

# Climate-smart agriculture in the context of sustainable development of agroecosystems (on the example of crop production)

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**Abstract.** The aim of the work is to study the mechanisms of implementation and results of climate-smart agriculture. On the example of projects implemented in different countries, the possibility of ensuring food security in the context of climate change is considered. The mechanisms of adaptation of the industry to climatic impacts and natural hazards are considered. The aspects of transformation of the industry in Russia, planning and sequence of adaptive measures, economic and social contradictions are analyzed. The issues of order and history of management decisions on adaptation of the industry and assessment of progress in agro-ecological approaches are investigated. Directions for achieving the realization of the three clusters of sustainable development with the introduction of relevant approaches to agriculture recommended in the Strategy for Climate Change (FAO) are formulated.

## 1 Introduction

Climate impact on the implementation of agriculture should be considered in several vectors: 1) geo-ecological - impact on the landscape, its transformation, transition to a crisis, non-resource state and degradation; 2) ecological (biological) - transformation of the regional biome, changes in plant phenophases, the arrival of new pest species, rapid transformation of communities, up to the climax stage and complete degradation; 3) technological - changes in agro-technology, the main emphasis on the shift of seasons, as well as the need for the development of the agricultural sector and food security. Thus, environmental, economic and social factors are taken into account, which need serious transformation for the successful development of the agricultural sector and food security. In 2022, FAO prepared the Climate Change Strategy 2022-2031, which actively discusses approaches to climate-smart agriculture. The approach regulates sustainable increase of agricultural productivity and income; maximum possible reduction of greenhouse gas emissions; adaptation to changing climate parameters and increasing the resilience of the agricultural sector to them. To this end, the programme “Adaptation and Mitigation of Climate Change in Agrifood Systems” is being implemented: FAO focuses on creating an

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enabling environment for agro-industrial systems to build resilience and achieve the Sustainable Development Goals, adopting adapted practices, policies and programmes based on the principles of climate-smart agriculture. The main focus of the program is on achieving SDG 1 “Eradicate Poverty”, SDG 2 “Eradicate Head Start”, as well as SDGs 5, 7, 10, 12, 13, 14, 15 and 17. Russia utilizes the best foreign experience, actively researches the extent of transformation of its agricultural ecosystems and introduces its own effective adaptation methods for growing food crops.

## 2 Methods and materials

### 2.1 Research Order

The FAO Strategic Framework 2022-2031 proposes many modern methods, such as: erosion control plowing for rooting and growing new crops on the residues of previous crops, for greater resistance during the first growth period, a method very relevant for Latin America, Africa and parts of Asia; anthropogenic nutrient management to increase resistance to plant pests and diseases, a method with good results in saline soils as well as in cold mountainous areas; and the application of anthropogenic nutrient management to increase resistance to pests and diseases. In summary, FAO's Climate Change Strategy envisages actions at three levels, with the following features: Global and regional levels: policy measures and guidance on climate change and improving industry efficiency and food security; Country (national) level: developing countries' own capacities to combat climate change; Local level: scaling up climate change work on the ground.

### 2.2 Research work

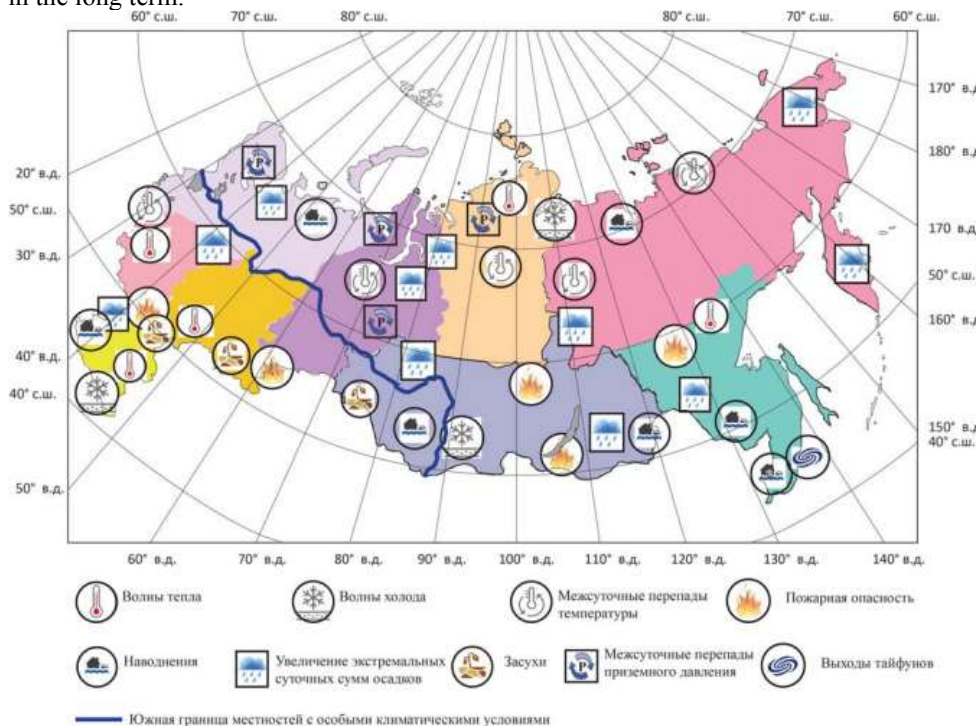
Transformation of agriculture in Russia due to climatic changes. The peculiarity of Russia is that for short periods of time yield estimates due to the regional increase in seasonal temperatures give even a positive effect, good germination of crops, high yields, the ability to grow a new set of crops in non-traditional locations (tab. 1).

**Table 1.** Harvest of all cereals and leguminous crops

Federal District	Actual average gross harvest, mln tons	Cereals and leguminous crops in general	Winter wheat	Spring barley	Cereals and legumes in general	Winter wheat	Spring barley						
								Changes to sustainability					
								(ts/ha)/10 years			%/10 years		
Privolzhsky	21.92	0.32	0.47	0.26	2.6	2.8	2.1						
Southern	26.22	0.30	0.36	0.44	2.2	2.0	3.2						
Central	15.31	-0.02	0.06	-0.02	-0.3	0.4	-0.2						
Sibirsky	12.84	0.16	-	0.19	1.6	-	2.0						
Far-Eastern	0.41	0.23	-	0.23	2.0	-	1.98						
Uralsky	4.75	0.23	0.10	0.15	1.7	0.6	1.1						

But this is only an occasional effect, as often the positive effect is completely destroyed by natural hazards (hail, hurricane winds, precipitation of abnormal intensity, etc.) (Fig. 1). The Seventh National Report of the Russian Federation indicates that if the current high precipitation situation persists in the 21st century, floods are expected to increase in most parts of Russia; floods have become much more dangerous in Siberia and in mountainous areas during spring floods, for example, in the Lena and Yenisei basins.

The National Agrarian Agency discloses information about the main directions of adaptation of the industry in Russia: large-scale modernization of food production on the basis of resource-saving technologies, ecologization of the agricultural sector, use of the potential of breeding and genetic research, ensuring sustainable development of rural areas (according to: Strategy for Sustainable Development of Rural Areas of the Russian Federation until 2030: URL: [https://rosstat.gov.ru/storage/mediabank/strateg\\_2030.pdf](https://rosstat.gov.ru/storage/mediabank/strateg_2030.pdf)). Only with this approach the agricultural sector becomes a competitive advantage of Russia in the long term.



**Fig. 1.** Distribution of extreme weather and climatic phenomena on the territory of the Russian Federation

### 2.3 Basic criteria for assessing adaptation

*Dynamics of land degradation due to climate change.* According to long-term analysis of the agricultural sector in the context of global climate change [1], in the world crop production there is a decrease in crop yields in arid, semi-arid and tropical zones, as well as in the Mediterranean region. There is a dynamics of yield growth in some regions of northern latitudes. Now in Russia there is a shift of traditionally grown crops from the south to the north, due to the drying climate in the south and reduced water availability. In Russia, the set of measures for adaptation of cultivated land is divided into 4 categories [2]: 1) land management (increase soil organic matter reserves; cropland management; sustainable forest management; wetland restoration and reforestation, prevention of soil contamination and overconsolidation; prevention of toxic and chemical pollution); 2) value chain management (reduction of crop losses; inclusion in urban food system supply chains; reduction of food waste and supply chain shoulder length; efficiency and sustainability); 2) value chain management (reduction of crop losses; inclusion in urban food system supply chains; reduction of food waste and supply chain length; efficiency and sustainability); and 3) value chain management (reduction of crop losses and overconsolidation).

## 2.4 Working with the state and public agenda

Sectoral adaptation plan for sustainable development of the agro-industrial complex of Russia. Sustainability indicators of different regions and agricultural sectors, their exposure to climatic risks, goals, objectives and ranking of adaptation measures have been developed - this is the basis for the implementation of programs to increase sown areas, improve soil management, and modernize the infrastructure of the industry. Planning objectives include 1) scientific support of the decision-making process; 2) actualization of the agro-industrial complex development strategy within the framework of state programs and investment projects; 3) improvement of safety, reduction of losses and damage to the economy; 4) improvement of the quality of weather forecasts for optimal economic decisions; 5) optimal economic decisions based on accurate forecasts; 6) fulfillment by Russia of international obligations and treaties related to climate change.

The tasks for ranking adaptation measures are defined in such a way as to reduce the risks of climate change for the agricultural sector; to plan the priorities of the sectoral plan for adaptation; to monitor the effectiveness of adaptation measures and indirect adaptation measures on food security issues under the guidance of the Russian Security Council; to take into account losses by natural zones of Russia, if necessary. In Russia, the monitoring of adaptation mechanisms is carried out by Roshydromet; at present, a unified system of climate risk assessment has been developed within the framework of the sectoral national adaptation plan for the agro-food sector (Annex 1 - *ibid.*), taking into account the significant difference in geographical location and natural-climatic features in different parts of the country.

*Achievement of sustainable development objectives in the directions of available resources and factors in Russia.* An integrated approach to sustainable development of the agricultural sector based on the ideology of sustainable development is included in almost all state planning documents in Russia at the federal and regional levels. In general, these measures can be summarized into three clusters with a link to the implementation of specific SDGs (Table 2).

**Table 2.** Examples of resources that condition adaptive capacity

<b>Resources and factors</b>	<b>SDG</b>	<b>Directions for achieving goals and objectives</b>
Economic	7, 8, 9, 12, 17	Transformation of insurance criteria, new approach to subsidies and credits taking into account climate factors and risks. Investments in innovations in the agricultural sector. Increase of wages in the sector. Updating technical requirements for seed, grain and crop storage facilities. Restoration and creation of new, land reclamation systems, improvement of agricultural machinery. Restoration of pastures on floodplain areas of rivers. Modern equipment of pens and other infrastructure for livestock breeding taking into account dangerous climatic changes, etc.
Environmental	6, 13, 14, 15	Sustainable use and preservation of high quality of available water resources, observance of crop rotation rules for within natural zones and in highlands, increasing productivity of agricultural crops due to modern agrotechnics and improvement of soil quality.
Social	1,2,3,4, 5,10,11, 16	Traditional institutions of social support and welfare of families living in rural areas. Involvement of young people in the industry. Improved access to medical services and education. Decent remuneration of labor. Creation of modern workplaces, protection of people's labor from unfavorable weather conditions. Creating conditions for the revival of large families and rural traditions. Improving the qualifications of employees of the industry. Automation of labor. Emergence of new professions related to the

		use of artificial intelligence. Intelligent agricultural management systems. Increase in the prestige of rural professions. Reducing the role of resellers of products.
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## 4 Analysis

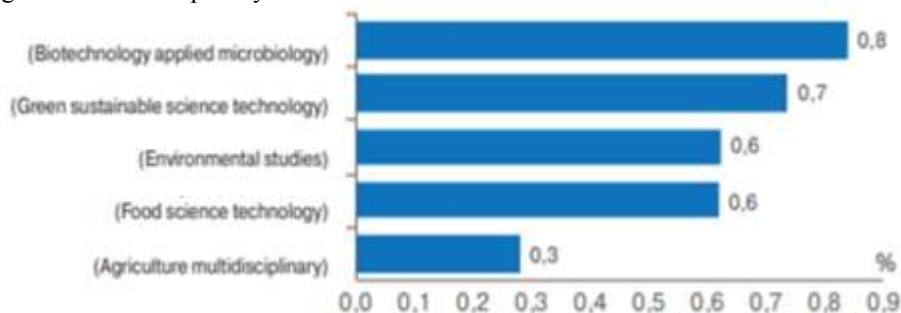
At the national level in Russia 6 strategies are adopted and implemented [2], each of which was analyzed (Tabl. 3) by the collective authors in the interests of sustainable development of the industry and social factors.

**Tabl. 3.** Universal strategies of response to climate change in the agricultural sector and their contribution to sustainable development

Strategies	Effects
Strategy 1: multifunctional land management strategies and practices.	The scientific approach and revitalization of experimental research methods in Russia allowed to create agrarian clusters [3], in which there are also experimental areas where new types of agro-technologies are practiced: scientific innovative development strategies; unique competitive advantages; generation of innovative technologies; growth in the number of inventions and patents.
Strategy 2: Ensure sustainability and minimize the impact of external negative factors.	The sustainability of the industry is ensured [4] by two main directions: optimization of the crop production system and innovation management. A large amount of food is produced, corresponding to the solvent demand of different consumers (Russian and foreign). Maximum rational use of land, labor and capital, support of small farms that are able to quickly change crops, depending on the forecast for the season.
Strategy 3: Focus on a large number of positive effects	Traditional institutions of social support and welfare of families living in rural areas. Involvement of young people in the industry. Improved access to medical services and education. Decent remuneration of labor. Creation of modern workplaces, protection of people's labor from unfavorable weather conditions. Creating conditions for the revival of large families and rural traditions. Improving the qualifications of employees of the industry. Automation of labor. Emergence of new professions related to the use of artificial intelligence. Intelligent agricultural management systems. Increase in the prestige of rural professions. Reducing the role of resellers of products. Effective innovation management is the ratio of marginal costs and marginal expected revenues [5]
Strategy 4: Separation between agrarian and forested areas; separation between urban and industrial areas.	Ecology: the ratio of availability of lands of different categories is changing [6], the quality and productivity of forest lands are decreasing. Economy: intensive support of agrarian lands, the motivation of local authorities to manage lands for different purposes is changing, economic approaches to assessing the value of forest and agrarian products are changing. Social factors: there is a change in the structure of employment in the regions, insignificant labor migration, often farmers receive a second education in technology, economics, law, agro-technology.
Strategy 5: Prevent Complex Losses.	Reproduction and maintenance of soil fertility requires high costs [7], climate fluctuations dictate new approaches in agrotechnics, choice of crops, timing and types of fertilizer application [8]. The maximum efficiency was shown by the combination of several crops on small sown areas, so agroecosystems are much more stable [9]. Ecology: Russian regions are beginning to change agro-crops due to

	<p>weather conditions; in the southern regions the yield of traditional crops is decreasing. The structure of the industry in semi-desert regions (Kalmykia and others) is changing strongly.</p> <p>Economy: today in Europe more than 55-65% of land is plowed, in Russia less than 8% and this is much lower than in Soviet times, the potential for the industry is huge; exports have increased significantly, losses have been reduced to a minimum, in some regions practically nonexistent. In 2012, 25% of the crop was lost in the southern territories of the country, conclusions were made, the line of crops grown was changed. Rice cultivation in Krasnodar Krai became unprofitable due to acute water shortage.</p> <p>Social factors: in order to maintain food security and employment of the population, and to develop the agro-complex, federal projects "Development of exports of agricultural products", "Digitalization of agriculture", "Creation of a support system for farmers and agricultural cooperation" have been created.</p>
<p>Strategy 6: Build and maintain enabling environment factors</p>	<p>Ecology: formation of forest belts that retain wind flows, snow, and maintain groundwater table.</p> <p>Economy: Russia welcomes public-private partnership, investments, strict compliance with legislation in the agro-complex; a variety of forms of ownership of the harvested crops and forms of their realization; support of the agrarian industry means of production, seed material.</p> <p>Social factors: optimization of the number of permanent and salaried employees; the form of remuneration allows employees to independently determine the form of employment (permanent or salaried).</p>

*Publication activity on innovative approaches in the field of adaptation.* The assessment of adaptation of the agro-industrial complex has been made in Russia for more than 10 years. Public and private expenditures and investments on research and development in the field of agro-industrial complex are constantly and significantly increasing, as the task of achieving sustainable food production and sovereignty in many positions is set at the state level [10]. So far, there are very few scientific publications in this area. According to this criterion, Russia is ahead of such countries as Iran, Brazil and Poland. But, globally, the volume of publications on this topic is very low (Fig. 2). Russian publications most often concern biotechnology and green technologies, very few publications on the topic of agrarian multidisciplinary research.



**Fig. 2.** Share of publications in different directions (Source: Order of the Ministry of Agriculture of the Russian Federation dated December 30, 2021, N 716-r "On Approval of the Sectoral Plan of Adaptation to Climate Change in the Sphere of Agro-Industrial Complex and Fishing for the Period until 2022")

## 5 Summary

As expected, the main contribution to achieving sustainable development of the industry comes from public investments and private investments. Control over the allocation and targeting of funds is carried out by specialized organizations, and the results are assessed by the Ministry of Economic Development of Russia according to the real growth of SDG indicators.

Technological aspects of developing new technologies, improving infrastructure, using high-tech agricultural equipment, disease control, and financial costs are regulated only within the working groups of the sectoral plan for adaptation to climate change in the agricultural sector. It is this plan that created a space for effective interaction between the state, business and civil society in the direction of adapting agriculture to climate change.

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