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CHARACTERIZATION OF RUSSIAN REGIONS BY VARIATION IN AVERAGE TEMPERATURE, PRECIPITATION, AND AGRICULTURAL DEVELOPMENT

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SUMMARY

In the present era, the characteristics of agricultural development most exposed to the effects of global warming and irregular precipitation patterns remain scantily understood in the regions. The latest study aimed to identify the target regions with different degrees of variation in the average temperature, followed by their resource potential, conditions, strengthening, and production efficiency. Based on their groups through statistical studies, three groups of Russian regions attained partition (using a sample that included 77 Russian regions), with low (Group I - 20 regions), medium (Group II - 25 regions), and high (Group III - 32 regions) estimates of the linear temperature trend. In Group III, 72% of the regions appeared favorable for agriculture, according to the classification approved by the Russian Government. In Group I, 60% of the regions emerged as unfavorable. Based on the statistical indicators, these established that Group III has a considerable resource potential for agriculture, comprising 30% of agricultural lands, 36% of all crops, up to 50% of the area of fruit and berry plantations, 40% of milk production, and 69% of meat and meat products manufacture intended in this group of different regions. In Group III, conditions and intensification of production are developing more dynamically (the volume of subsidies allocated during the study period has increased almost five times), efficiency is higher (profit per 100 ha of agricultural land in Group I is 0.2 million rubles, whereas, in Group III, it equals 1 million rubles), with significant labor and human potential gathered there. This circumstance requires the development of a program for the adaptation of these regions to emerging climate changes.

Keywords: Agriculture, global warming, agricultural resources, intensification, milk and beef production, statistical analysis, rural population, gardening

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Key findings: Presently, Russian agriculture is facing the challenges of global warming, with rising temperatures and uneven precipitation patterns, particularly affecting regions with the highest enhancement in the prevailing temperatures. Despite these contests, the areas with significant resource potential and intensive agricultural production have shown vibrant development, partially due to considerable state support and investment.

INTRODUCTION

The agriculture sector bears significant influences from various effects of global warming (Shaitura *et al.,* 2021), including variations in average temperature, precipitation, carbon dioxide emissions, and other climate change factors (Koshkin *et al.,* 2019). Past studies confirmed that the average surface temperature of the earth has increased by 1°C over the past 100 years (Tian *et al.,* 2021) and continues to grow at a faster rate, approaching 1.5 °C over the last two decades (Chamindri *et al.,* 2023). In the Russian Federation, the temperature rises faster than in the rest of the world (Yakovleva, 2022). The consequences of the considerable and continuous rise in global temperature might be due to variations in the sum and nature of precipitation and an enhancement in the frequency of extreme weather proceedings, including heat waves and droughts (Bondarenko *et al.,* 2018).

According to the estimates of temperature norms in Russia from 1976 to 2020, published by the Academician Yu.A. Izrael Institute of Global Climate and Ecology, the dynamics of this indicator are positive and heterogeneous region-wise (Yu.A. Izrael Institute of Global Climate and Ecology, n.d.). In addition to the temperature, the uneven rainfall and its deviation from the norm demonstrates the multidirectional dynamics across the Russian regions. However, in some zones of Russia, a trend of increased temperature with a simultaneous negative deviation of precipitation from the norm exists. It also leads to negative consequences for the agriculture sector in the form of an enhancement in the likelihood of drought and crop failure in these regions.

Rising temperatures and increasing droughts precisely threaten agriculture, especially the three crops serving as the chief food base of the world, i.e., corn, rice, and wheat (Templ and Calanca, 2020; Almanova *et al*., 2023). Wheat, a winter and drought-afflicted crop has already suffered much as it needs generous precipitation. In Russia, wheat is the prime export commodity in agricultural products. Russia is the largest grain exporter in the global wheat export structure, with the vital role enhancing with time (Zhilyakov *et al.,* 2020; Ybraikozha *et al*., 2024). The horticulture industry, the improvement of which is an essential aspect of the sustainable development of the agriculture industry, is also subject to negative influence (Kunanbayev *et al*., 2024).

Over the past decades, significant transformations have occurred in the Russian agricultural economy. With an increase in financing and subsidizing of the industry since 2006 and the beginning of the implementation of the National Project "Agro-industrial complex (AIC) development" and the state programs for the development of agriculture for 2008-2012, 2013-2021, and 2022-2030, regional differentiation and concentration of the resource potential of agriculture in certain Russian regions have increased (Zinchenko, 2018). In some zones, agriculture is developing more successfully, resulting in the rural areas of these regions coping slowly because the other regions have more vegetation and cannot build infrastructure, innovation, and digitalization in production (Skvortsov, 2023).

Global agriculture depends upon the positive and negative effects of global warming (Makarova *et al*., 2022). In agriculture, the growing negative impact of global warming is an increase in the duration of dry periods, soil salinization and degradation, and the expansion of the habitat of pests affecting crop plants (Ma *et al.,* 2021; Ainebekova *et al*., 2023). However, in some Russian regions, global warming may positively impact agriculture, such as the considerable expansion and an increase in the growing season of crop plants, the precipitation, and indicators of plant productivity (Stepanyan, 2022). It is also accurate for previously unsuitable specific regions, where some are hardly be appropriate for agriculture, and for areas with more developed technological aspects (Kondratenko and Soboleva, 2023; Richards *et al.,* 2023).

Global warming can lead to economic consequences, including variations in agricultural commodity flows (Svetlov 2018a), an increase in the cost of production of different products, a decrease in profitability, and, as a result, a loss of income by agricultural producers (Paptsov and Shelamova, 2018). Income loss by farming communities unavoidably leads to social consequences, including a reduction in wages, the rural population’s purchasing power, and the need for migration in search of new and additional earnings. Global warming will have a principally negative influence on residents of the Southern regions of Russia. The increase in the frequency and duration of drought will also affect the population's living conditions in the form of a shortage of high-quality drinking water and cardiovascular diseases against the background of an increase in average summer temperature. An indirect impact of the rise in dry periods also occurs in the form of deterioration of conditions for crop production, leading to a decrease in the rural population’s level of employment in the agricultural sector (Chugunkova *et al.,* 2018).

Thus, concentrating the Russian agricultural resources and potential in regions most affected by global warming, the risk of technological, economic, and social consequences for the industry and rural areas increases, threatening the country's food security. However, balancing all these risks will require careful planning of the placement of agricultural sectors (Svetlov, 2018b), the development of measures to prevent and eliminate the effects of global warming, and increasing the adaptability of agriculture to climate change. By developing such measures, it is obligatory to remember that global warming and agriculture sectors are interrelated processes.

Encountering the global warming effects, agriculture itself is the chief cause of its occurrence. It primarily happens due to high greenhouse gas levels, crop and livestock industries’ methane and nitrogen oxide emissions, and the plowing of non-agricultural lands. The latest study aimed to identify the regions with different rates of change in average temperature with their subsequent development characteristics, including resource potential, environmental conditions, intensification, and production efficiency assessment.

MATERIALS AND METHODS

This theoretical study based on the impacts of global warming on agriculture in Russia and other countries depended on past research (Bondarenko *et al.,* 2018; Svetlov, 2018a, b; Koshkin *et al.,* 2019). The study also paid thorough attention to Russian agriculture’s features and current state (Svetlov, 2018b; Zinchenko, 2018; Martynushkin *et al.,* 2020). Food security and export risks also serve as prime consequences of global warming for agriculture (Paptsov and Shelamova, 2018; Svetlov, 2018a, b; Zhilyakov *et al.,* 2020). Besides the economic consequences of global warming, an influential basis for the presented study was the social consequences concerning the rural populations employed in agriculture (Chugunkova *et al.,* 2018; Msimanga and Mukwada, 2022; Petersen-Rockney, 2022).

Past studies have shown that the agriculture sector in the regional context is developing extremely unevenly (Costella *et al.,* 2023; Galan *et al.,* 2023), concentrating resources in individual regions (Xue *et al.,* 2019; Templ and Calanca, 2020). It also has significant variations in economic efficiency, environmental consequences, and global warming’s impact on the grain yield of different crops (Demichev and Filatov, 2022; Dubovitski *et al.,* 2021; Ma *et al.,* 2021). Despite numerous research publications devoted to the impact of global warming on Russian agriculture, several issues remain poorly studied (Shaitura *et al.,* 2021; Tian *et al.,* 2021; Guo *et al.,* 2022). It includes grouping the regions based on the level of change in average temperature over a specific period (Stepanyan, 2022; Richards *et al.,* 2023) and assessing resource potential (Klimentova *et al.,* 2021), conditions, efficiency, and the number of people employed in agriculture in these zones (Sharko 2022; Yakovleva 2022; Chamindri *et al.,* 2023). Therefore, it is necessary to consider global warming in developing agricultural policy and agricultural development programs to adapt to the variations taking place.

The study's chief hypothesis was the assumption that in the regions with the highest rates of temperature increase, there concentrated a significant resource potential of agriculture, becoming the location of the most developed agricultural production. Unlike areas with a positive impact from global warming, these regions may suffer considerably and require the development of suitable adaptation measures to changing climatic conditions.

In this study, the statistical methods used comprised the construction of interval distribution series, typological grouping, and a system of general indicators, tabular method, and calculation of dynamics indicators. When constructing the interval distribution series, the data for 77 Russian regions represented the statistical aggregate (except federal cities and autonomous districts, which belonged in their administrative districts, the Republic of Crimea, and new territorial subjects).

The prime data sources for the analysis were the open data of the "Norms and trends of temperature and precipitation for the Russian regions" report on climate risks in Russia by the Yu.A. Izrael Institute of Global Climate and Ecology, statistical collection of the Federal State Statistics Service (Rosstat) (Regions of Russia and Agriculture in Russia) for the period from 2006 to 2022, statistical publications of the Ministry of Agriculture (Agro-Industrial Complex of Russia), and data from all-Russian agricultural censuses of 2006 and 2016 posted on the Rosstat website.

RESULTS AND DISCUSSION

After composing the distribution series for the territorial subjects of Russia (without the autonomous districts, cities of federal significance, the Republic of Crimea, and new territorial subjects), three region groups with different levels of appraisal of the linear temperature trend emerged, i.e., Group I with a low rate, Group II with a medium rate, and Group III with a high rate of temperature change (Table 1). The uneven distribution of different regions based on the studied indicators is available in Table 1. Regions with a high rate of temperature change prevail (32 regions - Group III). Also, 25 regions showed a medium rate of temperature increase over the study period (Group II). However, only 20 regions indicated a low rate of temperature increase (Group I).

The average scores vary for the said groups, from 0.4 °C (Group I) to 0.61 °C (Group III). Therefore, meticulous attention should go to the linear trend of precipitation assessment (% of deviation from the norm of precipitation). Meanwhile, in Group I, the amount of rainfall compared with the norm increases by an average of 1.48% annually. In Group III, the average annual precipitation decreases by 0.76% of the norm. Thus, Group III was most at risk of an upsurge in drought, which means a surge in potential losses in the agriculture sector. However, the composition of different groups does not indicate a strong association between the climatic potentials of the regions and the rate of temperature fluctuations (Table 2).

The correlation coefficient between the average climate productivity score and the estimate of the linear temperature trend was 0.27. In Group I, the Government of the Russian Federation recognized 60% of the regions as unsuitable for agriculture (Order of the Government of the Russian Federation No. 104-r, January 26, 2017). Groups II and III had an indicator of 44% and 28%,

Table 1. Distribution of the subjects of the Russian Federation according to the assessment of the linear trend of temperature (°C) for the period from 1976 to 2020.

Indicators	Groups			Total (average)
	I	II	III	
Number of territorial subjects	20	25	32	77
Temperature range	0.26-0.43	0.46-0.54	0.55-0.71	-
Weighted average estimate of a linear trend				
in temperature (°C)	0.34	0.50	0.61	0.48
in precipitation (% of the norm)	1.48	0.50	-0.76	0.46

Source: Calculated by us based on open data from the Academician Yu. A. Izrael Institute of Global Climate and Ecology (Yu. A. Izrael Institute of Global Climate and Ecology, n.d.). The indicator of the area of agricultural land acted as a weight.

Table 2. Composition of the selected groups of Russian subjects.

Group I (lowest)	Group II (medium)	Group III (highest)
Republics: Bashkortostan, Altai, Buryatia, Khakassia. Territories: Perm, Altai, Transbaikal, Kamchatka, Primorsky, Khabarovsk. Regions: Kurgan, Sverdlovsk, Tyumen, Chelyabinsk, Kemerovo, Novosibirsk, Omsk, Amur, Sakhalin, Jewish Autonomous.	Republics: Chechen, Komi, Adygea, Kalmykia, Dagestan, Kabardino-Balkarian, Karachay-Cherkess, North Ossetia–Alania, Tatarstan, Udmurt, Tyva. Territories: Stavropol, Krasnoyarsk. Regions: Kostroma, Kaliningrad, Astrakhan, Rostov, Kirov, Orenburg, Samara, Saratov, Ulyanovsk, Irkutsk, Tomsk, Magadan.	Republics: Karelia, Sakha (Yakutia), Ingushetia, Mari El, Mordovia, Chuvash. Territories: Krasnodar. Regions: Belgorod, Bryansk, Vladimir, Voronezh, Ivanovo, Kaluga, Kursk, Lipetsk, Moscow, Oryol, Ryazan, Smolensk. Tambov, Tver, Tula, Yaroslavl, Arkhangelsk, Vologda, Leningrad, Murmansk, Novgorod, Pskov, Volgograd, Nizhny Novgorod, Penza.

Source: Self calculated.

respectively. It means that only 28% of the regions in Group III were unsuitable for agricultural production. However, in the future, it may be affected positively by global warming, including through the cultivation of land that was unsuitable for agriculture earlier (Demichev and Maslakova, 2020; Feng *et al*., 2022; Sharko, 2022).

The correlation coefficient between the climate productivity score and the assessment of the linear precipitation trend (% of deviation from the norm) was -0.50, which indicates the average inverse level of the relationship between these indicators, resulting that the higher the indicator of climate productivity, the lower the value of precipitation deviation from the norm. The Russian Meteorological Services (Roshydromet, 2023) have also recorded the reduction of annual precipitation and the increase in the dry period’s duration in the Southern regions.

Considering these different patterns, it is intensely relevant to characterize the resource potential (land resources and farm animals, area planted with fruit and berry crops), the level and dynamics of agricultural intensification (fertilization, feed consumption, subsidies, and capital investments), and the level of efficiency (grain, milk, and meat yields) of these regions. These characteristics will further allow us to assess the state and pace of the different regions’ development, including those with the highest increase in temperature and decrease in precipitation over the studied periods (Group III).

Characteristics of the agriculture resource potential

For Russian agriculture, with its relatively low bioclimatic potential and widespread nature of reproduction, it is vital to preserve the

Table 3. Characteristics of the agricultural resource potential of the grouped Russian territorial subjects.

Indicators	Groups			Total (average)
	I	II	III	
Area in 2022 (million ha):				
Agricultural land	63	72	57	192
Arable land	33	42	41	116
All sown crops	23	30	29	81
Reclaimed farmland	1.7	3.4	4.0	9.1
Including those used in agricultural production	1.3	2.7	2.8	6.8
Livestock of cattle in farms of all categories, million heads	4.8	7.2	5.6	17.5
Production in 2021 in all categories of farms, million t:				
Milk	8.0	11.6	12.5	32.1
Meat and slaughterhouse byproducts	1.3	1.4	6.0	8.7

Source: Calculated based on the Rosstat data (Federal State Statistics Service 2023a, 2023b).

resource potential of the industry and increase the extent of its use. The intensity of resource potential in the regions most affected by global warming develops additional risks for agricultural production's sustainability and the country's food security. In the zones, the parameters of agriculture's resource potential will allow us to estimate the share of the resource potential of the country most exposed to the global warming effects (Table 3).

Group III concentrated up to 30% of agricultural land, 35% of arable land, and 36% of sown crops in the different regions. Noteworthily, the concentration in these regions of fruit and berry plantings is up to 50%, a chief source of minerals, vitamins, and other elements essential for maintaining human well-being and health. Also, the third group of regions contains 41% of the area of grape plantings and 40% of the gross grape harvest.

The coefficients of plowing and use of agricultural land for sowing in Group III were higher, amounting to 72% and 51%, respectively, whereas in Group I, the same indicator was 52% and 37%. This characteristic indicates that in Group III, the agricultural land use was to a greater extent, and these regions have mainly plant-growing specialization. In plummeting the negative impact of global warming on crops, an imperative tool is developing a network of reclamation lands (Kireicheva and Glazunova, 2017). The area of the reclaimed farmland in Group III was higher relative to Groups I and II. However, the area of these agricultural lands was insufficient, especially given the circumstances of the advancing temperature rise and precipitation reduction in Group III.

Group III includes primary producers of livestock products (Table 3). Up to 40% of milk production and 69% of meat and meat products manufacturing are prominent in these regions. Therefore, the said aspect should consider developing a state policy to neutralize the effects of global warming based on a differentiated approach to Russian areas since animal husbandry is a prime source of greenhouse gas emissions and a factor of global warming (Xue *et al.,* 2019). Also, in Group III, the concentration of resource potential is an influential aspect; however, it is compulsory to observe how the resource potential has changed in dynamics, especially during increased state support in 2006.

During the study period, the area comprising agricultural and arable lands changed slightly. It might be mainly because, by 2006, the decline in crop production and other agriculture sectors had already bore replacement by increasing production volumes. In Group III, the crop area increased by 11%, in Group II by 10%, while in Group I, the indicator enhanced only by 3%. In Groups I, II, and III, the number of cattle decreased by 30%, 8%, and 20%, respectively. Also, milk production declined in Group I and increased by 15% and 3% in Groups II and III, respectively. However, the meat production and slaughterhouse byproducts significantly enhanced in all the groups. In Groups I and III, it rose by 41% and 49%, while in Group III, almost three times. The calculated indicators revealed that in Group III, where the temperature has increased most dynamically, it also developed in the crop production and production of meat and slaughterhouse byproducts, particularly the manufacture of poultry, pork, and beef.

Conditions of the management, intensification, and agricultural production

In the groups, the crucial aspects of the characteristics are the conditions in which the agricultural sector operates and the intensification of production. This characteristic will allow us, on the one hand, to more fully reflect the level of development of the industry in these regions, while on the other, to assess the degree of their possible adaptability to the global warming effects (Table 4). In Group III, the Indicators of conditions and intensification of the production were significantly higher than in Groups I and II, except for feed consumption, which confirms the earlier conclusion about the specialization of Group III.

The volume of subsidies and investments is particularly of significant attraction. Group III accounts for up to 49% of the volume of subsidies and 59% of the volume of investments. During the study period in Group I, the average application of mineral fertilizers increased from 8.5 to 35.6 kg/ha; in Group II, from 24.5 to 60.1 kg/ha, while in Group III, from 38.8 to 103.3 kg/ha, which also exceeded the 1990 Russian average of 88.2 kg/ha (Federal State Statistics Service, n.d.). With the concurrent increase in the average tractor capacity and the withdrawal of low-power tractors from the vehicle reserves, the shortage of tractors and agricultural machinery is characteristic of Russian agriculture in general (Martynushkin *et al.,* 2020).

In Group III, the volume of agricultural subsidies in nominal terms enhanced by 4.8 times, while in Groups I and III, it increased by 3.7 and 3.5 times, respectively. Thus, in Group III, a significant potential of Russian agriculture was concentrated, dynamically developing, and having an expanded reproduction of resources, conditions, and intensification of agricultural production, partially due to the significant attraction of state support and investment. The production and economic efficiency of all the groups also differed. The yield of grain crops averages 17, 24, and 34 c/ha in Groups I, II, and III, respectively. Milk yield per head was 5.3, 5.4, and 7.3 t, respectively. Profit, including subsidies, per 100 ha of agricultural land equals 0.2, 0.3, and 1.0 million rubles, respectively.

Rural population and people employed in agriculture

Climate change affects employment in agriculture, and rural populations are often fully involved in agricultural production (Pavlova and Sirotenko, 2012). However, this was especially true in regions where the role of agriculture was crucial in the economy (Ukolova and Dashieva, 2022). For these regions, the decline in the competitiveness of agriculture and the economic losses of agricultural enterprises caused by extreme weather conditions will be particularly sensitive (Nugroho *et al.,* 2023). Climate change also has an economic, social, and cultural impact on rural residents (Msimanga and Mukwada, 2022). The concentration of a significant proportion of the Russian rural population is in Group III (Table 5).

Group III was the largest for the rural population and the most descriptive based on the people’s share of employment in the agricultural sector (Table 5). Group III contains 39% of the rural population and up to 40% of those employed in agriculture in the studied regions. Despite a significant decrease in rural population and those engaged in agriculture, Group III often occupies significant positions compared with all other Russian indicators. In the total population, the share of the rural population is almost the same and has not undergone significant variations during the study period.

Table 4. Conditions and intensification of agricultural production in grouped Russian territorial subjects in 2021.

Indicator	Group			Total (average)
	I	II	III	
1. Application of mineral fertilizers per hectare of crops, kg	33.5	60.6	105.2	68.6
2. Feed consumption per conditional head of cattle, c of feed units	30.4	29.9	29.9	29.8
3. Availability of tractors per 100 ha of agricultural land, units	68.7	90.7	153.6	126.1
4. Volume of subsidies:				
- total, million USD	33	42	71	146
- based on 100 ha of agricultural land, thousand rubles	52.4	58.0	126.1	76.2
5. Volume of investments in fixed assets aimed at the development of agriculture:				
- total, billion rubles	81	121	293	495
- based on 100 ha of agricultural land, thousand rubles	127	168	519	258

Source: Calculated by us according to the Ministry of Agriculture of Russia (Ministry of Agriculture of the Russian Federation 2022).

Table 5. Dynamics of the average number of rural population and people employed in agriculture in grouped Russian territorial subjects.

Indicator	Group			Total
	I	II	III	(average)
Rural population, million people				
2006	10.0	13.2	15.2	38.4
2022	8.9	12.9	13.7	35.5
Share of the rural population in the total number (%)				
2006	27	33	30	30
2022	25	32	28	28
People employed in agriculture, million people				
2006	1.9	2.6	2.9	7.4
2022	1.0	1.7	1.7	4.4

Source: Calculated by us based on the Rosstat data (Federal State Statistics Service 2023a).

Based on the present results, three groups of diverse regions identified had different average temperature increases over the observation period from 1976 to 2020. Group III had concentrations of the areas favorable for agriculture. However, the share of regions unfavorable for agriculture was also large and amounted to 28%. The groups have a multidirectional linear trend of precipitation variations. In Group III, in contrast to Groups I and II, precipitation has a negative trend, annually decreasing by an average of 0.76% of the norm. The maximum decrease in rainfall recorded was in the Volgograd region (on average -2.1% deviation from the norm annually).

During the study period, Group III includes the regions with the highest increase in average temperature and the utmost decline in precipitation, which significantly enhances the likelihood of the intensity and duration of dry periods. The presented analysis of the resource potential of the groups revealed that Group III contained a significant potential for Russian agriculture. It also contains one-third of agricultural lands, 35% of arable lands, and 36% of areas of sown crops. In all the regions, the area of reclaimed land was insufficient, and this circumstance was especially hazardous for Group III. Besides crop production, Group III has significant potential to produce livestock byproducts.

The conditions and intensification of the production is an essential characteristic of all the groups. Group III differed significantly from Groups I and II. It was also especially true for the application of fertilizers, the availability of tractors, the volume of subsidies provided, and subsidies sent for agricultural development. As a result in Group III, the production and economic efficiency of agricultural production was also higher. In dynamics, the development of the groups was also heterogeneous. During the study period from 2006 to 2022, in Group III, the volume of agricultural production was considerably enhanced, the resource potential of the industry was preserved, and the conditions, intensification, and production efficiency were significantly improved. The state support and investments were also sent at a faster pace to these regions.

Apart from the economic consequences, one must not ignore the social issues caused by global warming due to climate change. The problems that arise against crop failures, droughts, and other extreme and unfavorable conditions will ultimately affect those engaged in agricultural production, especially the rural population. Despite the general decline in the number of people employed in agriculture and the rural population, 40% of those in agriculture and 39% of the rural population of the studied subjects proliferate in Group III. In the case of a continuing and possibly accelerating trend of temperature increase and precipitation decrease in these regions, there will be a need to solve not only production and economic but also the social problems that will arise.

CONCLUSIONS

The relevant study revealed that global warming poses significant challenges to Russian agriculture. The acceleration of temperature rise, uneven precipitation patterns, and increased drought risk threaten crop yields, especially for essential crops like wheat, rice, and corn. These effects were most prominent in the regions experiencing temperature increases, where considerable concentrations of agricultural resources abound. In the course of analyzing the resource potential of regional groups, it was evident that the third group contains the significant potential of the country's agriculture - it is a third of agricultural land, 35% of arable land, 36% of the crop area, and up to 50% of the areas of fruit and berry plantings. Despite this trend's economic prerequisites, the concentration of significant resources and potential for developing agricultural production in specific regions casts doubt on the sustainability of food security and export potential in Russia. In the groups of diverse zones, the degree of exposure of agriculture to the negative impact of climate change necessitates creating measures and introducing advanced technologies that contribute to the adaptation of agriculture to the new emerging conditions. The emerging climate risk requires an appropriate adjustment of the strategy for improving agriculture and developing mechanisms for fair compensation for the damages caused by global warming.

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