most promising way of obtaining accurate data on the location of organic production and the conditions of its determination (Ayyad *et al.* 2022). A study by Łukasz Wiśniewski *et al.* (2021) proves that there is a need to increase the territorial targeting of support for organic agriculture to improve the correspondence between the development of funds and the natural conditions in the area. Given the intensity of agricultural production, it was found that the share of agri-environmental measures was low in intensive production regions (in Poland, in the Wielkopolskie, Kujawsko-Pomorskie, Opolskievoivodeships). At the same time, the results are similar to those of other countries (including Germany, France, Spain, Hungary, etc.). Many studies confirm that agrarian policies to support organic producers should be more tailored to individual territories, including their natural regional and local characteristics (Reckling *et al.* 2020; Wiśniewski *et al.* 2021). Based on the critical analysis of existing methods for studying the location of organic production in various countries, the authors identified areas for improvement that require adjustment to provide optimal conclusions for assessing its effectiveness. From the point of view of the information used, studies aimed to describe the factors that formed the location of organic production, as the object of study used sets of producers, including many elements. This ensures the validity of the conclusions obtained in the process of modeling the relationship between location factors and the actual area under organic farming, but the source information was the results of surveys (Pejnović *et al.* 2021; Alotaibi *et al.* 2021; Noor *et al.* 2022; Barnes *et al.* 2022), which makes it difficult to obtain comparable long time series and the possibility of using the proposed approaches to the analysis of location in other countries and regions. From the point of view of the system of factors analyzed, the factors characterizing individual conditions for growing organic products, and not their complex, were studied (Egorov 2014; Sajadian *et al.* 2017; Ruschitskaya 2019; Ishchenko 2020; Altukhov *et al.* 2020; Wiśniewski *et al.* 2021). From the point of view of the methods used to assess the impact of conditions, methods of mathematical and econometric modeling were used based on empirical data on the existing location of production and the linear nature of relationships, which makes it difficult to extrapolate the findings to the future, use to develop a location strategy for territories when conditions change (Yevdokimova & Romanenko 2013; Svetlov 2017; Romanenko *et al.* 2018; Altukhov *et al.* 2020; Kolesnikov & Vasil'yeva 2021; Migunov *et al.* 2021, 2023; Babanskaya *et al.* 2022).

MATERIALS AND METHODS

The authors propose a methodological approach to the location of organic crop production, which includes the substantiation of a comprehensive system of sectoral factors, taking into account the level of socio-economic development of the regions and agricultural sector, the environmental state of the territory, expressed by the indicators, unified by international standards of official statistical observation. The approach is based on factor and cluster analysis methods, which ensure the objectivity of combining the territories into homogeneous groups in terms of all the listed conditions with a high degree of accuracy. This proves the efficiency of the location of organic production on the country's territory and makes it possible to develop strategic and tactical objectives for developing this segment of the Green Economy. The methodological approach includes six stages (Table 1). The first stage involves developing a system of indicators that characterize the conditions for organic production. The content of groups of indicators may change when this methodology is adapted to other territorial structures and countries.

Table 1. System of indicators of organic production and consumption conditions.

V1. Level of Development of the Region
Gross regional product (GRP) per capita (RUB). Density of paved public roads, km of track per 1,000 km^2 of territory. Share of households with broadband access to the information and telecommunication network "Internet" (%). Costs of introduction and use of digital technologies (mln. RUB). Domestic expenditures on research and development in agricultural sciences (mln. RUB).
V2. Level of Agricultural Development
Gross value added (GVA) of agriculture in GVA (%). Turnover of organizations in agriculture, forestry, hunting, fishing and fish farming per hectare of agricultural land (thous. RUB). Balanced financial result (profit minus loss) of agricultural, forestry, hunting, fishing and fish farming organizations per hectare of agricultural land (thous. RUB). Share of loss-making organizations by types of economic activity, as a percentage of the total number of organizations. Profitability of sold goods, products (works, services) of organizations (%). Number of agricultural enterprises per capita (units/ thous. Persons). Number of peasant (private) farms and individual entrepreneurs per capita (units/ thous. Persons). Agricultural holdings in total area of the region (%). Crop yields (centner/ha; 5-year average). Area of fallow lands (km^2) Mineral fertilizer application per hectare of crops in agricultural organizations (converted to 100% of nutrients; kg; 5-year average).
V3. Climatic Conditions
Normative temperature in January (℃). Normative temperature of July (℃). Normative January rainfall (mm). Normative July precipitation (mm).
V4. Ecological Conditions
Emissions to the atmosphere per area of the region, (kg ha^{-1}). Share of captured and decontaminated air pollutants in the total amount of waste pollutants from stationary sources. Spending on environmental protection per area of the region (thous. Rub. ha^{-1}). Polluted wastewater discharge into surface water bodies per area of the region (tons ha^{-1}). Share of neutralized waste Availability of waste at the end of the reporting year per area of the region (kg ha^{-1}).
V5. Standard of Living
Rural population in total (%). Consumer spending on average per capita (rubles per month). Median per capita cash income of population (rubles per month). Population with monetary income below the subsistence minimum, as a percentage of the total population of the region. Average cash income of population per capita (rubles per month). Consumption of vegetables and gourds per capita (kg per year). Public catering turnover per capita (in actual prices; RUB.).

Source: developed by the authors.

Various groups of indicators are distinguished in several studies on organic production. Thus, in the study of Sajadian (2017), the authors use indicators characterizing demography, socio-economic development, ecological state, and level of agricultural production. Ishchenko (2020) highlights economic, environmental, and social indicators for the characteristics of organic production. For the Russian Federation, one of the main roles in the location of organic production is given to natural and climatic conditions (Altukhov *et al.* 2020).

As a result, five groups of indicators were identified to study the location of organic production in Russian regions:

1. Level of the region development – characterizes the general level of the region development and the prospects for the introduction of digital technologies;
2. Level of agricultural development –characterizes the potential of the region for crop production;
3. Climatic conditions – characterize the ability of the region to produce various crops;
4. Ecological conditions – characterize the potential of the region for organic production;
5. Standard of living – characterizes the potential of the population's demand for organic products.

The level of development of a region as a potential area for organic production should be characterized in terms of the scale of production activities and the amount of value-added, as organic production requires a large amount of investment and the application of science and technology to ensure efficient production (Sajadian *et al.* 2017; Ishchenko 2020; Heinrichs *et al.* 2021). This is summarized in terms of gross regional product per capita (to eliminate the impact of scale) and funds for agricultural research. Organic production places high demands on the quality of resources and, therefore, may not be produced in every region, i.e., the study should consider the ability to transport the products, so the availability of roads is included in the system of indicators of the first group. Organic crop production is closely linked to the development of precision farming, which requires digital technology. The area's digitalization level is most objectively characterized by Internet access and the amount of finance spent on I.T. applications (Altukhov *et al.* 2020). The territories primarily focused on developing industrial production are less likely to aim at a transition to organic production, so a group of characteristics of the level of agricultural development is included in the proposed system of indicators (Sajadian *et al.* 2017). The most common of these is the role of agricultural production in forming the region's gross value added. Organic production is high-cost, so considerable attention is paid to the efficiency indicators of the agricultural sector enterprises. Enterprises with high turnover, high profit, and profitability indicators have the funds to develop production. Many enterprises engaged in agricultural production provide competition and form the need to develop new areas of interest to consumers, including organic production. So, the number of agricultural enterprises and farms is included in the agricultural development indicators system. The indicator of the area of fallow land as land on which no chemicals have been applied is considered the basis for the transition to organic production in the short term, considering the possibility of including them in circulation without prior clearance from prohibited organic substances. Grain farming is the most widespread in the Russian Federation, so the level of production efficiency in this sector is considered in the indicator system as a general characteristic of the potential of crop productivity in organic production. The indicator is considered a 5-year average since this period includes years with various climatic deviations from the typical level for the territory. The high degree of chemicalization of agricultural land is a limiting factor for organic crop production, so this indicator, which has been around for five years, is included as mandatory in the proposed system. As the study deals with crop production, climatic conditions should be characterized by the normative temperatures in January and July and the rainfall in those months for the object of study (Altukhov *et al.* 2020; Guarín *et al.* 2020; Viguier *et al.* 2021). A distinctive feature of the proposed methodological approach is the consideration of the population's standard of living as a factor in the formation of consumer demand for expensive organic products compared to traditional ones. From this point of view, the system of indicators includes the characteristics of the population's income, including the share of the rural population in the total population with a lower income compared to the urban population, per capita consumption of crop products with the highest potential for transition to organic production, and the revenue from the sale of products in the catering sector as the potential volume of using organic products through the most extensive channel. In the second stage of the study, a system of indicators should be calculated for each population unit (subjects of the Russian Federation). In the third stage of the study, a factor analysis method should be applied for each group of indicators, highlighting the principal components in the R programming environment. Factor analysis is applied to reduce the number of variables (Musafiri *et al.* 2020). The essence of the method is to find linear combinations of random multivariate variables {η}pi = 1. (indicators in each group) with vector mean m = (m1, mp) and covariance matrix D = (σij), by which we can obtain a concise description of the dependence structure:

$$\eta_1 = \sum_{j=1}^{p} \alpha_{1j}\xi_j \ \dots \ \eta_p = \sum_{j=1}^{p} \alpha_{pj}\xi_j \qquad \textbf{(1)}$$

Thus, a subset of the first variables of the system ξi will explain most of the total variance. Implementing the principal component method involves determining the coefficients αij, i, j = 1...p. We can only see the relationship between the initial indicators and the generated component within each selected factor based on correlation coefficients. However, they are most often used for the semantic interpretation of the components. The task of factor analysis in the proposed methodology is to reduce the dimension of the initial population for each group of similar indicators, so the contribution of each factor is not significant. To assess whether a component can be extracted, we proposed to use the Kaiser criterion: only those factors whose eigenvalues are greater than one are identified first. This means that if a factor does not allocate a variance equivalent to at least one variable's variance, it is omitted (Aivazyan *et al.* 1989). This method should result in the identification of five components describing each group of indicators, which will form the basis for dividing the elements of the population into clusters. The fourth step involves determining the optimal number of clusters for the identified components for cluster analysis and applying the k-means method for cluster extraction. It is proposed that the optimal number of clusters using the NbClust package in the R programming environment be determined. Cluster analysis is a method that allows grouping elements of the population so that the elements belonging to one group are the most "similar" and the elements from different groups are the most "different" from each other by a whole set of characteristics. Common cluster analysis methods are hierarchical clustering and k-means (Romantseva & Kolomeeva 2021; Assogba *et al.* 2022;). The first one involves the construction of a tree diagram, in which the elements of the set of grouped objects that are most similar to each other are placed on branches close to each other. The procedure begins with forming a cluster by each element, and then the clusters are combined. The procedure can continue until the elements are combined into 1 cluster. By the speed of combining elements, the researcher can decide for himself at what stage the procedure should be stopped. This method is used for a small set of elements. Unlike hierarchical algorithms, the k-means method (iterative) does not require calculating and storing the similarity matrix between objects. However, it uses only the variables' initial values, making its use convenient for large statistical populations (Eliseeva *et al.* 2022). However, it requires a preliminary determination of the number of clusters; in the authors' methodological approach, this stage is proposed to be performed using the NbClust package. The metric used is the Euclidean distance.

$$d_{Eij} = \sqrt{\sum_{i=1}^{m}\left(x_i^l - x_j^l\right)^2} \quad (2)$$

The k-means method performs clustering as follows:

1. The number of groups (k) into which the data will be divided is assigned. As the initial centers of the clusters, k objects in the original set are randomly identified.
2. Each observation is assigned a group number by the closest centroid, i.e., based on the smallest Euclidean distance between the object and the point.
3. The centroid coordinates μk of all k clusters are recalculated, and the within-group variation volumes $W = \sum (xi - \mu k)^2$ are calculated.
4. The total within-group variation volume $Wtotal = \sum W \rightarrow \min$ is minimized, for which stages 2 and 3 are repeated many times until the group assignments stop changing or a given number of iterations is reached.

A similar approach to the identification of homogeneous groups of objects is often used in agro-economic research (Platania 2014; Szafrańska 2018; Hloušková & Lekešová 2020). At the same time, the choice between two clustering methods was carried out in the researches (Churilova & Salin 2016; Krylova & Kibardina 2019; Krylova 2021) and for grouping the regions of Russia, as an object of study, which includes a large number of units, the k-means method was preferred.

After defining the composition of each cluster, it is necessary to describe each group by a system of relative indicators to identify the regions most suitable for organic production, regions that consume organic products, etc. Based on the identified groups of regions, recommendations for the optimal location and mechanism of state support of the subjects of the Russian Federation are developed at stage 6. The study's source data were official statistical observation data published by the National Organic Union and the Federal State Statistics Service (Rosstat), including compendiums of "Agriculture in Russia," "Regions of Russia”, "Socio-economic Indicators," "Russian Statistical Yearbook," and Rosreestr.

RESULTS AND DISCUSSION

In accordance with the study's methodological approach, factor analysis was applied to each group of indicators, and principal components were identified. The “prcomp” function of the R programming language was used in the study. The results of factor analysis are presented in Tables 2-3.

Table 2. Characteristics of identified components on the results of factor analysis.

Component	Explained variation (%)	Adequate standard deviation
V1	36.3	1.34
V2	31.3	1.86
V3	45.5	1.35
V4	38.6	1.52
V5	61.4	2.07

Source: constructed by the authors using the results of the analysis.

Table 3. Distribution of organic producers by clusters.

Cluster	Number of certified organic producers	Number of certified organic producers per region on average	
		total	incl. crop production
1	23.0	3.3	1.7
2	36.0	1.5	0.9
3	2.0	0.3	0.0
4	22.0	1.4	0.9
5	11.0	0.8	0.2
6	9.0	9.0	4.0
7	2.00	0.3	0.3
Total (average)	105.00	1.33	0.73

Source: constructed by the authors using the results of the analysis.

Each identified component accounts for more than one standard deviation, corresponding to the Kaiser criterion (an acceptable level for identifying a component according to the theory of factor analysis). The low level of explained variation of 31.3% for the component V2 indicators is due to the large number of its included variables. Cluster analysis was applied to the identified components. It is advisable to determine the optimal number of clusters beforehand, which can be done using the NbClust function in the R environment. Based on the results of the six criteria function, it was confirmed that the optimal number of clusters is seven (Fig. 1). The k-means method ("kmeans" function of R programming language) was applied to identify the clusters. The identified clusters explained 72.9% of the variation in the raw data (Fig. 2). At the same time, analysis of variance showed that the components highlighted by living standards of the population, environmental conditions and climatic factors had the greatest influence on the distribution of the groups. The cluster analysis has made it possible to group the regions according to economic, environmental, climatic and social conditions (Fig. 3); their spatial distribution is shown in Fig. 3.

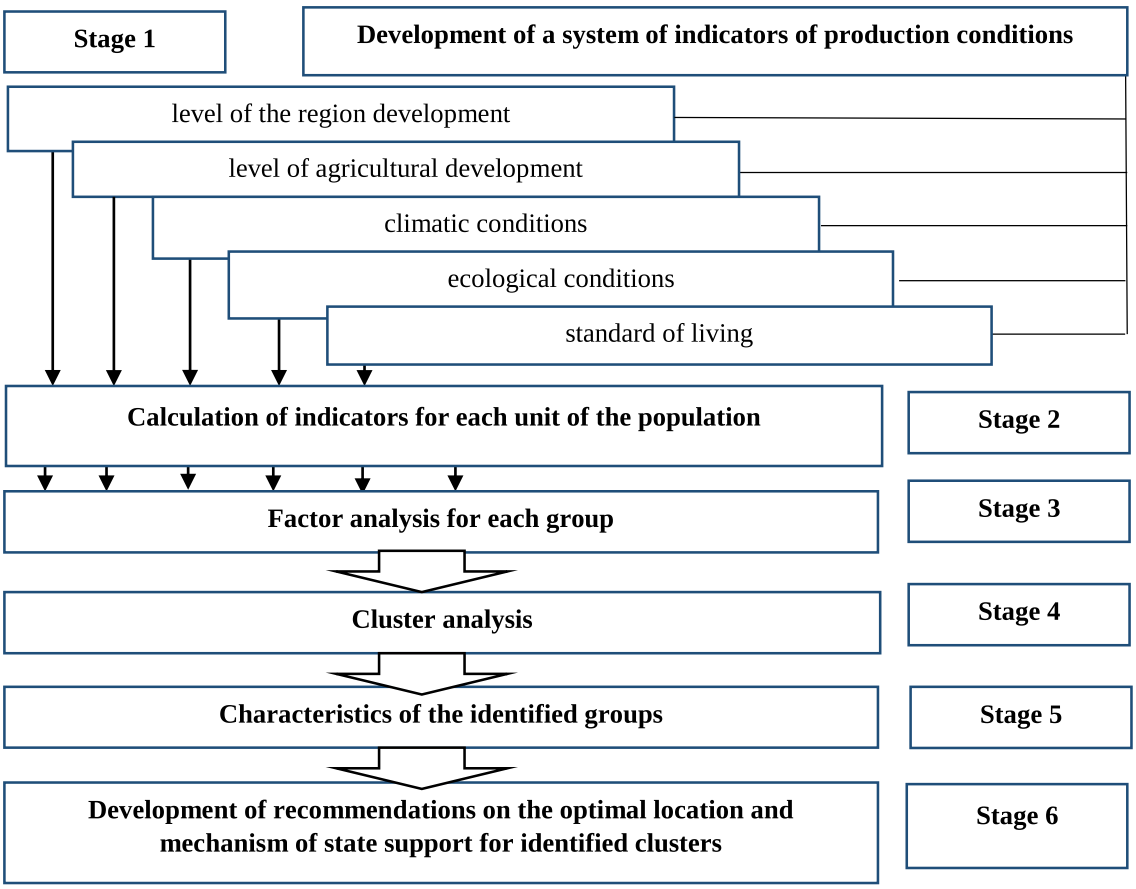

Fig. 1. Methodological approach of the study; Source: developed by the authors.

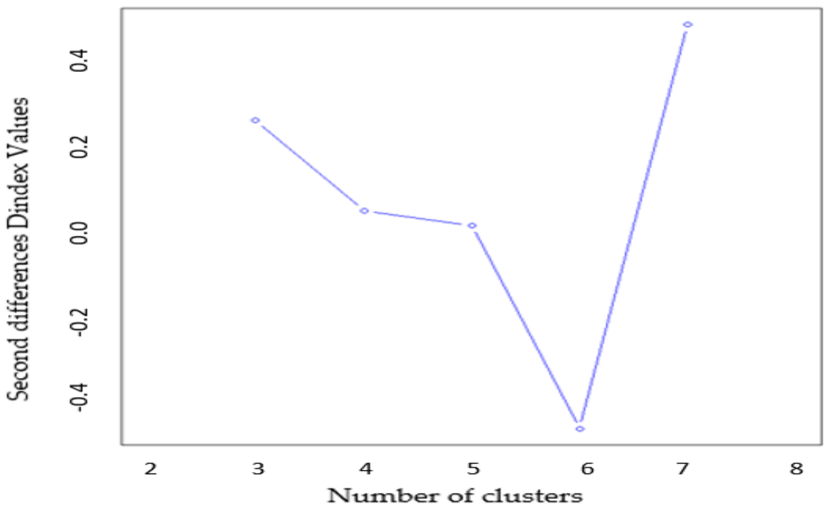

Fig. 2. Determining the optimal number of clusters; Source: constructed by the authors using the results of the analysis.

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K-means clustering with 7 clusters of sizes 24, 7, 1, 8, 16, 10, 13

Cluster means:
          V1         V2          V3          V4          V5
1  0.1605267  0.8759483  0.09685344  0.06148013  0.02616027
2 -1.1455091 -1.2358924 -0.70558900 -3.10598808  0.55662886
3 -8.5185219  1.0870245  0.14277820 -6.91865711  3.54523232
4  0.2478939  2.2740023  1.70446462  0.93591387  4.50112984
5 -0.1993515 -2.1381944 -1.17693446  0.16677617 -0.48043822
6  0.8232191  1.6693415  1.76838551  0.78418866 -0.16860494
7  0.4352867 -1.0871430 -0.77051987  0.70672572 -2.66965066

Clustering vector:
 [1] 2 5 1 5 1 1 1 5 2 3 5 5 1 5 1 2 1 1 6 6 1 5 1 4 1 1 5 7 7 2 5 5 5 5 7 7 7 5 7 5 1 7
 7 2 1 7 1 1 1 1 5 2 5 1 7 1 4 1 7
[60] 7 6 7 6 6 2 1 1 6 6 4 6 4 1 4 6 4 4 6 4

Within cluster sum of squares by cluster:
[1] 48.87992 49.88668  0.00000 62.70385 34.64368 24.25887 69.44877
 (between_SS / total_SS =  72.9 %)

Available components:

[1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss" "betweens
s"     "size"        "iter"
[9] "ifault"
[1] 24  7  1  8 16 10 13
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Fig. 3. Results of cluster analysis; Source: constructed by the authors using the results of the analysis.

Fig. 4. Distribution of the subjects of the Russian Federation by clusters; Source: constructed by the authors using the results of the analysis.

The first cluster includes regions with a predominantly agricultural orientation (the Belgorod, Lipetsk, Tula, Samara, and Kemerovo regions, Krasnodar Krai, and the Republic of Tatarstan), where the industry accounts for 7.2% of gross regional product. The regions in this cluster play a decisive role in ensuring the country's food security, so production here is large and highly intensive. However, the regions have the most unfavorable environmental conditions for organic production. For example, emissions of air pollutants per unit area in these regions are almost nine times as high as the national average, and eight times as much as polluted wastewater is discharged into surface water bodies. Per capita waste generation is three times as high as the national average and 73 times as high as that in regions in cluster 5 with the most favorable environmental conditions. Thus, the environmental conditions suggest that it is not feasible to produce organic products here despite well-developed agriculture. For example, grain yields averaged 38.4 centner/ha over five years, achieved through a record level of mineral fertilizer application per hectare sown (1.7 times as high as the average). However, the prospects for the development of these regions are quite high. Expenditure on introducing and using digital technologies per region is 1.8 times as high as the national average, and internal expenditure on research and development by field of science is twice as high as the national average. Subject to anti-pollution measures, these regions will be able to produce high-quality organic products in the future, however at this stage, they remain consumers of such products with average incomes (32.8 thous. RUB), consumer spending is higher than the national average (26.9 thous. RUB, 9.7% above the average) and the population with incomes below the subsistence level (10.0%) is low. The second cluster is the most numerous. It includes almost a third of all the regions under consideration, mainly in the Central European part of Russia. This group of regions uses 31.8% of all agricultural land in the country. GVA production of agriculture, forestry, hunting, and fishing accounts for 24%, indicating an insufficiently efficient use of resources. The regions play an important role in the country's food supply and in the formation of the gross regional product (4.6%). Natural and climatic conditions for agricultural production, including organic products, can be average. The regions are located in the moderate climatic belt of Russia, which is favorable for producing livestock products. The share of crop production here is 42.7% of the total agricultural output, and grain yields are the lowest in Russia, accounting for 16.5 centner/ha, which is 37.9% lower than the average for the aggregate. The low share of crops in the agricultural area (0.33), large areas occupied by pastures, and a low gap between the profitability of sales of crop and livestock products (traditionally, in Russia, crop production has higher sales efficiency) indicate the livestock orientation of the regions. The environmental situation in the studied group is characterized as insufficiently favorable: atmospheric emissions are 19.3 kg per hectare, which is almost twice as high as the average, and the availability of waste at the end of the reporting year is 2.2 times as high as the average, while environmental protection costs do not exceed 900 rubles per hectare. Nevertheless, the cluster regions have a significant potential for organic production as the costs of introduction and use of digital technologies – the primary basis for reducing environmental impact – are higher in the regions both in absolute terms than the Russian average (by 20%) and per capita (by 10.1%). Also, agricultural producers do not abuse mineral fertilizers, and in the cluster under study, their volume per hectare of crops is the lowest in the country, accounting for only 39.2% of the Russian average. Thus, by the improvement of the ecological situation in the regions, there is an opportunity and potential for organic crop production. It is a question of organic fodder, which is the basis for developing organic livestock farming. Organic vegetable production is possible on small farms and in subsidiary plots. In Primorsky Krai, which differs from the rest of the cluster regions, the possible expansion of organic soybean crops is a promising area of agriculture. The third cluster is represented by sparsely populated regions and local development regions, mainly located in the zone of risky farming. So, the cluster's agricultural land share is only 1%, of which only 16.5% is occupied by crops. Crop and livestock production sales could be more profitable (-22.3% and -19.4%, respectively). Crop yields are 20.5 centner/ha on average over five years, 22.6% lower than the national average. However, taking into account the fact that the level of mineral fertilizer application per hectare of crops in agricultural enterprises does not differ from the national average, one may conclude that the achieved yields are ensured by fertilizers, and with the possible transition to organic production the yield of crop production will be even lower. The inability of agricultural producers to achieve an acceptable level of crop yields is also due to the most unfavorable climatic conditions in the studied territories. Thus, the normative temperature in July is only 13 °C (while the average is 18 °C), and in January 22.4 °C, which is also 9.2 °C below the national average. The environment in the regions of this group is characterized as rather favorable: the amount of waste by the end of the reporting year is 6,750 kg, one of the best values per unit area, while atmospheric emissions and polluted wastewater discharge to surface water bodies are the lowest in the aggregate. This is due to the low level of territory development (1.1 people per square km), its huge area (42.1% of the total territory of Russia), and, consequently, the density of paved public roads, which is almost 20 times as low as that in Russia as a whole. At the same time, there is a fairly high level of waste generated per capita due to the extractive industry, exceeding the average by 2.7 times. It should be noted that the standard of living in this cluster is the highest. Thus, the average per capita cash income is 1.5 times as high as the national average, as is the median per capita cash income (1.8 times), and per capita catering turnover is more than twice as high as the average. Thus, the regions in this cluster have the highest potential of solvent demand for organic products, so they can be considered as possible main consumers of organic products. The fourth cluster includes regions of predominantly extensive types of agriculture with favorable temperature conditions for farming. Thus, the normative temperature in July is 20.2 ℃, which is 20 ℃ higher than the Russian average, and in January it is 6.1 ℃ higher. However, precipitation is 10.8 mm below the national average, which places these territories in risky farming zones. For example, while July temperatures in 2021 were 2.3 ℃ above the norm, precipitation was 26.3% below the norm. Nevertheless, the level of agricultural development in the regions is the highest. The share of agricultural land in the total land area is 75.9%, and the GVA of agriculture, forestry, hunting, and fishing is 12.5%, 6.9% higher than the average. Agricultural production per capita is the highest among the considered groups for crop and livestock production (97.7% and 24.7% higher than the average, respectively). Agricultural production in the regions is a profitable activity; the profitability of selling both animal and crop production is the highest among all the clusters, amounting to 11.8% and 44.0%, respectively, while the share of loss-making enterprises, by contrast, is the lowest and amounts to 22.8%. These are territories of high-intensity agricultural production with high potential. With a cereal yield of 32.6 c/ha, which is 23.0% higher than the aggregate average, fertilizer application doses are 45% higher than the average. The cluster has limited opportunities to consume more expensive organic products because household income is 12.6% lower than the national average, and the median per capita cash income is 11.4% lower. Nevertheless, per capita consumption of vegetables and gourds is 27% higher due to the availability of products from local producers and household production for their own consumption. This determines the population's increased demand (21% of the total population) for agricultural products produced in the area and at affordable prices. Thus, the level of development of the agricultural sector and the favorable climatic characteristics of the cluster regions allow for discussion of the possibility of producing organic products, provided the anthropogenic impact on the environment is reduced. The sale of organic products is possible, both for domestic and foreign markets, which is confirmed by the existing developed infrastructure in the cluster. Despite well-developed livestock farming, organic fodder production is difficult due to limited available land. The main crops for the cluster regions could be cereals, maize, and grapes. Among technical crops, soil and climatic conditions are suitable for sunflower and sugar beet, for which a hot and dry climate favors the accumulation of oil and sugar in fruits. The climate is also favorable for the commercial cultivation of field vegetables, fruit plantations, and grapes. In terms of environmental conditions, the regions of the fifth cluster (Altai Krai, Kabardino-Balkar Republic, Karachay-Cherkess Republic, Kurgan Oblast, Altai Republic, Ingushetia Republic, Kalmyk Republic, Republic of Crimea, Republic of Mari El, Republic of Mordovia, Republic of Tyva, Chechen Republic and Chuvash Republic) are most suitable for production of organic products. The cluster is represented by low-urbanized regions where only 9.3% of the total population live, with the lowest per capita GRP (248.6 thous. RUB, more than twice as low as the national average). The level of agricultural development, characterized by the industry's contribution to the GRP of the regions, is one of the highest and amounts to 12.6%, which is 4.3% higher than the national average, with a slight shift towards livestock farming (50.5%). This is due to insufficiently favorable conditions for crop cultivation in the mountainous areas of the Caucasus region and Altai, which is also confirmed by the low share of crops in agricultural land (28.8%) and low grain yield (30% below the national average). These are regions of extensive traditional agriculture. At the same time, the regions in this group have the largest number of agricultural enterprises and small businesses (peasant farms and subsidiary plots) per capita, then one-third higher and twice as high as the aggregate average respectively. Climatic conditions in these regions are rather good; the normative temperature in July is 19.7 ℃, 1.7 ℃ above the national average. The temperature in January is also higher than the average by 2.8 ℃, which makes it possible to successfully engage in crop farming not only with the focus on forming a fodder base for livestock. Despite the geographic spread of the cluster regions, they have one of the lowest levels of pollutant emissions (6.18 kg per hectare) and wastewater discharges to surface water bodies (4.93 tons per hectare), as well as the lowest waste generation level at 1,693 kg per hectare, which is 94.5% lower than the national average. Thus, given the low level of application of mineral fertilizers (only 29.5 kg per hectare compared to the national average of 52.6 kg), the potential for organic production in these regions is the highest. However, the standard of living of the population in the cluster under study is very low: the average per capita cash income is the lowest in the country and is 22.1 thous. RUB, which is 30% lower than the aggregate average. The number of people with cash income below the minimum subsistence level is 19.9%, with the national average being 12.8%, and the nationwide average of catering is only 5.3 thous. RUB. Thus, organic production's climatic and ecological conditions are more than favorable. However, given the low income of the population, which will not be able to provide sufficient demand for more expensive than traditionally produced products, it is recommended that production be expanded to export organic products to other regions and countries. A positive development is the density of paved public roads, which is 40% higher than the national average. Another important factor is the high proportion of the rural population (47.4%), which can be attracted to the cultivation of organic crops, which traditionally require a lot of manual labor, leading to the development of rural areas. The lowest costs for the introduction and using digital technology (almost five times as low as the national average), as well as extremely insufficient domestic spending on research and development in the fields of science (2.7 times as low as the average), can be considered as constraining factors to strengthen the position of organic production. The regions in this group need special state aid mechanisms to develop organic production. The main areas of organic crop production are fodder production due to the meat-and-wool and meat-and-dairy specialization of the North Caucasus regions and Altai and sheep breeding in Kalmykia. In addition, in the Volga Federal District regions included in the cluster, it is also possible to grow organic crops: in the Mordovian Republic – cereals, sugar beet, and peas; in the Republic of Mari-El – cereals (barley, oats, rye, wheat), potatoes, flax, hops, vegetables, and potatoes, in Chuvashia – potatoes and vegetables. These are the crops on which growers have traditionally specialized and for which growing conditions are considered the best. The Moscow region, which is the only representative of cluster 6, can be included in the third cluster region in terms of the degree of urbanization (the share of the rural population does not exceed 20%), in terms of income and purchasing power. In the Moscow region, despite its proximity to the main market, only nine certified organic producers were engaged primarily in processing rather than growing on July 5, 2022. This low number is due to the high degree of land development, with agricultural land comprising 37.5% of the total land area and a 33.5% share of crops. There are also difficulties in attracting additional land for organic production. The agricultural sector plays a minor role in forming the gross regional product. It accounts for only 1.6% of the GRP, while the average for the region is 5.6%. The share of unprofitable enterprises is 52.5%, the highest among all clusters. While the climatic conditions in the Moscow Region are acceptable for organic production, the ecological condition of the territory could be better. For instance, discharges of polluted wastewater into surface water bodies per unit area are 33.3 times as much as the average; emissions of pollutants into the air from stationary sources are 4.7 times as much as the average. At the same time, the highest expenditures for environmental protection are 22.4 times as high as the average. They amount to 8.58 thousand rubles per hectare and need to compensate for the lack of possibility to produce ecologically clean food for a large population of the region and megapolis. Therefore, the development of city farming can be recommended for this cluster, taking into account the increased demand for organic products. The seventh cluster includes large regions, most territory of which, as in the regions of the third cluster, belongs to the zone of risky agriculture of the Northern District of Russia and mountainous terrain. The normative temperature in July is 2.2 ℃ lower than the average, and in January, it is 9.4%, while July precipitation is 19.7 mm higher than the national average. Agricultural production is poorly developed in the regions: turnover of enterprises in the type of economic activity – agriculture, forestry, hunting, fishery, and fish-farming – per hectare of agricultural land is over twice as low as the average. This cluster accounts for 6.4% of the GVA of agriculture, forestry, hunting, and fishery. The specialization of these regions is predominantly animal husbandry (55.2% of gross output), and it is the only cluster in which the profitability of livestock production sales is higher than that of crop production (6.9% and 2.5%, respectively). The 12% of the country's agricultural land produces 5.3% of gross agricultural output, indicating a quite efficient use of land resources. The environment in the regions can be characterized as favorable for environmentally friendly production. For instance, atmospheric emissions of pollutants per unit area are 21% lower than the average, the discharge of polluted wastewater into surface water bodies is twice as low as the average, and wastes are three times as low as the average. A factor restraining the development of organic farming is the cluster's low potential for digitalization: the share of households with broadband access to information and telecommunications networks is 71.4% (the lowest overall level), and the cost of introducing and using digital technology is 28.4%

lower than the national average. Since the specialization of the southern regions is predominantly cattle breeding (meat and dairy farming, sheep breeding), agriculture can be developed to produce organic fodder for livestock. In addition, climatic conditions allow spring grain crops (wheat, barley, etc.) and greenhouse vegetables to be grown. The Amur Region is the leader in soybean production in Russia, so it is possible to expand its organic production here, including a focus on export. The methodological approach presented by the authors to determine the optimal location of organic crop production is based on a generalization of the experience of previous studies in a system of indicators and clustering methods (Sajadian *et al.* 2017; Ruschitskaya 2019; Altukhov *et al.* 2020; Ishchenko 2020; Wiśniewski *et al.* 2021). Previous researches were aimed at studying the influence of individual conditions for the production of organic products on the already existing location, while not in a complex, but only of individual groups of factors. They did not intend to develop recommendations for the location of organic production. In this regard, the proposed approach has several advantages over similar studies. In addition, its adaptation allowed us to identify the conditions most favorable for the production of organic products and also make recommendations for crops to be grown in these territories. The main advantage of the developed methodological approach is its universality, which is based on the use of official statistical information available to all users unlike the studies of Pejnović *et al.* (2021), Alotaibi *et al.* (2021), Noor *et al.* (2022), Barnes *et al.* (2022), based on the results of surveys of producers, the methods are not available to all researchers. The created database can be used to monitor the conditions and dynamics of organic product location at all levels of government and engaged researchers, in contrast to methods that use specific information available to a narrow range of users (Ruschitskaya 2019; Paptsov & Avarsky 2020). In addition, the proposed methodology allows modifying the system of indicators for each section, depending on the researcher's goals and the need to consider the specific features of the studied territories (Guarín *et al.* 2020; Viguier *et al.* 2021). The application of factor analysis to each group of indicators made it possible to identify the main components that consider the main variation of the initial indicators. In contrast, the number of initial data can actually be different, depending on the data availability and the analysis goals. Many authors have used the advantages of factor analysis in their studies (Guarín *et al.* 2020; Musafiri *et al.* 2020). The proposed author's methodology for determining the optimal location of organic crop production can be implemented in regions and according to the data of enterprises, municipalities, natural areas, etc., for further detailing. Using cluster analysis allows taking into account the influence of each group of indicators on organic product location, in contrast to the studies of Malek *et al.* (2019), as well as groupings applied by several authors (Romantseva & Kolomeeva 2021; Assogba *et al.* 2022). Determining the optimal number of groups, based on the application of different clustering approaches, allows justifying the selection of clusters that are as different from each other as possible (Musafiri *et al.* 2020). By a significant alteration in the values of factor characteristics, the composition of the selected clusters will change, which indicates the sensitivity of the approach to changes in the economic situation. However, serious economic shocks call into question the direction of the development of agriculture based on organic production. According to the authors, based on the study of scientific works of agricultural economists, only traditional agriculture, and not organic, can provide sufficient food production by the physiological norms of consumption in conditions of limited resources and low-income levels. The methodological approach proposed by the author allows for assessing not only the impact of individual factors on the existing location and concentration of organic production (Ruschitskaya 2019; Malek *et al.* 2019) but also planning it, taking into account the complex economic and environmental, climatic, social and other conditions. The universality of this methodology makes it possible to use it to analyze the efficiency of organic production locations for countries with differentiated conditions, in contrast to some authors (Svetlov 2017a,b; Romanenko *et al.* 2018; Altukhov *et al.* 2020; Kolesnikov & Vasil'yeva 2021). The main problem in testing the methodological approach was the need for more access to information on the activities of organic producers due to the existing process of collection and publication of departmental reports that would have allowed assessing their performance for each allocated cluster. To address this problem, a digital platform is proposed to be developed where information about organic production conditions in Russia and the EAEU member states is accumulated. Board of Trustees for Technology and Construction in Agriculture (KTBL) in Germany can be considered an example of such a platform. Its experts constantly update the database, combining information on markets, field experiments, and research projects, as well as expert estimates and surveys of producers (Heinrichs *et al.* 2021). This will allow the formation of a publicly available database to assess the prospects of organic production in different territories, which will involve improving statistical accounting and regulating state support.

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