Role of agriculture in climate change and adaptability: Use of innovative technologies in the Russian agricultural sector for climate conservation and protection

I. V. Kryukova[1*], *A. A.* Lagun[1], *S. G.* Golubeva[1], and *E. N.* Yakovleva[2]

[1] Vologda State Dairy Farming Academy named after N.V. Vereshchagin, 2 Schmidt St., Molochnoe village, Vologda, 160555, Russian Federation
[2] Russian Presidential Academy of Natural Economy and Public Administration, 71 Leningradskaya, Str., Vologda Oblast, Vologda, 160017, Russian Federation

Abstract. Global climate change poses two major challenges to the agricultural sector of the economy. First, it is necessary to assess the value and extent of its impact on atmospheric pollution by greenhouse gases, and, based on this, to determine priorities and the emission reduction strategy. The second concerns the adaptation of agriculture to threats and the use of causes from global climate change. Therefore, the purpose of the study is to disclose these two aspects. First, the national contribution of agriculture to greenhouse gas pollution was studied using the example of the Russian Federation according to the author's methodology. Then the directions of the state adaptation policy towards the studied sector in the light of climate change are proposed. The results of the study can be useful in developing the adaptation strategy, increasing the flexibility of the agricultural sector of different countries to climate change.

1 Introduction

The interaction of agriculture with climate risk factors is quite complex and requires careful study. On the one hand, this sector makes a significant contribution to air pollution with greenhouse gases: nitric acid emissions account for 90% of the world's emissions, methane – 70% and carbon dioxide – 20% of all emissions [1]. Therefore, there is a need for innovations to reduce the technogenic burden of the agricultural sector on the environment without increasing average costs and prices for agricultural products. On the other hand, the natural interest is caused by an increase in the flexibility of agriculture response to changing climatic conditions. This increases the relevance of developing and implementing an effective climate change adaptation mechanism. Many works of foreign and domestic authors are devoted to the study of these problems. Since traditional agricultural methods are associated with greenhouse gas emissions [1], it becomes necessary to look for opportunities to reduce the negative impact of this sector on the climate [2]. In turn, the efforts to reduce greenhouse gas emissions also have a negative impact on the capacity of agricultural markets and their pricing. In this regard, the threats to ensuring food security of the world community as a whole and the problems of hunger in certain poor regions of Africa and South Asia are increasing [3]. The issue of methodical provision of climate risk assessment for the agricultural sector remains unresolved [4, 5, 6]. It is critical to address this issue since regional climate change forecasts and modeling of the associated future change in socio-economic systems are needed to regulate, adapt and develop the climate risk management strategies [4]. In addition, global warming is causing changes in land use and increases competition for land and water resources. The existence of a number of consequences of climate change seems quite positive, for example, an increase in the growing season and the involvement of previously unused northern territories in agricultural circulation [7], the development of agriculture due to an increase in demand for biofuels as a low-carbon energy resource [2], and so on. Therefore, the development of adaptation strategies and measures for agriculture is one of the most debatable issues [8, 9]. Particular attention is paid to the study of ways to intensify the adaptation of the agricultural industry to climate change, since the incentives for such adaptation by private enterprises are underestimated [7]. A reactive approach prevails in agriculture, when farmers make short-term management decisions in response to climate challenges [10]. At the same time, it is the agricultural sector that requires the development and application of proactive strategic adaptation policies, since long-term climate risks may be much greater than the current ones [6]. An attempt to solve methodological problems at the national level was made earlier by the authors [11]. Within the framework of this study we will test the proposed methodology to determine the role of agriculture in the anthropogenic component of climate change using the example of the Russian Federation and propose recommendations for the development of appropriate adaptation policies.

* Corresponding author: iri917717@yandex.ru

Let us study the intersectoral structure of greenhouse gas emissions in the Russian Federation to identify the position of the industry in the Russian economy in terms of natural and climatic impact. The energy sector dominates in this structure (according to Rosgidromet), the share of which in the total emission was 78.7% in 2019, in the second place – industry (11.2%), in the third – agriculture (5.4%). This state of affairs is also characteristic of other countries. For example, in Turkey in 2016 the energy sector took first place with a share of 72%, followed by industry (12.6%) and agriculture (11.4%) [1]. In 2019, greenhouse gas emissions from the agricultural sector of the Russian Federation amounted to 114.2 million tons of CO_2-eq., which corresponds to 46.1% of the 1990 level (247.5 million tons of CO_2-eq.). The reasons for this reduction are a decrease in the number of farm animals (for example, during this period the number of livestock decreased by almost 2.4 times and poultry – by 17.2%), a decrease in sown areas (decreased by 30.6%) and the norms for introduced mineral fertilizers (application of mineral nitrogen fertilizers decreased by 59.4%). Soils (mainly from nitrogen fertilizers) and internal fermentation (CH_4) account for the largest share of CO_2-eq. agricultural emissions (Figure 1).

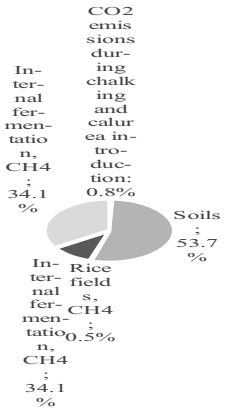

Fig. 1. Structure of greenhouse gas emissions in Russian agriculture by sources (thousand tons of CO_2-eq.) in 2019.

2 Materials and methods

The previously conducted comparative assessment of the Russian regions using the author's methodology [11] in the coordinates "climate intensity-energy intensity" showed that the majority of the Russian regions in both indicators is around the median [12]. The exception is energy intensity – Vologda Region (78.5% of the turnover – enterprises in the manufacturing industries, mainly ferrous metallurgy and chemistry), Kemerovo Region (72% of turnover – mining and manufacturing), Lipetsk Region (69.5 – enterprises of manufacturing industries, mainly ferrous metallurgy) and the Republic of Khakassia (44% of turnover – manufacturing enterprises), and in terms of climate intensity – Nenets Autonomous Okrug (70% of the turnover – mining), Yamalo-Nenets Autonomous Okrug (66% of the turnover – mining), Khanty-Mansi Autonomous Okrug (73% of the turnover – mining), Krasnoyarsk Territory (59% of the turnover – mining and manufacturing) and the Republic of Komi (42% of the turnover – mining). It seems clear that the high energy intensity of the regional economy is formed by enterprises in the manufacturing industries, mainly ferrous metallurgy, and significant climate intensity is formed by mining.

Figure 2 shows the TOP-15 in the ranking of the Russian regions by the volume of agricultural products produced in 2019. According to the figure, the presence of a developed agricultural sector in the region's economy does not have a decisive impact on its position in the climate risk matrix [12]: agricultural territories are found in almost all groups of the matrix. Thus, the leader of the agricultural industry – Krasnodarsky Krai has high climate intensity and low energy intensity. Eight subjects from TOP-15 have low climate intensity and high or medium energy intensity.

The application of the author's methodology for the comparative characterization of sectors [13] revealed that in terms of the combination of two indicators, the highest natural and climatic risks are inherent in the energy sector (due to the predominant use of traditional energy sources) and the mining industry (mainly due to the high energy intensity of production). Waste sector holds the second place and Agriculture – the third. All three types of economic activity fell into the group with the highest level of climate intensity. Mining turned out to be the most energy-intensive activity. Transport and Manufacturing sectors have average climate risks. No sector has low risks.

The subject of this study is agriculture as one of the climate-intensive types of economic activity and a solution to the problem of developing the adaptation policies due to the impact on climate.

The purpose of the study is to analyse the national contribution of agriculture to greenhouse gas pollution using the example of the Russian Federation via the author's methodology and to propose directions for the state adaptation policy towards the studied sector in the light of climate change.

A set of methods of scientific knowledge were used in the study, including analysis, synthesis, induction, deduction, abstractions, tabular method, etc.

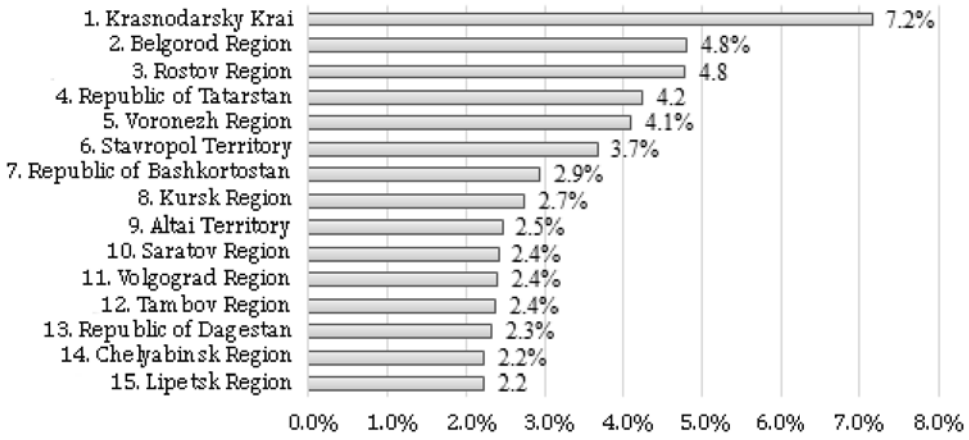

Fig. 2. Relative share of agricultural products of the regions from the total agricultural products in the country (in farms of all categories in actual prices), %.

3 Results and discussion

The study showed the average impact of the agricultural sector of the Russian Federation on the level of climate threats. The application of this method is of scientific and practical interest not only for inter-industry, but also for intra-industry analysis, which requires the statistical accounting of greenhouse gas emissions and energy consumption in the context of industries and sub-sectors of the country's national economy.

Since agriculture, in either absolute or relative terms, clearly does not belong to the leaders of the negative impact on climate, it is possible to recommend that the national climate policy focus on the adaptation of this sector to climate threats. This is especially true because global climate change is causing a whole set of new problems in agricultural production that can be combined into three groups.

1) The climate factor is decisive in ensuring agricultural productivity, and the increase in climate

risks and their negative consequences (expansion of pest ranges, the spread of bacterial and viral diseases, etc.) increase threats to the country's food security. Therefore, there are conceptual and methodological problems related to the need to take into account, assess the likelihood of occurrence and scale of the spread of the consequences of natural and climatic risks for agriculture, and their management tools. Theoretical and applied solutions are also needed to adapt the industry to this risk group.

2) Global warming leads to a longer growing season in the northern regions, creating conditions for an increase in the area of farmland, the development of which requires the attraction of very scarce investment resources. The enrichment of the atmosphere with CO_2 creates conditions for the increased yield of grain and feed crops. However, the positive effects of climate change on agriculture may be less significant than the negative ones (Table 1).

Since increased climate risks lead to both additional threats and chances for agricultural development (Table 1), the adaptation measures are needed to reduce the former and use the latter.

3) There is a need for a mechanism to stimulate the reduction of anthropogenic greenhouse gas emissions from the agricultural sector, as well as technologies and methods for such a reduction. However, if the state imposes stringent requirements to reduce greenhouse gas emissions, this could have a more significant negative impact on the country's food security than direct losses from climate change [3].

All three of the above groups of problems are most effectively solved through the activation of innovative processes. Innovation plays a decisive role in intensifying economic development with qualitative improvement in farming. Innovative activity in agriculture has significant specifics in connection with the peculiarities of the industry itself: low profitability, competitiveness, and as a result, the investment attractiveness of the industry, high land capacity, long production cycle, stationary and seasonal nature of production, high dependence on climatic conditions, low rates of scientific and technical innovations in comparison with other industries, etc. Strengthening the innovative development of the agricultural sector is possible only by increasing the volume and list of measures of state support for this process.

The interests of the state in this process lie in the plane of ensuring food security, developing import substitution, increasing the competitiveness of the industry, developing rural areas, and, as a result, solving such social problems as improving the quality of life of the population, reducing poverty, differentiating incomes and others. In our opinion, the state policy on the adaptation of the agricultural sector to climate change should be focused on the innovative development of the industry using the following support measures:

– distribution of state resources (orders, grants, loans) between priority R&D areas;
– stimulation of innovative cooperation between agricultural, educational and scientific

enterprises;
- support for innovative entrepreneurship in the agricultural sector;
- application of tax, depreciation, antimonopoly, patent, foreign trade policy instruments through differential subsidies and the provision of benefits that create conditions for accelerating scientific and technological progress in the field of adaptation of agriculture to climate change;
- stimulation of public-private partnership in the considered sphere;
- regional support for the development of innovations, including digital technologies.

Table 1. Impacts of climate change on agricultural sectors and their adaptation to climate risks.

Types of risks	Climate change impacts		Risk adaptation pathways
	negative	positive	
Increase in soil erosion, increase in groundwater level, flooding of areas, floods, droughts, fires.	Expansion of the habitats of some weeds, parasites, insects – pests, zones of viral and bacterial diseases of animals and plants. Soil erosion due to increased wind loads, landslides, etc. Deterioration of agricultural conditions due to an increase in the level of groundwater, underfloods, flooding, floods, desertification of territories. Reduction of pasture areas.	Expansion of possibilities of growing forage, grain and vegetable crops in the northern regions due to an increase in the growing season. Increase in the yield of grain and forage crops due to the enrichment of atmospheric air with CO_2.	Selection of crops and zoned varieties, measures to preserve moisture, irrigation, application of fertilizers, application of new technologies, improvement of material and technical base for full implementation of agricultural technology of cultivation, diversification of agricultural production, creation of food stocks, insurance against hazardous hydrometeorological phenomena, prevention of negative human interference in natural processes (drainage, plowing of floodplains, errors in the construction of irrigation systems, etc.), enhancement of the competitiveness of the industry and its investment attractiveness.

4 Conclusion

The study revealed the following:
- first, the agricultural sector contributes several times lower to the anthropogenic component of the greenhouse effect than energy, and lower, but comparable, than the manufacturing industry;
- second, the relationship between the regional contribution to the greenhouse effect and the level of agricultural development was not identified: the agricultural sector is developed in territorial entities with both high and low climatic impact;
- third, the agricultural sector belongs to the types of economic activities with an average level of risk of impact on the climate;
- fourth, since agriculture is not a priority in the management impact of reducing greenhouse gas emissions, it is recommended that key attention be paid to developing a government mechanism for adapting the industry to climate change. The best direction of adaptation, according to the authors, is innovative development. The study gives general recommendations on the state stimulation of the introduction of innovations at agricultural enterprises.

References

1. M. Çetin, S. Saygın, H. Demir, The impact of agriculture on environmental pollution, *Turkish Economy For A Cointegration and Causality Analysis* **17 (3),** 329 (2020)
2. K. M. Findlater, T. Satterfield, M. Kandlikar, S. D. Donner, Integration anxiety: the cognitive isolation of climate change. *Global Environmental Change* **50,** 178 (2018)
3. T. Hasegawa, et al., Risk of increased food insecurity under stringent global climate change mitigation policy, *Nature Climate Change* **8 (8),** 699 (2018)
4. W. J. W. Botzen, J. C. J. M. Van Den Bergh, Managing natural disaster risks in a changing climate, *Environmental Hazards* **8 (3),** 209 (2009)
5. F. Ewert, et al. Crop modelling for integrated assessment of risk to food production from climate change, *Environmental Modelling & Software* **72** (2015)
6. I. Brown, Assessing climate change risks to the natural environment to facilitate cross-sectoral adaptation policy, *Philosophical Transactions: Mathematical, Physical and Engineering Sciences (Series A)* **376 (2121)** (2018)
7. N. N. Yashalova, T. K. Molchanova, D. A. Ruban Prerequisites for effective management of climate risks in Russian agriculture: investment and innovative aspect, *Bulletin of UrFU. Economics and Management* **18 (5),** 637 (2019)
8. R. P. Motha, M. V. K. Sivakumar, Managing weather and climate risks in agriculture summary and recommendations, *Managing Weather and Climate Risks in Agriculture* **477** (2007)
9. R. E. Schattman, G. Roesch-Mcnally, S. Wiener, M. T. Niles, D. Y. Hollinger, Farm service agency employee intentions to use weather and climate data in professional services, *Renewable Agriculture and Food Systems* **33 (3),** 212 (2008)
10. M. T. Niles, M. Lubell, V. R. Haden, Perceptions and responses to climate policy risks among California farmers, *Global Environmental*

Change **23 (6),** 1752 (2013)
11. E. N. Yakovleva, N. N. Yashalova, D. A. Ruban, V. S. Vasiltsov, Methodological approaches to natural and climatic risks for the sustainable development of the state, *Scientific notes of the Russian State Hydrometeorological University* **52,** 120 (2018)
12. V. S. Vasiltsov, N. N. Yashalova, E. N. Yakovleva, A. V. Kharlamov, National climate policy: Conceptual frameworks and adaptation challenges, *Economy of the Region* **17 (4),** 1123
13. E. N. Yakovleva, N. N. Yashalova, V. S. Vasiltsov, Analysis of natural and climatic risks of economic activities in the Russian Federation, *Scientific notes of the Russian State Humanitarian University* **61,** 421 (2020)