Ensuring the security and sustainability of the food system in the face of climate change

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Abstract. The article presents the results of a study on the capabilities of food system, agricultural sector of the economy and rural areas to withstand modern challenges caused by the adverse effects of climate change. The purpose and objectives formulated in the work are implemented using review and analytical research methods undertaken in relation to both the theoretical achievements of these areas of research and the practices available in the world. The main scientific conclusions presented in this article are related to such important issues as (1) specification of directions for improving the food system that are promising from the point of view of climate conservation and sustainable development, (2) identification of options for adapting the food system and agriculture to climate change, as well as opportunities to reduce their negative impact on the climate, (3) identification of mechanisms and tools for involving all stakeholders in the development and implementation of climate-saving measures in the rural space.

1 Introduction

Today, among the threats of a biological, climatic, and geopolitical nature, problems related to climate change are increasingly in the focus of agricultural science and rural policy, leading to the emergence of relevant research and the approbation of new economic practices [1, 2]. As experience shows, the modern food system has shown its irrelevance to the challenges of the time, responding to them (to the demands of intensification, first of all) by deteriorating the quality of food (its increasingly smaller range is identified as contributing to health promotion), the instability of agricultural practices (many of them enhance the anthropogenic impact on the climate), the inefficiency of natural resource management tools resources (deterioration of their condition is becoming a significant problem for rural areas).

In this regard, the development of sustainable, diversified, inclusive and effective food systems that contribute not only to ensuring food security, but also to overcoming the complexities of social and environmental nature, is becoming an important state task related

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to the priorities of society in the field of demography, employment, rural conservation, climate change, innovative rural development. As a result, research areas related to healthy nutrition, climate-optimized agriculture, environmentally sustainable agri-food systems, cyclical and efficient use of resources, and empowerment of rural communities through various technological and organizational innovations are becoming more active in agricultural and economic science.

2 Materials and Methods

To obtain reasonable conclusions, the key scientific postulate in the work is the statement that agriculture is one of the most climate-sensitive sectors of the economy, which can have serious consequences for food security, on the one hand, and the well-being of the rural population, on the other. Considering the use of alternative methodological approaches by scientists in the procedures for specifying the effects of climate warming on agriculture, as well as the impact of agriculture on the climate, different points of view formulated in available publications on this topic were reviewed during the research undertaken [3, 4, 5]. While science has made significant progress in questions related to the correlation between agriculture and climate in recent years, there are still no clear answers about (1) what consequences agriculture expects at different levels of warming, (2) exactly how it is possible to reduce the negative impact of agricultural activities on climate and (3) which list of cost-effective measures of adaptation to the negative effects of climate change is most relevant at the present time, as well as what is the role of all participants in the rural space (local administrations, agricultural producers, rural communities) in this process. In addition, modern research actualizes the task of developing model forecasts, which remains elusive, despite considerable research efforts currently underway.

In the course of the work, both purely theoretical and practice-oriented research were subject to study. Thus, the works devoted to the assessment of statistical correlations between climate change variables (weather conditions, first of all) and crop yields [6, 7] deserve attention, based on historical observations and reflecting not only the biophysical reactions of yields to fluctuations in weather variables, but also the processes of adaptation of farmers in certain countries and individual localities. Yet, the difficulties noted in this approach lead to the fact that neither statistical nor procedural methods do not reflect many socio-economic links and consequences. For example, long chains of sequential effects are rarely affected, including price changes as a result of climate impact, decisions of business entities regarding crop areas, technological innovations for the effective use of local resources (including natural ones). More modern approaches based on integrated assessment models, affecting all elements of the agri-food system and related relationships, differ in the inclusion of factors mitigating the negative impact of warming on crop yields, such as technological changes, the possibility of resource substitution, crop change and others [8].

Among the methods implemented in the study, one can single out, first, a scrupulous review of Russian institutional documents, on the basis of which the provisions of the climate agenda adopted for implementation are implemented. Second, economic practices (both domestic and foreign) were subject to study, either aimed at reducing the negative impact of agriculture on the environment and climate, or being an example of adaptation of the agricultural industry and the relevant territories to the negative manifestations of climate change for them. Some conclusions and forecasts have been proposed to the scientific community on the basis of theoretical generalizations and empirically verified hypotheses that take place in modern scientific publications. Finally, the expert opinions expressed by practitioners at scientific and practical events (seminars, conferences) were considered when determining the options available to farmers, other business entities, and rural communities with their participation in the implementation of Russian climate policy.
3 Results and Discussion

Modern programs for the sustainable development of the agricultural sector of the economy and rural areas are closely correlated with the seventeen Sustainable Development Goals formulated by the United Nations (UN) in 2015, and with those that relate directly to humans (eliminating poverty, hunger, ensuring good health, education, employment), and with those more related to the functioning of the food system and the economy as a whole (clean water, acceptable sanitary conditions, inexpensive electricity, stopping land degradation and loss of biodiversity, responsible production and consumption). It is obvious that such global problems can be solved only on the basis of an equally global partnership, and therefore modern national institutional documents are based on both internal interests and international agreements. Thus, adopted in 2023 Climate Doctrine of the Russian Federation (approved by the President of the Russian Federation on 11/26/2023, hereinafter referred to as the Doctrine) designates the Vienna Convention on the Law of Treaties of 05/23/1969, the Montreal Protocol on Substances that Deplete the Ozone Layer of 09/16/1987, the UN Framework Convention on Climate Change of May 9, 1992, the Kyoto Protocol to The Framework Convention of 11.12.1997, the Paris Agreement of 12.12.2015 and other international treaties of the Russian Federation on issues related to climate change, the environment, and sustainable development as basic international documents [9].

Considering that without the implementation of the climate agenda, the sustainable development goals cannot be achieved, in the Doctrine, as in other strategic documents (the Strategy of Socio-economic Development of the Russian Federation with low greenhouse gas emissions until 2050, the National Security Strategy of the Russian Federation, the Concept of Foreign Policy of the Russian Federation, the Strategy of Economic Security of the Russian Federation for the period up to 2030, The Strategy of Environmental Safety of the Russian Federation for the period up to 2025, the Energy Strategy of the Russian Federation for the period up to 2035, etc.), the course is set for a significant reduction in greenhouse gas emissions (limiting to 70% of the 1990 level by 2030), and in this regard, to reduce the anthropogenic impact on the climate from industries economy (including agriculture) [9]. Due to the generally recognized, and significant, impact of agriculture on the environment and climate, agricultural producers have to adapt to climate change by introducing technologies that reduce greenhouse gas emissions, effectively using fossil fuels and other non-renewable natural resources in production, reducing food losses and waste, and other climate-saving initiatives. It is important that the solution of these tasks, identified by society as priorities, entails both direct economic, social and environmental benefits (starting with a significant improvement in public health and ending with the preservation of the habitat for future generations), as well as many relevant externalities [10]. As already noted, many aspects of the climate agenda relate to practical activities organized in the rural space, come to the attention of many scientists, and determine the content of various areas of national and international policy.

As for the transformation of the food system, only innovative approaches to the functioning of all its elements can make it more viable, sustainable, flexible, and, as a result, adaptive to climate change and other global threats and challenges, including extreme weather events. The breadth of the range of tasks related to the implementation of climate policy determines the active involvement in their solution of all participants in the food system, as well as civil society (rural populations, their professional communities, social networks), which determines the list of activities related, firstly, to the transition of agriculture to climate-saving or climate-optimized models, secondly, innovative, favorable for the state of the climate, the development of other sectors of the rural economy, including bioeconomics, and thirdly, the functioning of rural areas considering the content of climate
policy. It is on these issues that this study focuses, some of the results of which are presented below.

Turning to the issue of agriculture transformation, observed both in response to the demands of society regarding the reduction of anthropogenic impact on the climate, and in connection with the need to adapt the industry to negative climate changes, it is important to consider that traditional agriculture is characterized by a relatively narrow specialization, significant dependence on fertilizers and pesticides, and the use of powerful equipment for tillage which worsens its structure and quality, inhibits the development of soil microorganisms that ensure natural fertility and plant protection [11]. As a result, the transition to regenerative agriculture, which differs from the traditional one by caring for the environment and focusing on healthy nutrition of the population (today and future generations of people), is becoming in demand. The broadest definition of regenerative agriculture is to organize the production of agricultural raw materials and food products in such a way as to improve the "health" of the soil, preserve rural landscapes, achieve climate stability, increase ecosystem functionality, while remaining economically beneficial for agricultural producers, on the one hand, useful and safe for consumers, on the other. In fact, regenerative agriculture means conducting agricultural activities in accordance with the laws of nature and for the benefit of man and his environment [12].

To clarify the essence of regenerative agriculture, it is useful to identify the principles underlying it, as well as the management methods used by it. Thus, among the principles of regenerative agriculture, it is advisable to single out (1) the creation of healthy (biologically active) soils, since they, by supporting the vital activity of bacteria, fungi and other soil microorganisms, ensure the availability of nutrients to plants, protect them from diseases and are the basis for the functioning of carbon, minerals and water cycles through a complex soil system, (2) maximizing photosynthetic activity, during which plants feed soil microorganisms necessary for soil health and receive nutrients and other benefits in return (in addition, covering the soil with living plants and plant residues also protects the soil from erosion and temperature changes), (3) minimizing the use of chemicals as fertilizers and plant protection products which (in the absence of restrictions) violates soil biology and suppresses the symbiotic relationship between soil microbes and plants (in return, regenerative farming methods rely on natural processes and the "circular" involvement of crop and livestock resources in circular agricultural production), (4) taking advantage of diversity and consistency, meaning the cultivation of various crops and trees on the same land, breeding of different species of animals, and so that each production system contributes to the development of the other, (5) achieving a balance of economic, environmental and social goals, as a result of which society is able to realize such important priorities for it as improving the condition of soils and other natural resources, preserving biodiversity and rural landscape, high quality of food, satisfaction of the economic interests of farmers and the social needs of the rural population. Considering that these same principles underlie agriculture, referred to in modern scientific literature as "climate-saving", "climatically optimized", "organic", "biodynamic", their implementation is important for determining promising trends in the development of many areas of agricultural activity.

Definitely, the implementation of these principles is entrusted to the main economic entities of the rural space – agricultural producers. They are the ones who use these principles to choose farming methods, focusing on the climatic and environmental problems of society. For example, in farming systems, agricultural producers who adhere to the above principles minimize tillage, plant cover crops, and apply more diverse crop rotations. In addition, they avoid synthetic fertilizers, using biological fertilizers instead. A similar situation is observed in such farms and in pest control (reduce or eliminate the use of chemical pesticides). No less significant in the development of regenerative agriculture is the adherence to its principles by producers in the field of animal husbandry. In such farms, farmers tend to raise animals.
on pastures most of the time (as far as weather conditions allow), adapt the methods of the pasture feeding system, avoid the use of hormones and antibiotics in the treatment of animals. Finally, business entities integrate agroforestry or pasture techniques into their production by planting trees on arable land, growing crops in tree-free flatlands, planting trees on pastures or grazing animals in existing open forests.

The second important direction of promoting rural areas and activities carried out within their borders towards climate conservation and successful adaptation to climate change covers the food system as a whole, focusing on some important circumstances. First of all, modern research identifies a number of contradictions that society will have to resolve in the near future. The first of them emphasizes the importance of innovation in the development of a food system optimized according to modern criteria and, at the same time, the different access of its participants to both innovations and their results. Small agricultural, fish, food, and retail farms, which limit investments in innovations due to scarce financial resources and unacceptable risks, are at a disadvantage. Moreover, small food companies, farmers, and small producers in other fields of agricultural activity still lack incentives to produce sustainable and healthy food. Most consumers are also not in the best position, as many of them do not have sufficient income to purchase healthier (relatively expensive) food, which is accompanied by a rapid increase in obesity among the population and the spread of diseases associated with malnutrition [13].

All this allows to conclude that the food system cannot become more sustainable without changing the principles of its functioning, appropriate government policy, and the active participation of all stakeholders in sustainable development and climate conservation programs. Governments are called upon to stimulate business to significant transformations, including the development of innovations in a certain direction, assuming that affordable and high-quality food for the population, as well as high incomes for those working in agriculture and forestry, fishing, food production, will not be obtained at the expense of harming public health, environmental degradation reduction of biodiversity, deterioration of animal welfare conditions, and through the introduction of modern climate-optimized technologies and solutions. First. The nutrition structure and lifestyle of a person should be improved (the possibilities of reducing the impact of food consumption on the environment should be considered). Second. The company's task is to develop a resource-saving food system with a reduction in greenhouse gas emissions to the limits set by international and national documents. Third. It is advisable to direct the efforts of scientists and practitioners to empower small producers and rural communities in the development of climate-saving measures, as well as during the monitoring of their implementation.

Regarding the first point, it should be emphasized that in conditions of a wide variety of food products, it is important to change eating habits and increase physical activity, which already eliminates the main risk factors and reduces diseases associated with overweight and malnutrition by about 50% [14]. Recent research in nutrition and demography has comprehensively argued that successful nutrition and lifestyle strategies allow people to live longer, stay healthy, and reduce their health care costs. In addition to the efforts of consumers (the population), enterprises that offer consumers certain products, opportunities to maintain health, and living conditions in environmentally friendly areas play an important role in generating "healthy" (corresponding to the understanding of sustainability) eating habits. Representatives of the health sector, namely, nutritionists, doctors, employees of health insurance companies, can also promote the choice of environmentally friendly food products by the population and appropriate production technologies by manufacturers (innovative food products are being developed for the elderly, children, and other target groups of the population). The result of the efforts undertaken are such positive effects as (1) normalization of the weight of school-age children, adolescents, and adults, (2) increase in the life expectancy of the population and improvement of its health, (3) focus of the food industry
on obtaining more nutritious and tasty products that are both beneficial to the consumer and safe for the environment, (4) creation of a resource-saving food system with a reduction in greenhouse gas emissions Considering that a quarter of them fall on the food system.

Focusing on the need to reduce such emissions, this is the second direction of demanded transformations, we emphasize the options available to society for redesigning the food system (in addition to what has already been said) towards solving the climate problem, observing environmental requirements for soil, water and air quality, biodiversity and rural landscapes. Thus, the food system, in this regard, must eliminate unnecessary risks to public health and state of environment, respect ethical requirements and principles of social justice formulated by society. Crop production should be largely based on agroecological principles, supported by a reduction in the use of energy based on fossil fuels, the use of chemical fertilizers and pesticides. Integrated water resources management is needed. In the field of production, problems require attention, firstly, the effective use of waste, and secondly, the product ion of packaging material harmless to nature and humans, as a result, the task of developing technologies that allow them to be processed in a safe way in accordance with closed-loop economy principles. In a broad sense, the farming system is being rebuilt to use an integrated approach to animal husbandry and crop production, reducing anthropogenic impacts on climate and ecology, and converting waste streams into productive resources [15].

It is important to note that all this is not only consistent with the points of the Doctrine adopted in the Russian Federation, but is also supported by new technological capabilities (precision farming, robotization, digitalization, etc.), which can completely rebuild the food system and reduce its negative impact on the environment. Public debates today concern not only the industrial and environmental consequences of such restructuring, but also the ethical consequences, organizational innovations, mechanisms of cooperation between all stakeholders, algorithms for using new knowledge about proper management and effective organization in agriculture, animal husbandry, and food industry. At the same time, the following are defined as targets: 1) development of climate-sustainable food systems; 2) diversification of production, needs, opportunities so that resources are used in a sustainable and climate-friendly manner; 3) development and implementation of livestock farming systems with a low level of environmental impact; 4) reasonable use of soils and other natural resources; 5) reducing the impact on the human environment (and nature in general) of packaging of food and other products; 6) significant reduction of food and other waste, minimizing losses in food and agricultural systems; 7) development of social networks in the rural space, formal and informal institutions of cooperation and mutual assistance, inclusive management of rural areas to create a sustainable and safe food system.

Finally, the third noted direction of food system transformation is due to the fact that the innovations initiated in this regard need prompt feedback and widespread involvement in decision-making of all stakeholders (consumers, farmers, food producers, rural communities, scientists, authorities). To make the food system more inclusive, it is advisable to pay attention to the problems that lie in the social plane of the rural space [16]. These include stimulating social innovation, including empowering local communities, small agricultural organizations and small food industry enterprises to participate in the creation of new business and management models. Among organizational innovations in this regard, they are popular in international practice: 1) connecting local communities and small businesses, through digital technologies and information opportunities, to innovation centers; 2) involving citizens in making important decisions through educational and social programs; 3) promoting knowledge sharing, civil society participation and dissemination of best practices through the creation and development of digital platforms. All this, firstly, ensures security, transparency and trust (increasing the security of the entire food system), secondly, improves the management of global and national food systems (including through the growth of the innovative potential of small firms and strengthening the role of citizens in shaping a
healthy, diverse and sustainable food system), thirdly, it promotes the creation of a healthy living environment and the use of environmentally friendly and healthy food, and fourthly, it reduces the negative impact on the climate and the environment.

4 Summary

Modern rural areas have ample opportunities to take initiatives to create a food system that meets the requirements of tomorrow, works towards achieving sustainable development goals, and considers the threats posed by climate change. The existing institutional documents related to national climate policy and sustainable rural development stimulate modern food systems to produce safe food products of high standards, and agriculture to improve its competitive position at the same time with respect for the environment and climate. As established in the course of the study, the implementation of the climate agenda concerns, firstly, purely technological aspects of the functioning of the industry and related investments, secondly, the establishment of social contracts, close cooperation of all stakeholders and the general goal-setting of their activities focused on human health, a climate-optimized economy, the sustainability of the food system to threats and challenges of the new of a nature (including biological and geopolitical). The provisions of the Climate Doctrine of the Russian Federation adopted in the country imply not only the above-mentioned initiatives and actions, but also the intensification of relevant research that generates innovations and accompanies investments. Another important conclusion is related to the fact that social innovations and organizational changes are no less important for the functioning of a climate-optimized and sustainable food system, as well as for sustainable agricultural development and rural security, than technological innovations.

References

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