Modeling and typologization of rural areas by the level of agricultural production development and the population density

D A Korobeynikov¹, N V Ivanova¹, M A Ovchinnikov¹, E A Kolpakova¹ and K E Tokarev¹,²

¹Volgograd State Agricultural University, 26, Universitetskii Avenue, Volgograd, 400002, Russia
²Volgograd State Technical University, 28, Lenina Avenue, Volgograd, 400005, Russia

E-mail: tke.vgsha@mail.ru

Abstract. The article describes a method for clustering rural areas has been developed that involves building a composite index based on the aggregation of six individual indicators that comprehensively characterize the level of agricultural development. Regional differentiation of the calculated index values allowed us to identify five typological groups within which it is possible to trace the correlation between the level of agricultural development and population density. The first group included twenty-one subjects of the Russian Federation located in the European part of the country, with the most developed agriculture and a predominantly higher density of rural population in comparison with neighboring regions. The second group includes 24 subjects of the Russian Federation (including the most populated North Caucasian republics – Dagestan, Ingushetia, Kabardino-Balkaria) with a range of index values from 0.501 to 0.550, corresponding to developed agriculture. The third group includes 26 subjects of the Russian Federation with a range of index values from 0.401 to 0.500, indicating the average development of agricultural production, which is largely a consequence of the general socio-economic problems of the regions. The fourth group includes 5 subjects of Siberia and the Far East With a range of values of the complex index 0.351-0.400, which are characterized by unfavorable ground-climatic conditions that objectively limit the development of agriculture and rural territories. Six regions complete the rating, some of them belong to the Northern territories with unfavorable climatic conditions (Murmansk region, Nenets district, Yamalo-Nenets district), some are outsiders in terms of socio-economic development (Republic of North Ossetia-Alania, Republic of Altai, Republic of Khakassia).

1. Introduction

In the concept of sustainable rural development contains many economic, social, demographic, environmental and other aspects [1], which determines the variety of approaches to their typological assessment necessary for the development of regional and municipal sustainable development programs. As a result, there are no universal measurement methods [2-5], and due to the dynamism of regional socio-economic systems, there is a constant revision of approaches, criteria and tools for constructing integrated indicators.
The purpose of the article is to rank rural areas of the Russian Federation by the level of agricultural development, as the main driver of their economy, taking into account their differentiation by rural population density. Regional formations of the Russian Federation are selected as the main taxonomic unit of the typological grouping.

2. Materials and methods
The ranking of regions in descending order of the complex index values allowed for a typological grouping of Russian regions by the level of agricultural production development. The research methodology includes the following stages:

- forming a list of initial statistical indicators, taking into account their disclosure in the regional context in the materials of official statistics and significance for the assessment of agriculture;
- normalization of the array of statistical data by a linear scaling method that allows to bring different-scale values of indicators to a single scale [6]. The normalization is performed using a monotonically increasing function, since the higher rank corresponds to the higher value of all the initial indicators:

\[ y_i = \frac{x_i - \min x_i}{\max x_i - \min x_i} \]

where \( x_i \) is the actual value of the indicator, \( \min x_i \) and \( \max x_i \) are the minimum and maximum values of the indicator in the sample.

- forming a comprehensive assessment based on averaging the normalized values of individual indicators and ranking regions with the allocation of five typological groups. The obtained data allow further aggregation of the results obtained on the basis of the additive convolution formula with final estimates of other significant socio-demographic parameters of rural development [7];
- meaningful interpretation of typological groups taking into account regional differentiation of rural areas by population density.

![Indicators of agricultural development in Volgograd region](image)

**Figure 1.** Indicators of agricultural development in Volgograd region.

The traditional perception of rural areas as the location of agricultural productive forces has been replaced by a comprehensive concept of sustainable rural development [8]. However, changing the value paradigm of public administration does not change the fact that agriculture remains and will remain (in the foreseeable future) the main branch of the rural economy in most regions of our country.
To assess the depth of the correlation between the level of development of agricultural production and the density of rural population, six private economic indicators were selected, which were used for sampling statistical data by region for 2018 year. Normalization of the data array relative to the best values of each indicator allowed us to form a standardized matrix and determine the integral value of the complex index of agricultural development for each region.

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Table 1. Grouping of Russian regions by level of agricultural development.

| Groups | Range of index values | Number of regions | Subject of the Russian Federation |
|--------|-----------------------|-------------------|----------------------------------|
| 1      | > 0,551               | 21                | Belgorod region, Bryansk region, Voronezh region, Kursk region, Kaluga region, Ryazan region, Leningrad region, Lipetsk region, Oryol region, Tambov region, Republic of Kalmykia, Volgograd region, Republic of Adygea, Krasnodar region, Rostov region, Karachay-Cherkess Republic, Stavropol region, Republic of Mordovia, Kirov region, Penza region, Saratov region |
| 2      | 0,501-0,550           | 24                | Vologda oblast, Yaroslavl oblast, Tula oblast, Kaliningrad oblast, Pskov oblast, Dagestan, Ingushetia, Kabardino-Balkaria, the Republic of Mari El, Tatarstan, Udmurtia, Samara oblast, Kurgan oblast, Sverdlovsk oblast, Chelyabinsk oblast, Altai Krai, Irkutsk oblast, Kemerovo oblast, Omsk oblast, Tomsk oblast, Republic of Buryatia, Kamchatka Krai, Amur oblast, Sakhalin oblast |
| 3      | 0,401-0,500           | 26                | Vladimir region, Ivanovo region, Novgorod region, Kostrama region, Moscow region, Smolensk region, Tver region, Republic of Karelia, Komi Republic, Arkhangelsk region, Republic of Crimea, Astrakhan region, Chechen Republic, Republic of Bashkortostan, Chuvash Republic, Perm region, Nizhny Novgorod region, Orenburg region, Ulyanovsk region, Tyumen region, Republic of Tyva, Krasnoyarsk region, Novosibirsk region, Primorsky territory, Magadan region, Chukotka Autonomous district |
| 4      | 0,351-0,400           | 5                 | Khanty-Mansiysk auth. district, Republic of Sakha (Yakutia), Zabaikalsky Krai, Khabarovsk Krai, Jewish Autonomous region |
| 5      | 0 – 0,350             | 6                 | Murmansk region, Nenets auth. district, Republic of North Ossetia-Alania, Yamalo-Nenets auth. district, Altai Republic, Republic of Khakassia |

The choice and number of indicators determine the structure of the integrated indicator in the evaluation areas [9], which requires additional reasoning for the content of each indicator used to build a comprehensive index of the level of agricultural development.

3. Results
The indicator that characterizes the share of agriculture, fish farming and fishing in the structure of the regional gross product is the most generalized indicator of the development of agriculture in the region. When differentiating regions by this parameter, the scale of their economy was also taken into account. For example, in the industrially developed Moscow region, the share of agriculture in the regional gross product was 1.3%, with an average of 4.6% in the Russian Federation. Similar and even lower values of the index are typical for territories of the far North with large-scale commodity economy and
The profitability of livestock products is an integral characteristic of the efficiency of this industry. The determinants of the Central Federal district's leadership in terms of the industry's profitability (18.6%) also mainly lie in the demographic plane: first, the overall higher population density and proximity to the largest Metropolitan agglomeration determine the maximum concentration of consumers and create prerequisites for localization of production; secondly, the regions of the Central Chernozem region that demonstrate the highest profitability indicators of the industry (up to 42.1% in the Kursk region) have the necessary labor and intellectual resources for the implementation of large industrial projects in animal husbandry due to the higher density of the rural population [11]. High efficiency of the industry is noted in the regions of the North Caucasus Federal district, in the national republics of which animal husbandry (in particular sheep farming) is a traditional activity of the rural population, as well as in the regions of the North-Western Federal district due to its proximity to the second largest city of our country.

The profitability of crop production is less affected by demographic effects. In the whole country, the level of profitability of the industry was 20.6%, and the leadership belongs to the southern Federal district (29.1%) with the most favorable soil and climate conditions. A similar trend can be observed in the Republic of North Ossetia - Alania (73,6 thousand rubles), Voronezh region (77,7 thousand rubles), and the Kursk region (87,4 thousand rubles), indicating a positive correlation of these indicators. The industrial regions of the Central (3,0%), North-Western (2,9%) and Ural (1,9%) show the lowest contribution of agriculture and fishing to the domestic regional product.

The highest ratios of the industry’s gross product to the regional gross product are shown by relatively poor subsidized entities with traditional agricultural economies (Republic of Kalmykia – 30,2%, Tambov region-21,7%, and Bryansk region-19,7%). This group also includes the Kamchatka territory (20,1%) and the Murmansk region (13,0%) as the main fishing regions of the country. In the context of Federal districts for a given parameter are the leaders of the North Caucasus (15,2%) and South (10,8%), with most favourable climatic conditions for agriculture development, but demonstrating the highest rural population density (31,22 and 15,79 %/km², respectively), indicating a positive correlation of these indicators. The industrial regions of the Central (3,0%), North-Western (2,9%) and Ural (1,9%) show the lowest contribution of agriculture and fishing to the domestic regional product.

The region that characterizes the production of Agricultural Products per one rural resident and the differentiation of rural territories is more indicative in terms of describing the scale of development of agriculture specifically, since it is less sensitive to the scale of the region's economy as a whole. On average, this indicator in the Russian Federation in 2018 amounted to 143,3 thousand rubles with a range of variations from 93,8 thousand rubles in the North Caucasus Federal district to 210,2 thousand rubles in the Central Federal district. The lowest values of the indicator were formed in the national republics of the North Caucasus (Chechen – 30,1 thousand rubles, Ingushetia – 46,9 thousand rubles, Dagestan – 73,6 thousand rubles), this means that the industry cannot objectively absorb excess labor resources (and when calculating the indicator, the gross output of the industry is divided by the entire rural population), and it is necessary to develop non-agricultural activities. The regions of the Central Chernozem region (Belgorod, Voronezh, Kursk, Lipetsk, and Tambov regions), as well as the Oryol region, became the leaders in terms of the cost of gross agricultural output per 1 rural resident, due to its natural potential, combined with its relative proximity to the capital, it has an industrially developed agriculture, and on average a higher level of rural population density in comparison with the neighboring regions of the Central Federal district.

The share of profitable organizations, as well as the following two Indicators characterize the efficiency of agricultural production [10]. It should be noted that agricultural organizations are formed only 56,5% of all industry output, and profitability indicators have been calculated for all categories of farms, that is, to more fully characterize the efficiency of the industry. In the country as a whole, the share of profitable agricultural organizations was 73,8%, while the highest value of the indicator was formed in the North Caucasus (87,4%), Volga region (77,7%) and Siberian (76,2%) Federal districts. The outsider regions are the far Eastern (63,8%), Central (66,2%) and North-Western (66,6%) Federal districts. The scope of variation in the indicator level is much wider in the sub-object context-from 0% in the Republic of North Ossetia-Alania to 98,8% in the Republic of Tyva.

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The profitability of crop production is less affected by demographic effects. In the whole country, the level of profitability of the industry was 20.6%, and the leadership belongs to the southern Federal district (29.1%) with the most favorable soil and climate conditions. A similar trend can be observed in
other territories, for example, with an average level of profitability of crop production in the Ural Federal district of 8.8%. In the Kurgan region, located in the South-Western part of the Siberian plain with mainly black earth soils, the profitability of crop production was 32.5%.

The average monthly salary of agricultural, fishing and fish farming workers depends on the level of well-being of the region as a whole, as well as the availability of regional subsidies and surcharges. A higher level of remuneration in agriculture is typical for the Central Federal district (32 441 rubles at the national average of 28 243 rubles), as well as for the territories of the Far North and the Far East, where the level of remuneration is influenced by regional surcharges. At the same time, in the main agricultural regions of the southern and North Caucasus Federal district, the level of remuneration in agriculture is lower than the national average.

4. Conclusion
In the course of the study, the authors proposed a method for ranking rural areas by the level of agricultural development, taking into account differences in population density, which allowed us to identify five typological groups that can serve as a basis for clustering [12] and structuring regional socio-economic policy.

The first group with the highest value of the integrated index of agricultural development included one subject of the Russian Federation (with the leadership of the Belgorod region). These regions are all located in the European part of the country, and in addition to the maximum levels of agricultural development, they mainly demonstrate a higher density of rural population in comparison with neighboring regions of the Russian Federation. The second group includes 24 subjects of the Russian Federation with a range of indexaot values of 0.501 to 0.550. These regions have a fairly high level of agricultural development. The inclusion in this group of the most populated North Caucasian republics (Dagestan, Ingushetia, Kabardino-Balkaria) is associated with low indicators of gross agricultural output per capita (which is an objective consequence of the high population density), as well as the lowest levels of remuneration in the industry. The third group (the most extensive) includes 26 subjects of the Russian Federation with a range of values of the complex index from 0.401 to 0.500. These are regions that have less developed agricultural production, but it is not possible to reduce all the problems of these territories only to restrictions caused by soil and climate factors. In many ways, the lower level of development of the industry is a consequence of the socio-economic problems of the region as a whole. The fourth group includes 5 subjects of the Russian Federation (Khanty-Mansiysk auth. district, Republic of Sakha (Yakutia), Baikal territory, Khabarovsk territory, Jewish Autonomous region) with a range of values of the complex index 0.351-0.400. These are regions with unfavorable soil and climate conditions for the development of agriculture and rural areas.

The rating is completed by the fifth group of subjects, which includes six regions (Murmansk region, Nenets district, Republic of North Ossetia-Alania, Yamalo-Nenets district, Republic of Altai, Republic of Khakassia) with the lowest level of indicator values. For the Northern regions included in this group, the opportunities for agricultural development are objectively limited by climate factors. In the three remaining regions, the low level of agricultural development is a reflection of the difficult socio-economic situation.

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