The impact of climate change on regional food security

G V Fedotova1,2, Yu V Vertakova3,4 and M G Klevtsova3

1 Plekhanov Russian University of Economics, 36, Stremyanny lane, Moscow, 117997, Russia
2 Volga Region Research Institute of Manufacture and Processing of Meet-And-Milk Production, Rokosovskogo street, 6, Volgograd, 400131, Russia
3 Financial University under the Government of the Russian Federation, ul. Lomonosova 3, Kursk, 305000, Russia

4 E-mail: vertakova7@yandex.ru

Abstract. Climate change has serious consequences for agriculture and food security, creating new risks and challenges and exacerbating existing local to global vulnerabilities. Climate change can affect all aspects of the food security of vulnerable groups, as well as various elements of food systems. Climate transformation and food security are two challenges that need to be addressed together. The aim of this research is to study the impact of climate change on regional food security. In the course of the research, the following methods were used: structural and logical analysis, monographic analysis, methods of statistical grouping. As a result of the study, using the example of the Southern and Central Federal Districts, the authors have analyzed the dynamics of various indicators of the state of natural conditions and the actions of regional government structures, which reflect individual elements of maintaining food security. The proposed methodological approach to assessing the impact of climate change on regional food security is distinguished by the use of private indicators for diagnosing the level of food security. The system of these indicators includes both the study of natural conditions and the level of ecological safety of the region. The use of the proposed tools for measuring the impact of climate change on regional food security will increase the effectiveness of the actions of regional government structures, which reflect individual elements of maintaining food security.

1. Introduction

Nowadays climate change and global problems of mankind are addressed in many works of domestic and foreign scientists. The growing threats on a planetary scale are forcing the leading world powers to cooperate and look for solutions to find a way out of the current situation. International Climate Conventions and Agreements approved and ratified by many countries over the past decades require revision and updating.

The world community considers climate change as one of the main global threats on a planetary scale, which can not only reduce the quality of life on Earth, but also significantly change its appearance. WMO gives disappointing forecasts regarding the concentration of carbon dioxide in the atmosphere. Measurement data from ice cores show a significant increase in CO2 concentration over the past decades. According to the data for the last 2 years, it can be noted that the indicator has reached a record value of 407.8 ppm. And this figure will continue to grow in the future, creating a greenhouse effect.
The main part of the formed gas (up to 30%) and heat (up to 90%) is absorbed by the World Ocean, which gradually acidifies and heats up. Thus, the high environmental costs due to chemical reactions of the absorbed gas with seawater lead to a gradual rise in the level of the World Ocean, which for the period from 1993-2019 rose by 90 mm. A further rise in the level of the World Ocean will lead to the flooding of part of the coastal land areas, which will disrupt the life of more than 800 million inhabitants of the planet. Therefore, it is necessary to pay proper attention to this problem and to seek joint efforts for solutions to get out of this situation.

Many international organizations such as UN, UNIDO, WMO, World Bank and others are concerned about the deterioration and depletion of the state of the environment around the world, which is confirmed by many international conferences and intergovernmental agreements signed during the 20-21 centuries.

The rapid growth of the world’s population and the demand for agricultural raw materials, especially in the countries of Africa, Asia, Latin America, which do not have sufficient potential for food production and the provision of social conditions for living, are reducing agricultural areas suitable for land use and grazing animals.

If serious measures are not taken to level the situation, a world social crisis may occur, caused by the struggle for survival between developed and poor countries. The aim of this research is to study the impact of climate change on regional food security.

2. Research results
The modern economy functions in the conditions of recurring crises, the growth of global challenges and threats, which entails the need to search for new approaches and concepts for the formation of a future model of sustainable development. The model of the consumer attitude to the environment, the constant consumption of natural and biological reserves, up to their complete disappearance, practiced today, can no longer meet all the growing needs of mankind for resources to support life on the planet [1]. In fact, today one can observe the depletion of the ecosystem of life support of a living form, caused by anthropogenic impact and predatory attitude of man towards nature.

In accordance with the decision taken at the 1996 World Food Summit, the official definition of the essence of food security is determined by the availability of physical and economic access by the population of different territories to safe and nutritious food in sufficient volume to meet their nutritional needs in accordance with their preferences for active and healthy life.

The presence of one or another production disruption and the availability of the required quantity and quality of food supply is a sign of the lack of the required level of food security. Also, a manifestation of this violation is the lack of an adequate and safe diet while limiting the possibilities of a full-fledged active and healthy lifestyle [2, 3, 4].

The specific nature of the possible consequences of climate change for food security lies in such characteristics as:

- Direct influence on the nature of nutritional value, which is expressed by changes in the volume and structure of consumption.

- The impact on the livelihoods of the population, which is associated with the disruption or lack of opportunities to find a job in order to generate income, as well as a significant increase in the cost of acquiring food of the necessary quality and sufficient nutritional value.

- Climate instability determines the instability of agricultural production with subsequent fluctuations in prices for agricultural products, as well as a decrease in the income of producers of these goods [6, 7].

- The presence of one or another disruption of production and the availability of the required quantity and quality of food supply is a sign of the lack of the required level of food security. Also, a manifestation of this violation is the lack of an adequate and safe diet while limiting the possibilities of a full-fledged active and healthy lifestyle.

- The presence of threats to the stability of maintaining food security is characterized by three factors:

  - Exposure to food insecurity risks.
• Violation of the required scale of food production.
• The nature of the decrease in the level of satisfaction of the population with food in the absence of methods and means of overcoming food crises.

Using the example of the Southern and Central Federal Districts, it is possible to demonstrate the dynamics of various indicators of the state of natural conditions and the actions of regional government structures, which reflect individual elements of maintaining food security. These districts were chosen because, despite the fact that the territories differ significantly in terms of climate, the production of food products, agricultural production in these regions is of priority importance in the development of the economy of the territories [8, 9].

The authors have compared the indicators of the provision of agricultural land in the two federal districts (figure 1).

![Figure 1. Provision of agricultural land in the Southern Federal District (SFD) and Central Federal District (CFD). Source: compiled by the authors based on data from the Federal State Statistics Service rostat.gov.ru.](image-url)

The results of the study showed that the availability of agricultural land in the Southern Federal District significantly exceeds the value of a similar indicator in the Central Federal District, which is associated with different agro-climatic conditions [10].

The influence of climatic factors is multifaceted, which manifests itself in positive and negative forms. Thus, an increase in average temperatures will accelerate the growth and development of plants. But for most livestock species, the comfort zone is between 10-30 °C, and as temperatures rise, animals tend to reduce their feed intake by 3-5% for every degree of temperature change. Thus, there is a decrease in the growth of live weight of animals with a subsequent decrease in productivity in the livestock industries.

A change in temperature causes a fluctuation in the harvest of individual crops that make up forage when their quality and quantity change [11]. In turn, a decrease in the specified characteristics of feed can also cause a decrease in the required results in meat and dairy production.

The cumulative change in the temperature and precipitation regime can have a significant impact on the productivity of forestry, which is expressed in a decrease in the economic efficiency of agroforestry systems, on the functioning of which the population of many rural settlements depends.

Taking into account the foreign experience of studying the peculiarities of the influence of the dynamics of climatic conditions on ensuring food security, it is necessary to highlight the results of experiments carried out in the USA under the FACE program. These results indicate that there is a significant decrease in the content of protein and minerals such as iron and zinc in cereals. Also, the results of a comprehensive analysis of the yield noted its growth with an increase in CO2 concentration.
in the form of an increase in the number of grains, rather than in their size, which is accompanied by a decrease in protein content and starch level growth (figure 2).

Figure 2. Emissions of pollutants into the air from stationary sources in the Southern Federal District (SFD) and Central Federal District (CFD). Source: compiled by the authors based on data from the Federal State Statistics Service rosstat.gov.ru.

According to figure 2, it is possible to say that emissions in the Central Federal District are significantly higher than similar emissions in the Southern Federal District. In addition to quantitative indicators, the factors that determine the efficiency of food use are the availability of drinking water and a variety of food in certain territories (figures 3, figure 4). Based on statistical data, economic and mathematical modeling of trends in the use of fresh water has been carried out, while there is a decrease in the Central Federal District and, on the contrary, a positive trend in the Southern Federal District. At the same time, the very nature of these territories is able to change depending on the dynamics of climatic conditions. Due to the drop in the level of humidity in these regions, degradation of land and water resources may occur, which will cause an increase in food shortages for the growing population. Such phenomena as drought and high temperatures cause an increase in the level of fire hazard conditions.

Figure 3. Fresh water use in the Southern Federal District (SFD) and Central Federal District (CFD). Source: compiled by the authors based on data from the Federal State Statistics Service rosstat.gov.ru.
The volume of recycled and consistently used water in the Southern Federal District (SFD) and Central Federal District (CFD).

Source: compiled by the authors based on data from the Federal State Statistics Service rosstat.gov.ru.

On the basis of statistical data, an economic and mathematical modeling of trends in the volume of recycled and consistently used water has been carried out. The volume of recycled and consistently used water is significantly higher in the Central Federal District, i.e. the amount of savings in fresh water intake in this region is several times higher than the value of the same indicator in the Southern Federal District. The authors have built trends that reflect the change tendency in the cost of environmental protection. In this case, a period of five years has been considered with the calculation of the average indicator of these parameters for the constituent entities of the Russian Federation that make up the Southern Federal District and Central Federal District. At the same time, these indicators of agricultural land reflect one of the key components of farming and maintaining food security. This indicator is supplemented by the numerical values of the use of fresh water as a necessary factor in the life of the population and the conduct of production, which is also evidenced by the indicators of the volume of recycled and consistently used water. Finally, the authors have calculated the average costs of environmental protection as a manifestation of one of the key measures to counter the emerging threats to food security (figure 5), which, in particular, are caused by changes in climatic conditions.

Figure 5. Costs for environmental protection in the Southern Federal District and the Central Federal District.
The formation of an arid climate, which is accompanied by a drop in the level of crops, causes an increase in the level of bankruptcy of many agricultural producers.

Possible countermeasures for this phenomenon can be the following actions:

- increase in the sown areas of heat-resistant crops, such as corn;
- increase in the area of winter grain crops (wheat, rye and barley) as they are more productive in the noted climatic changes;
- increase in the use of moisture-saving land cultivation technologies;
- increase in the insurance stocks of food;
- optimization of import and export policy in cooperation with foreign agricultural producers.

It is necessary to highlight the key characteristics of agriculture while maintaining food security, taking into account the climatic conditions of individual regions [12].

These characteristics are:

1. Heat supply. This parameter manifests itself according to the results of observations in spring in 2018. It was estimated that the spring was colder by 0.7-2.8°C compared to the period 1998–2017. With the exception of the Southern Federal District (SFD), as well as the North Caucasus and Far Eastern Federal Districts (NCFD and FEFD). In these territories, the excess of the spring temperature was 1.4, 0.8, and 0.5 °C, respectively. On average, in the agricultural zone of Russia, below-zero air temperature anomalies in spring were –0.9°C.

The consequence of this phenomenon is the resumption of vegetation, which was revealed 3 days later than the average for the last twenty years. The general level of temperatures in the summer of 2018 and 2019 in comparison with the average values of the last twenty years, was higher by 0.1 °C on average for the territory of the agricultural zone of Russia. During the study period, there is a positive anomaly of the sums of active temperatures (above 10 °C) in the European part of Russia [3].

2. Moisture security. The data obtained indicate that the amount of precipitation during the growing season of spring grain crops in 2018 and 2019, on average over the territory of the agricultural zone of Russia, was lower by 9% relative to the average value over the previous two decades. In particular, in the territory of the North Caucasus Federal District and the Southern Federal District, the total amount of precipitation was below the average level by 52% and 44%, respectively. The authors have analyzed the trends in changes in agro-climatic indicators. An analysis of estimates of the linear trend of the sums of active air temperatures (T>10°C) showed that a positive trend towards an increase in this indicator over the past decades continues. For the period from 1976 to 2018 in the European part of Russia, the rate of its growth ranges from 98°C / 10 years in the Volga Federal District (VFD), as well as up to 155 °C / 10 years in the Southern Federal District. On average for the territory of Russia, the estimate of the linear growth rate of the sums of active air temperatures for 1976–2018 was 87°C / 10 years. The negative phenomena of the dynamics of climatic conditions are dangerous hydrometeorological phenomena, the number of which, according to Roshydromet in 2018, in the whole in the territory of the Russian Federation was 1040. This is 133 more than in 2017, when there were 907. In particular, heavy rains were observed in the Krasnodar Territory, and the rain floods caused by them [13]. In this case, a period of five years was considered with the calculation of the average indicator of these parameters for the constituent entities of the Russian Federation that make up the Southern Federal District and Central Federal District. At the same time, these indicators of agricultural land and forest land reflect one of the key components of agriculture and maintaining food security. This indicator is supplemented by the numerical values of the use of fresh water as a necessary factor in the life of the population and the conduct of production, which is also evidenced by the indicators of the volume of recycled and consistently used water [14]. Finally, the average costs of environmental protection are calculated as a manifestation of one of the key measures to counter the emerging threats to food security, which, in particular, are caused by changing climatic conditions.
3. Conclusion

The set of measures aimed at preventing a negative impact on regional food security is associated with the development of various programs for adapting the formed food system in certain constituent entities of the Russian Federation and macroregions (federal districts). This is related to a set of measures that have the character of socio-economic and biophysical transformations of food production.

This requires a comprehensive assessment of the ongoing climate change, identified threats and vulnerabilities of a particular food industry. This will make it possible to develop an effective system of measures for proactive adaptation in the prevailing natural conditions, which should be based on local experience in conducting economic activities and specific factors of growing individual crops.

These adaptation measures should focus on identifying vulnerabilities in functioning regional food systems. This is expressed in the rational combination of existing practical developments related to maintaining the required level of agricultural results, which will allow maintaining not only the required level of quantity, but also the quality of the crop for certain types of crops.

This is related to the well-grounded application of modern biotechnology in the framework of regional livestock production.

There should be noted the necessity of implementing such measures as:

- rational use of ecologically safe fresh water;
- scientifically based crop rotation;
- comprehensive use of local genetic diversity.

At the same time, it is required to name one of the key threats that undermine the sustainability of regional food production systems. This threat lies in the lack of sustainability and environmental compatibility of certain areas of this production.

The indicated problem can be eliminated through state-municipal regulation of regional and local production processes, which is aimed at moderate restraint of the level of demand for food products, the creation of which is associated with a deterioration of the ecological situation and increased pressure on various components of the natural environment [13]. Examples of these negative consequences are the depletion of land and increased use of water resources during land reclamation.

As already noted, this is associated with the expansion of the use of electronic digital technologies in maintaining the required level of food security, which may be reflected in the implementation of the following actions:

- Electronic digital modernization of information support for the activities of public administration structures in the constituent entities of the Russian Federation, taking into account the territorial features of land cultivation, technologies for the cultivation of agricultural crops and the specifics of the functioning of farms.
- Ensuring electronic digital interconnection between agricultural entities and suppliers of necessary economic resources (agricultural machinery, fuel and lubricants for it, information about weather changes, obtaining water resources, etc.) by using modern information networks of a global and local nature.

This makes it possible to take into account various factors of an agricultural nature at the level of federal districts and subjects of the Russian Federation. In this regard, it is necessary to significantly transform the system of measures of state support for individual agricultural producers in order to develop and master innovative technologies for food production. These measures are as follows:

- systematic analysis and assessment of the dynamics of climatic conditions and the state of the ecological situation in the region;
• expanding the processes of using digital technologies while continuously informing agricultural producers about the identified climatic risks and vulnerabilities of the functioning regional agricultural and industrial complex;
• electronic and technological modernization of the activities of information and consulting services, the functions of which are related to the creation of information resources as a key factor in making informed decisions by entrepreneurs operating in the field of food production;
• expanding access of private business entities to modern and efficient genetic resources of both existing crops and livestock and their wild relatives, as well as species and breeds that may appear in the future. For example, this is related to the establishment of crop genes that provide resistance to drought and floods, which allows maintaining the required level of agricultural production. The combination of various properties is capable of providing a stable harvest in a changing climate;
• development and implementation of an integrated land use strategy, taking into account the principles of the landscape approach, which implies a comprehensive consideration of the specifics of changes in the frequency and intensity of precipitation and the dynamics of moisture levels; identification of seasonal fluctuations in river flow with the development of a set of measures for the rational use of available water resources on the scale of the drainage basin and aquifers.

The innovative improvement of the food production system on the territory of a particular region of Russia is expressed in a number of transformations:

• comprehensive development of transport and market infrastructure with increased attention to effective resilience to climate change factors, which can be reflected by the example of refrigeration drying facilities when processing raw materials for subsequent processing;
• promotion of food preservation techniques;
• strengthening information communications between private business entities in agriculture to develop joint measures to preserve the quality characteristics of food products.
• expanding state support for entrepreneurial initiatives in the field of maintaining food stability, which occurs in the form of increased investment in the development of economic infrastructure with the extension of constructive relationships between food producers and markets, which contributes to the expansion of food supplies to large urbanized areas;
• focusing research on measures of adaptation and mitigation of climate change consequences on food security
• expansion of integrated production potential that combines socio-economic, production and technological, information and communication and personnel components to comprehensively counter the challenges of climate change.

In conclusion of this study, it can be noted that the growing global climatic threat entails serious consequences for the development of all continents and regions of our planet, the world economic system, which are expressed in the change of habitual ecosystems; the disappearance of a number of representatives of the flora and fauna of the Earth; the reduction of coastal land areas; also in the increased frequency of natural hydrometeorological cataclysms and natural disasters; a decrease in fresh water reserves in the glaciers of the Arctic and Antarctica; an increase in the incidence of diseases of the planet's population; an increase in food supply tension; an increase in climatic migration in the world, etc. The influence of climatic conditions on the nature of food security is manifested ambiguously, which can be seen in the presence of positive and negative effects in the processes of regional agriculture. But at the same time, a negative trend of climate change is visible, which is expressed in various threats to the food stability of certain territories. In this regard, it is necessary to expand scientific research on the specifics of this influence with the development of appropriate measures aimed at adapting industrial
complexes in changing climatic conditions. In particular, this consists in the development of effective public-private relationships based on modern electronic digital technologies, maintaining the natural qualities of various categories of land that can be used in production activities. At the same time, it is required to timely monitor the formation of increased climatic risks and the possible negative consequences of food security, which implies the provision of a comprehensive collection and systematization of information that will allow timely taking appropriate measures to preserve the obtained agricultural products.

Acknowledgements
The study was supported by the grant of the President of the Russian Federation for state support of the leading scientific schools of the Russian Federation NSh-2702.2020.6 "Conceptual foundations of a new paradigm of economic development in the era of technological and social transformation.”

References
[1] Food Security in the Eurasian Region 2019 Case Studies Eurasian Center for Food Security 40
[2] Report on the features of the climate in the territory of the Russian Federation for 2019 2020 (Moscow)
[3] Fetterer F, Knowles K, Meier W N, Savoie M and Windnagel A K 2017 Sea Ice Index, Version 3 National Snow and Ice Data Center
[4] Zhou C, Wang K and Qi D 2018 Attribution of the July 2016 extreme precipitation event over China's Wuhan Bulletin of the American Meteorological Society 99 107-12
[5] Plotnikov V, Fedotova G V, Popkova E G and Kastyrina A A 2015 Harmonization of Strategic Planning Indicators of Territories Socioeconomic Growth Regional and Sectoral Economic Studies 15-2 105-14
[6] Vertakova Y V, Klevtsova M G and Polozhentseva Y S 2020 Assessment of Asynchronous Development in the Implementation of the Main Areas of Regional Policy Lecture Notes in Networks and Systems 111 395-403
[7] Baranova P and Paterson F 2017 Environmental Capabilities of Small and Medium Sized Enterprises: Towards Transition to a Low Carbon Economy in the East Midlands Local Economy 32(8) 835-53
[8] Bracking S 2015 Performativity in the Green Economy: How Far Does Climate Finance Create a Fictive Economy? Third World Quarterly 36(12) 2337-57
[9] United in Science 2020 https://public.wmo.int/en/resources/united_in_science
[10] Chugunkova A V, Pyzhev A I and Pyzheva Yu I 2018 Influence of global climate change on the economy of forestry and agriculture: risks and opportunities Actual problems of economics and law 12(3) 523-37
[11] Emelyanov S G, Vertakova Yu V and Solodukhina O I 2016 Methodological approaches to the development of state policy in the field of rational use of regional assets News of the South-West State University Series: Economics Sociology Management 10(2) 102-10
[12] Vertakova Yu V, Kryzhanovskaya O A and Evchenko A V 2020 Improvement of the state forest management system taking into account foreign experience and Russian practice of digitalization of forest management and forest management News of the South-West State University Series: Economics Sociology Management 10(2) 46-62
[13] Dzyurdzya O A, Gudkova O E, Kamchatova E Yu, Fedotova G V and Komarov V Yu 2021 The transformation of the industrial economic sector in the conditions of industry 4.0 Business 4.0 as a Subject of the Digital Economy ed. E G Popkova (Cham, Switzerland: Springer Nature Switzerland AG)
[14] Fedotova G V, Epinina V S, Stepanova T S, Bardulin E N and Gipaev R V 2020 Cybernetic Approach to the Modern Knowledge Economy Scientific and Technical Revolution: Yesterday Today and Tomorrow 12-21