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WEATHER RISKS AS DRIVERS OF STRUCTURAL SHIFTS IN AGRICULTURE IN THE RUSSIAN FEDERATION

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Abstract

The climate trend today is reflected in the national, regional and sectoral socio-economic strategies of both developed and developing countries. Most often, the climate trend is presented in the form of predicted values of temperature increase on the Earth's surface by 1.5-2.0 degrees and the facts of the occurrence of the most probable weather risks. Practice shows that when making forecasts of socio-economic development, adverse hydrometeorological phenomena are not included in the system of significant and naturally occurring factors. Therefore, they do not find the necessary reflection in strategic documents. At the same time, weather anomalies systematically cause material and economic damage. The authors put forward a hypothesis about the significance of the factor of dangerous weather phenomena in the system of climatic factors that determine the level of agricultural production development and structural changes in the branches of the agro-industrial complex. The scientific task, to which the study is directed, is to establish a causal relationship between climatic parameters and production and economic indicators of the efficiency of the crop sub-sector. For this, a unique database was collected, which included values systematized by types of weather anomalies over the past 30 years in the context of the constituent entities of the Russian Federation. This made it possible to determine the most typical dangerous weather phenomena for different regions that cause material damage. In the sub-sector of crop production, these are wind, heavy rains, extreme fire hazard and a combination of these phenomena. A clear relationship has been established between their number and the dynamics of crop production. The most vulnerable categories of producers to each type of hazardous weather phenomena have been identified. The relationship between climatic variables and economic efficiency of the crop production sub-sector is determined. The results of the analysis will serve as a justification for the need to take into account dangerous weather phenomena in the system of the most meaningful trends when predicting the impact of climate change on agricultural production and food security of the country. This will contribute to the development of relevant sectoral and regional adaptation strategies in the face of the onset of the most probable natural and climatic risks.

Key words: *climate change, hazardous weather events, agriculture, crop production, agricultural organizations*

INTRODUCTION

The world community is increasingly agreeing that the risks driven by climate change, in terms of the likelihood of occurrence and the expected size of losses among global risks of social inequality, terrorist attacks, epidemiological threats, etc., are among the most significant threats to the world in medium and long term. There is concern about the risk that states will not be able to minimize the impact of global climate change and adapt to them [27].

Climate change does not consist only in an increase in the average air temperature near the Earth's surface by 1.5-2 degrees. It manifests itself in all components of the climate system, including changes in the intensity and frequency of dangerous and adverse weather phenomena.

The topic of chaotically occurring hazardous weather phenomena and their significance in the system of climatic factors was revealed by the Nobel Prize Laureate in Physics 2021 Klaus Hasselman. He developed a model that "ties together weather and climate", thereby showing that "climate models can be reliable despite the fact that the weather is changeable and chaotic" [28]. According to the regularly published assessment reports of the International Panel of Experts on Climate Change (IPCC) and the United Nations Food and Agriculture Organization (FAO), the number of climate anomalies and macro-level natural disasters in recent decades has increased 4 times in terms of climate disasters, and 6 times in hydrological ones [7]. At the same time, in the countries with the most productive agriculture, an increase in the number of negative weather events, their duration and intensity was observed [3].

National adaptation plans in different states have basic similarities and differences, which depend on the level of development of countries, the degree of exposure of the economy and society to natural and climatic risks, and priorities of state policy. National approaches are based on different scientific theories, different analytical assessments of what is happening, differences in determining national priorities in relation to sustainable development and an ambiguous interpretation of the main provisions of the concept.

The institutional basis of the state policy for adaptation of Russian agriculture to global climate change is made up of a number of regulatory documents at the national (federal) level (Climate Doctrine of the Russian Federation, National Action Plan for the first stage of adaptation to climate change for the period up to 2022, etc.). According to the main statements of the federal law "On Strategic Planning in the Russian Federation", in the regions of the Russian Federation, strategies for socio-economic development for the medium and long term should be developed and approved [5]. Separately, sectoral strategies for adaptation to the consequences of global climate change began to be developed. We have determined that most of these regulatory documents contain only general formulations and goals.

The “Strategy for the development of the agro-industrial and fishery sectors of the Russian Federation for the period up to 2030” in the system of key risks indicates, inter alia, climatic and agro-ecological threats caused by unfavorable climatic changes and abnormal natural phenomena, an increase in the share of degraded lands, and a decrease in land fertility agricultural purposes, the consequences of natural and man-made emergencies [15]. At the same time, in a number of key regions, the factors of the internal environment that threaten the sustainable development of agricultural systems include a high degree of influence of natural and climatic conditions on agricultural production. A detailed analysis of strategic planning documents for the development of the agro-industrial complex of the Krasnodar Territory, Stavropol Territory, Lipetsk, Saratov and Rostov Regions was carried out. As a result, it was found that the vector of adaptation is present in regional strategies in the form of general phrases and statements. The system of tasks marks the implementation of the principles and provisions of the 2030 Agenda for Sustainable Development, international environmental and climate programs and agreements.

The fact of the susceptibility of the region's agriculture to the risks of emergencies and the occurrence of anomalous natural phenomena is highlighted. At the same time, attention is drawn to the underestimation of the accounting of the consequences of the impact of hazardous natural phenomena on various aspects of agricultural production.

The examples of 1998, 2005 and 2010 years show that the repetition of several lean years leads to an imbalance in agricultural production, a sharp reduction in its carryover stocks, thereby creating a threat to domestic food consumption [12]. The growing number of dangerous weather events, an increase in their frequency and intensity, can create risks for the sustainable development of agriculture and food security of the country [21].

In the Food Security Doctrine of the Russian Federation, among the risks and threats to ensuring food security, climatic and agroecological threats are identified, caused, inter alia, by unfavorable climatic changes and anomalous natural disasters [6]. When structuring risks by components of food security, three groups are obtained: risks of ensuring the physical availability of food; risks of ensuring the economic availability of food; quality risks. The risks of ensuring the physical availability of food are directly related to agricultural production [26].

According to experts' forecasts, the number of extreme hydrometeorological events with potential material and social damage will continue to grow [13,18]. The large spatial extent of the Russian Federation, risky farming and differentiated agricultural production determine the high importance of the accelerated introduction of measures to adapt regional agri-food systems to global climatic changes. At the same time, without a quantitative assessment of risks, it is difficult to build a system of adaptation measures aimed at mitigating the consequences of their impact. The current regulatory framework does not facilitate their mandatory analysis and quantitative accounting when developing or adjusting strategies. Shpakova R.N. rightly notes that this is a violation of the principle of realistic strategic planning [22]. The purpose of our study is to identify a causal relationship between climatic, production and economic parameters in the crop production sub-industry. The results of the analysis will serve as a justification for the need to take into account dangerous weather phenomena in the system of the most meaningful trends when predicting the impact of climate change on agricultural production and food security of the country. This will contribute to the development of an up-to-date strategy for adaptation of agriculture in the context of the probable onset of natural and climatic risks.

MATERIALS AND METHODS

In recent years, a large number of studies have been devoted to analyzing the impact of climate change on various aspects of agricultural production. Quantitative measurement, combined with a variety of modeling and observation methods and approaches that focus on fundamental processes, captures the underlying drivers of crop yield, which may well include biophysical as well as production factors. In this regard, in more than half of the works, the risk was fairly assessed in connection with the variability of the yield [2, 4, 16, 24] or the consequences of water scarcity [1]. General issues of the influence of changes in temperature regimes on agriculture are considered mainly as a uniform displacement of the temperature gradient.

Today, the focus is increasingly shifting towards modeling and forecasting socio-economic risks in the context of the prospects for climate change. In general, many Russian researchers come to the conclusion that the shift in temperature regimes will increase productivity in the field of crop production in the Northern and Far Eastern regions of the country, while reducing productivity in the southern and central regions [8,14]. Specialists of the A.I. Voeikov Main Geophysical Observatory, based on the assessment of vulnerability and risks of under-harvesting of spring wheat during droughts, were found that in most of the Central federal district the risk of under-harvesting of spring wheat is assessed as "very low" and "low". Siptits S.O., Romanenko I.A., Evdokimova N.E. provide a forecast assessment of the gross production of grain and leguminous crops in the Russian Federation until the end of the 21st century, subject to the implementation of the climatic scenario RCP 4.5 and maintaining the size of sown areas at the current level by 2080. According to the authors' calculations, an increase in the average potential gross harvest of grain and leguminous crops is expected [23].

At the same time, Kattsov, V.M., Shkolnik I.M. et al. assessed long-term changes in yield factors in regions specializing in grain production. The authors come to the conclusion that an increase in the number of adverse weather and climatic conditions by the end of the 21st century will have an increasing impact on the process of growing cereals [11].

Does the decrease in productivity of the southern regions compensate for the increase in the growing season and mitigation of risks in the regions of the North and Far East? This issue requires a detailed study of the dependence of the influence of various types of hazardous weather phenomena on the cultivated crop, as well as the structure of producers.

Our focus on hazardous weather events is determined by their direct impact on the leading and export-oriented branch of Russian agriculture - crop production. In our research, we consider the problem in the medium and long term. The hypothesis is put forward that various types of unfavorable hydrometeorological phenomena have a regularity and significant weight in the system of climatic factors affecting the production and economic indicators of crop production, as well as its structural balance.

To test the hypothesis, we systematized adverse weather events that caused material and economic damage by type and duration of exposure. Based on the data of selective federal statistical observation on agricultural production and weather data, Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) has built a system of indicators that allows characterizing the degree of weather impact on the efficiency of the crop production sub-sector. The calculation of the correlation coefficients between production, climatic and economic variables has been carried out. The correlation of the obtained data with the current structural dynamics in the class of crop producers was investigated.

For empirical analysis, the meteorological data sets of the Roshydromet on the number of hazardous weather events on the territory of the Russian Federation were formed. The time period for climate data recommended by the World Meteorological Organization is 30 years. This time interval is adhered to by researchers in the field of climate influence [17]. The maximum length of a number of hazardous weather phenomena types studied by us was 29 years, due to the fact that until 1991 the statistical base in Russia in the chosen direction was fragmented. The sample included 14,014 observations in 84 constituent entities of the Russian Federation in the context of the following types of adverse hydrometeorological phenomena that caused material and social damage: abnormally cold weather, wind, hail, rain, downpour, freshet, flood, extreme fire hazard, a complex of unfavorable weather phenomena [29].

The information base of the study includes the values of indicators calculated based on the materials of the Federal State Statistics Service of the Russian Federation on regional development of agricultural production, reports of the Ministry of Agriculture of the Russian Federation.

Statistical approaches are most often used to study trends in yield under conditions of changes in the natural and climatic environment. However, potential variables explaining yield tend to be confused due to the strong correlation between these variables, which complicates the interpretation of empirically derived relationships.

Therefore, in working with sets of statistical data, combined methods of economic and statistical analysis were used, which made it possible to get an idea of the dependence of climatic, economic and production indicators, as well as correlate with the current structural shifts in the industry.

RESULTS AND DISCUSSIONS

The expediency of using the system of indicators is dictated by the narrow specialization of individual indicators, reproducing only one side of the phenomenon under study. There is a need for the integrated use of a number of indicators in the form of a system that makes it possible to obtain a reliable and versatile description of the trends or phenomena under study.

With regard to our research, indicators were selected that can be conditionally divided into three groups: climatic, industrial and economic.

The group of climatic factors included the types of unfavorable hydrometeorological phenomena most often manifested on the territory of the Russian Federation, as well as the total number of unfavorable weather events that caused material and economic damage.

The group of production indicators includes the gross harvest of grain and leguminous crops, the proportion of economic entities of various organizational and legal ownership in the general structure of crop producers.

The balanced financial result of the crop production sub-sector for the year is taken as the most important economic indicator that allows to reflect the significance of hazardous weather events (Table 1).

Table 1. Description of the analyzed variables

Indicator	Units	Indicator name
Climate		
Total number of dangerous weather events	unit	Sum
Abnormal cold	unit	C1
Wind	unit	C2
Hail	unit	C3
Rain	unit	C4
Complex of unfavorable weather phenomena	unit	C5
Downpour	unit	C6
Freshet	unit	C7
Flood	unit	C8
Extreme fire hazard	unit	C9
Economy		
Balanced financial result	Million roubles	E1
Production		
Gross harvest of grain and leguminous crops of agricultural organizations	Thousand centners/year	P1
Gross harvest of grain and leguminous crops of peasant (farmer) households	Thousand centners/year	P2
Sown area	Thousand hectares	P3
Share of agricultural organizations in the structure of production of grain and leguminous crops	%	P4
Share of agricultural organizations in the structure of sunflower seed production	%	P5
Share of agricultural organizations in the structure of potato production	%	P6
Share of agricultural organizations in the structure of vegetables production	%	P7
Share of households in the structure of production of grain and leguminous crops	%	P8
Share of households in the structure of sunflower seed production	%	P9
Share of households in the structure of potato production	%	P10
Share of households in the structure of vegetables production	%	P11
The share of peasant (farmer) households in the structure of production of grain and leguminous crops	%	P12
The share of peasant (farmer) households in the structure of sunflower seed production	%	P13
The share of peasant (farmer) households in the structure of potato production	%	P14
The share of peasant (farmer) households in the structure of vegetable production	%	P15

Source: Compiled by the authors.

The matrix of paired correlation coefficients of the main production, economic and climatic indicators, built on the basis of systematized data, indicates the presence of a close relationship between some features (Table 2). Table 2 shows that the change in the number of unfavorable weather events causing material and economic damage has the greatest impact on the dynamics of the gross harvest of grain and leguminous crops. This is felt to the greatest extent by agricultural organizations (correlation coefficient -0.807), to a lesser extent - by PFH (peasant (farm) households) (correlation coefficient -0.620). The maximum weather anomalies occurred in 2010 - 1,095 units. While the sown area remained unchanged, the gross grain harvest in the "peak" year decreased by 31% from the average value. The minimum number of dangerous weather events on the territory of the Russian Federation for the specified period was recorded in 1992 - only 299 units. In general, a general tendency for the growth of the number of climatic risks in the territory of the Russian Federation can be noted (Fig. 1).

Table 2. Matrix of paired correlation coefficients of the main production, economic and climatic indicators of the plant growing subsector in the Russian Federation

	Sum	C1	C2	C3	C4	C5	C6	C7	C8	C9	E1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Sum	1																									
C1	0.11924	1																								
C2	0.30381	-0.1942	1																							
C3	0.34604	-0.1968	0.07496	1																						
C4	0.13854	-0.1220	0.02438	0.04394	1																					
C5	**0.62592**	-0.0000	0.56471	0.25367	-0.2354	1																				
C6	0.32336	-0.0421	0.33037	0.17722	**0.78274**	0.00037	1																			
C7	-0.2254	-0.2255	0.00422	0.47984	0.24853	0.26776	-0.0532	1																		
C8	-0.3901	-0.2025	**0.78193**	-0.0221	-0.2140	0.48755	0.06136	-0.2564	1																	
C9	-0.0326	0.44312	0.03034	0.08403	-0.3385	-0.0687	-0.1539	0.00981	-0.0829	1																
E1	-0.2712	-0.3375	0.41181	-0.1052	**0.72088**	-0.1628	**0.66028**	0.02505	0.19793	-0.2048	1															
P1	**-0.8069**	-0.4947	-0.1360	-0.1795	0.54742	-0.5104	0.30966	0.02662	-0.3776	-0.1997	0.60056	1														
P2	**-0.6202**	-0.4434	0.12458	-0.0872	**0.77687**	-0.2849	**0.63445**	0.08328	-0.1201	-0.3373	0.73941	0.86532	1													
P3	-0.4635	-0.1721	0.13027	-0.1179	**0.69307**	-0.5459	0.51901	0.07329	-0.0809	-0.3116	0.62550	0.57094	0.69173	1												
P4	0.42173	0.27683	-0.1831	**-0.8200**	**-0.8200**	0.34098	**-0.7068**	-0.1429	0.10805	0.21765	**-0.7839**	-0.7165	-0.9192	-0.8294	1											
P5	0.49121	0.32992	-0.1117	-0.1238	**-0.7534**	0.05736	-0.5558	-0.4455	0.31650	0.18119	**-0.6494**	-0.7266	-0.8368	-0.5089	0.81726	1										
P6	-0.5591	-0.0853	-0.0303	-0.3023	**0.73012**	-0.4167	0.54441	0.07074	-0.3663	-0.1348	0.58353	0.78421	0.84983	0.72129	-0.8830	-0.7856	1									
P7	-0.5699	-0.1352	-0.0096	-0.2660	**0.65843**	-0.2254	0.52508	0.16059	-0.3867	-0.1230	0.49731	0.72525	0.80151	0.56796	-0.7923	-0.7989	0.95166	1								
P8	0.53121	0.27637	0.19161	0.49450	**-0.6440**	0.58185	-0.4575	0.16243	0.39635	0.12909	-0.4825	-0.7128	-0.7452	-0.6315	0.77971	0.60999	-0.8730	-0.7756	1							
P9	**0.60204**	0.57652	0.38946	0.31150	**-0.6247**	**0.78897**	-0.4070	0.11652	0.51410	0.09333	-0.4410	-0.7319	-0.6782	-0.6911	0.72458	0.52457	-0.8062	-0.6760	0.90521	1						
P10	0.53285	0.08510	-0.0109	0.28142	**-0.7523**	0.41831	-0.5760	-0.0826	0.33440	0.14597	**-0.6190**	-0.7662	-0.8530	-0.7685	0.91055	0.79017	-0.9960	-0.9364	0.86910	0.80522	1					
P11	0.54686	0.15602	-0.0049	0.27608	**-0.7319**	0.37424	-0.5733	-0.1181	0.33774	0.16768	-0.5815	-0.7474	-0.8504	-0.7463	0.90256	0.79532	-0.9880	-0.9605	0.85640	0.79113	0.99066	1				
P12	-0.4343	-0.2801	0.16163	-0.1029	**0.81967**	-0.3608	**0.70031**	0.12539	-0.1278	-0.2148	**0.77693**	0.72581	0.92029	0.82784	-0.9992	-0.8148	0.89413	0.80182	-0.8041	-0.7457	-0.9199	-0.9115	1			
P13	-0.5232	-0.3399	0.06744	0.08654	**0.77329**	-0.1315	0.56518	0.40970	-0.3495	-0.1803	**0.66529**	0.75844	0.85736	0.54876	-0.8434	-0.9965	0.82149	0.82129	-0.6652	-0.5937	-0.8257	-0.8291	0.84322	1		
P14	-0.4924	-0.0825	0.06451	-0.2508	**0.77229**	-0.4154	**0.61043**	0.09710	-0.2889	-0.1586	**0.65716**	0.73388	0.84724	0.82101	-0.9355	-0.7868	0.97925	0.90564	-0.8538	-0.7943	-0.9933	-0.9824	0.94276	0.82147	1	
P15	-0.4871	-0.1653	0.01804	-0.2659	**0.74870**	-0.4857	0.57777	0.07049	-0.2686	-0.1972	**0.62491**	0.71561	0.83603	0.85903	-0.9412	-0.7361	0.95231	0.85665	-0.8710	-0.8421	-0.9713	-0.9663	0.94922	0.77829	0.98464	1

Source: Authors' calculations based on data: a) Regions of Russia. Socio-economic indicators. 2020: Statistical collection/Rosstat. - Moscow, 2020, - 1242 p. (In Russian); b) Information about dangerous and unfavorable hydrometeorological phenomena that caused material and social damage on the territory of Russia. (In Russian) [19].

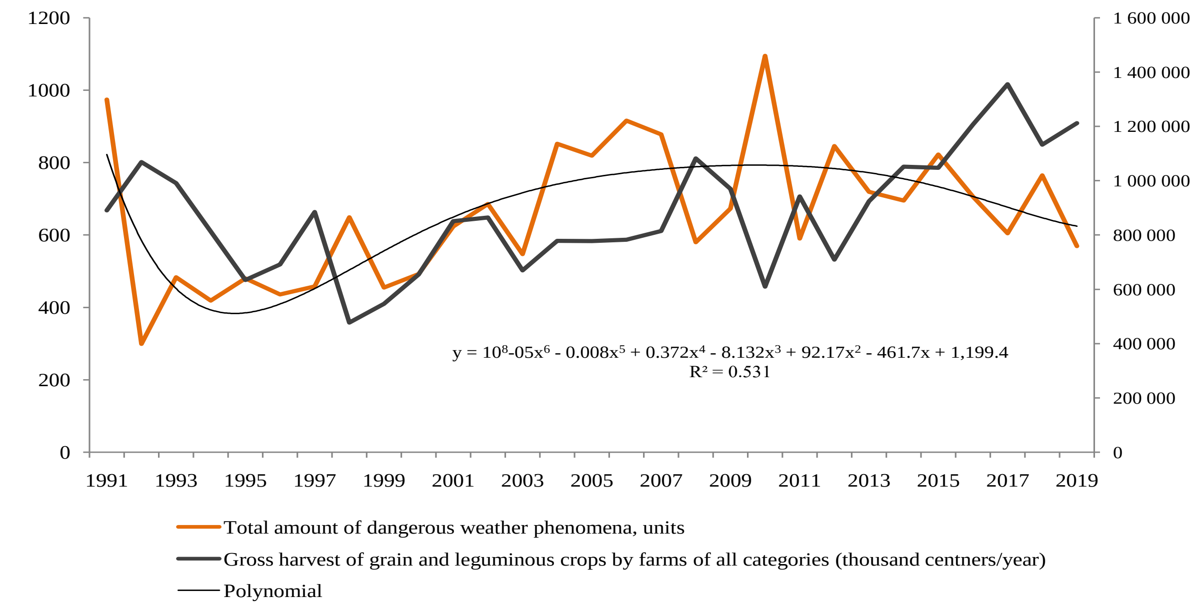

Fig. 1. Dynamics of the total number of dangerous weather events and the gross harvest of grain and leguminous crops by farms of all categories for 1991 - 2019.
Source: Own calculations based on data [20].

In the total number of hazardous weather events, the largest share is made up of wind, rain, extreme fire hazard and their impact in aggregate. Moreover, the greatest impact on the gross harvest of grain and leguminous crops is exerted by rains. Figure 2 clearly shows the trend towards an increase in the amount of rain in the territory of the Russian Federation.

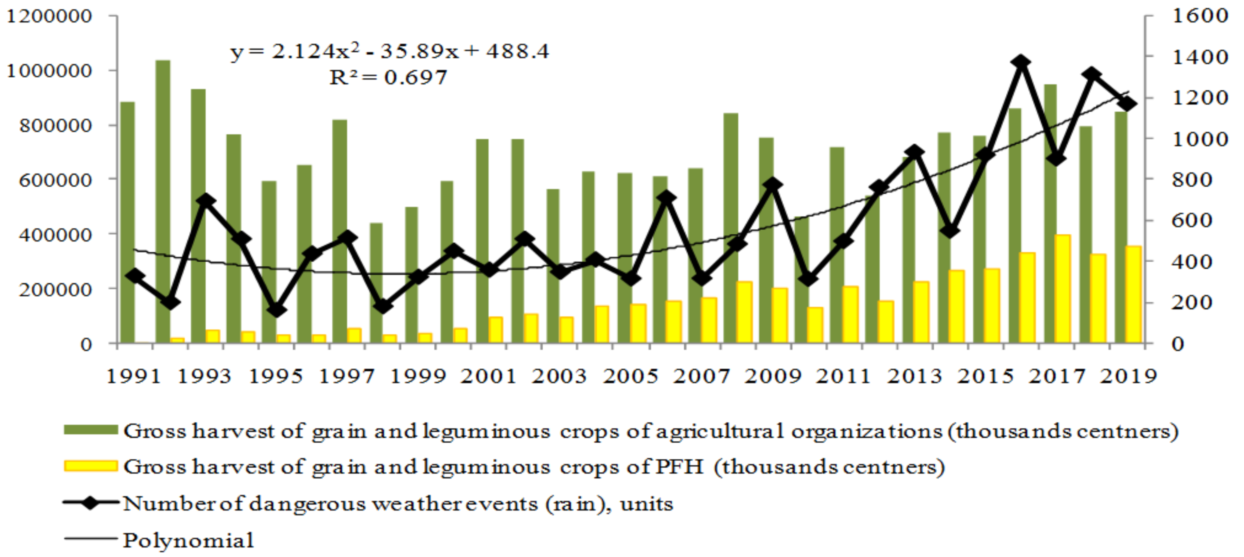

Fig. 2. Gross harvest of grain and leguminous crops by agricultural organizations and PFH in the Russian Federation and the dynamics of rainfall for 1991-2019.
Source: Own calculations based on data [19].

For small producers, who often do not have their own melioration system, the absence of rain threatens to destroy the crop (correlation coefficient 0.777). At the same time, in a rainy year, small forms of farming are able to increase their share in the total structure of grain crop producers, as evidenced by the correlation coefficient of -0.820 for agricultural organizations. The onset of heavy rains is closely correlated with hail precipitation.

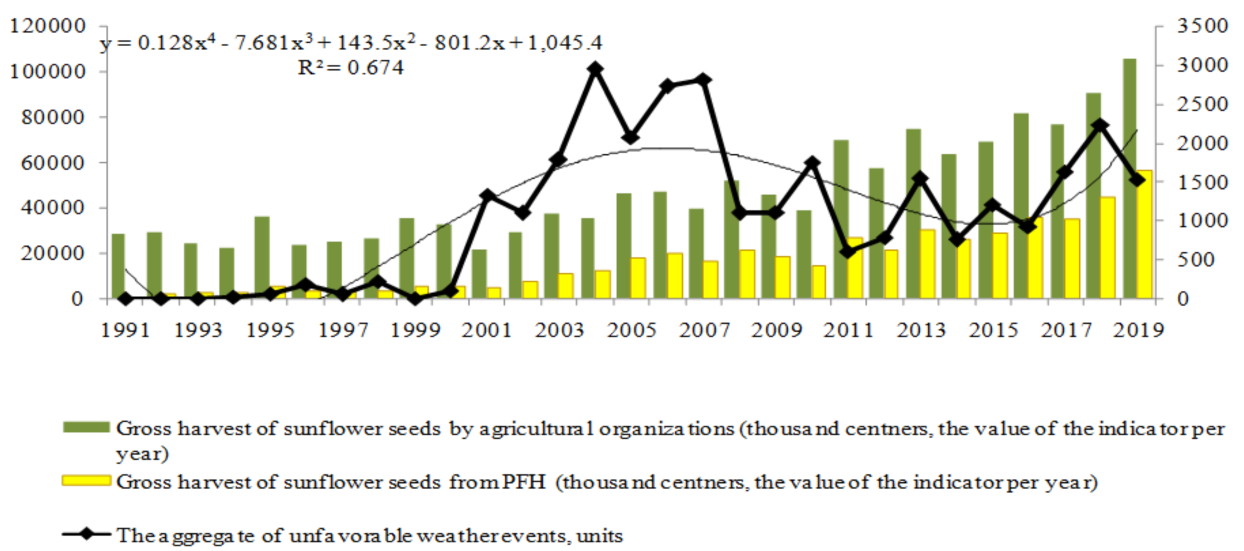

Fig. 3. Gross harvest of sunflower seeds by agricultural organizations and PFH in the Russian Federation and the dynamics of the complex of unfavorable weather phenomena in the territory of the Russian Federation of precipitation for 1991-2019.
Source: Own calculations based on data [19].

Table 2 shows that the most vulnerable category of producers from such a phenomenon as hail turned out to be precisely large organizations - agricultural holdings.

It is obvious that the factor of weather phenomena affects the change in the share of products produced by small farms in the structure of crop producers. For example, small farmers - sunflower producers are most susceptible to a complex of unfavorable weather events. Moreover, the maximum number of the aggregate of phenomena occurred in 2004 and 2006-2007 (Fig. 3).

The most affected were the Kemerovo Region and Altai Territory, as well as other regions of the Siberian and Far Eastern Federal Districts. In these regions, the production of crop products predominates, mainly by small forms of farming.

The indicators of the ratio of large, medium and small agricultural producers are closely statistically related and, accordingly, multicollinear. The same can be said about the presence of a linear relationship between this ratio and the size of the cultivated area. The larger the size of the sown (planting) area of a constituent entity of the Russian Federation, the smaller the share of households in the structure of producers of the main types of crop production. At the same time, an increase in the share of crop products grown by agricultural organizations in the region is typical (Fig. 4).

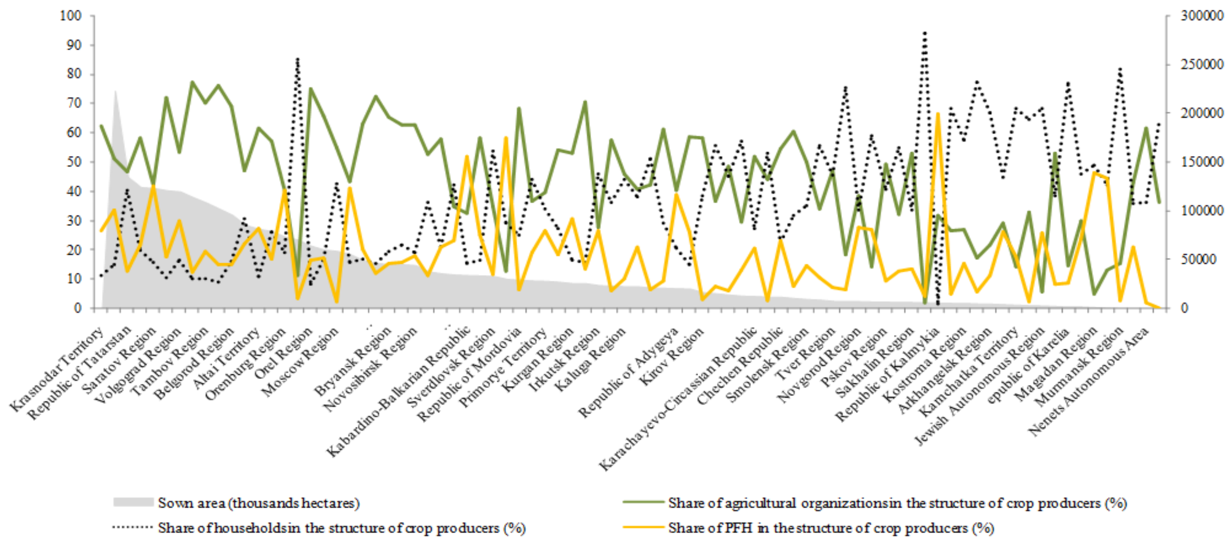

Fig. 4. The structure of crop producers by farm categories and the size of the sown area of the regions in 2019.
Source: Own calculations based on data [19].

Analyzing the structure of crop production by categories of farms, it should be noted that for regions with large sown areas (more than 4 thousand hectares), agricultural organizations dominate (from 60 to 65%). The share of PFH in the total number of crop producers is 20-25% on average. The remaining 15% falls on household farms. These regions include: Krasnodar and Stavropol Territories, Rostov and Voronezh Regions, and the Republic of Tatarstan. The following structure of agricultural producers is typical for regions with average productivity and sown area: agricultural organizations - 50%, PFH - 20%, households - 30%. This includes, for example, the Kirov, Bryansk and Penza regions, the Altai Territory, the Republic of Bashkortostan, etc. In regions with sown areas of less than 1,000 hectares: agricultural organizations - 33.5%, household farms - 51.5%, PFH - 15.0%. The balanced financial result of small businesses is more dependent on the impact of climate risks [9]. Such regions are Kamchatka Territory, Tyumen, Sakhalin and Nizhny Novgorod regions, etc.

The largest share in the structure of crop production is taken by the export-oriented grain industry, and in the leading regions in terms of sown areas, the main share is accounted for by agricultural organizations.

The positive balanced result of the crop production sub-sector is largely due to large integrated structures. The economic impact of climate triggers on the production of the main types of crop products is becoming more and more noticeable precisely in highly productive regions [10]. An effective measure of adaptation to climate change should be the creation of regional climate strategies for the development of agri-food systems. Science-based forecasting is an integral part of strategy development. Moreover, a forecast is a system of interrelated hypotheses. A reliable forecast begins with factor analysis and selection of the most meaningful trends.

When developing model tools for substantiating the directions of strategic development and placement of agriculture in regional agri-food systems, taking into account long-term climatic changes, the most common mistake is the condition of linear growth of greenhouse gas emissions. However, today the emission policy is being actively implemented in the Russian Federation. The new version of the low-carbon development strategy of the Russian Federation until 2050, which assumes the achievement of the country's carbon neutrality by 2060, prioritizes the intensive (target) scenario, which assumes a 79% reduction in greenhouse gas emissions by 2050 [25]. This strategy, in contrast to the previous ones, links the low-carbon transformation in the Russian Federation with economic growth in the context of ensuring the competitiveness and sustainable economic growth of Russia in the context of the global energy transition. At the same time, the expected increase in the absorptive capacity of ecosystems (forestry and agriculture) should be taken into account. In addition, manufacturers will be forced to modernize their production in the direction of "green technologies". Multiplicative micro- and macro-effects should also be considered. The combination of scenarios leads to different expectations.

A preliminary analysis showed that in the system of factors influencing regional crop production, unfavorable weather events have a significant weight. The dynamics of weather risks are superimposed on significant deviations in yield in “peak” and “disastrous” years.

Mass grain production technologies used in Russia, a portfolio of advantages of export-oriented agricultural holdings engaged in crop production, measures of state support for small agricultural producers - all this cannot yet compensate for the increased influence of natural factors. In addition, the asymmetry of the influence of various types of unfavorable hydrometeorological phenomena on different categories of producers is visible. In the future, this will change the ratio of large and small producers in the gross output of major agricultural crops.

Climate risk management tools should take into account the structure of producers, production potential, the types of hazardous weather events most expected in the regions, etc.

The increase in the number of unfavorable meteorological events in regions with a high proportion of crop production in the total volume of crop production in the Russian Federation, and mitigation of climate risks in the Northern and Far Eastern regions against the background of climate warming, will undoubtedly change the structure of regional production and transform production chains. But the increase in their intensity and the unpredictability of the offensive will neutralize the softening of temperature regimes and the expected increase in productivity in crop production in the northern regions.

Changes in natural and climatic characteristics, possibly, will lead in the future to a revision of the criteria for assigning regions to the list of constituent entities of the Russian Federation, the territories of which are considered unfavorable for the production of agricultural products. In accordance with the Agreement of the World Trade Organization on Agriculture, these entities can be exempted from obligations to reduce state support for agricultural producers.

Today, these are, for example, the republics of Komi, Kalmykia, Sakha (Yakutia), Perm and Primorsky Territories, Kaluga and Bryansk regions, and others. There are 29 regions in total.

The implementation of the strategy for sustainable development of the agro-food complex in Russia must meet the new requirements of the time. It seems relevant to form an institutional environment that will help increase the efficiency of state support for economic entities of various organizational and legal forms in the context of a changing natural ecosystem. We consider it expedient to improve the regulatory framework in the field of methodology for assessing and accounting for extreme weather events. The latter is especially relevant today. Estimates of expected climatic changes should be reflected in regulatory documents. For this, it is necessary to include quantitative characteristics of hazardous weather phenomena in the methodological base, develop a statistical base and a methodology for assessing risks. The data available in open statistical databases on the types of weather risks on the territory of the constituent entities of the Russian Federation are often incomplete, some are completely absent. Official data on damages are difficult to systematize and record. Therefore, the direct impact does not always create an objective picture of the territorial distribution of weather and climatic risks at the regional level, and the indirect one cannot be taken into account due to the lack of approved methods for calculating them.

It is necessary to develop indicators and prescribe them in a legal and regulatory framework. In this connection, we consider it expedient in the Federal Law "On Strategic Planning in the Russian Federation" to duplicate the concept of risk given in "Methodological guidelines for the development and adjustment of the strategy of socio-economic development of a constituent entity of the Russian Federation", and indicate a list of types of possible risks with mandatory inclusion in this list is natural and climatic. As a rule, clarification of terminology in regulatory documents encourages developers to take this parameter into account when developing a strategy or when making a forecast of socio-economic development.

Of course, regional climatic and resource characteristics will determine the specific content of both sectoral and regional strategies for adaptation to climate change, differentiated strategies for the development of various forms of agricultural producers and mechanisms of state support for agricultural producers will be developed.

Sectoral, departmental, regional and territorial adaptation plans should be flexible and mutually agreed. Therefore, actions taken in this direction should be taken in a balanced manner, taking into account specific circumstances and have a complementary character (for example, improving regulatory documents at the sectoral level, and reducing the vulnerability of objects and areas most vulnerable to climatic effects - at the regional and territorial levels).

CONCLUSIONS

The systematization of unique data on weather phenomena made it possible to identify a tendency towards an increase in the number of adverse hydrometeorological phenomena that cause material damage. In the structure of natural risks over the past 30 years, the largest share began to be taken by wind, rain, extreme fire hazard and the impact of such phenomena in aggregate.

In the course of the analysis of correlations, a high connectivity of indicators of weather risks with indicators of crop production was established. A detailed analysis showed that the territorial distribution and dangerous weather phenomena characteristic of the area are closely correlated with the structural balance in the region's agriculture. Large agricultural organizations and agro-holdings occupying up to 80% of sown (planting) areas predominate in the structure of crop producers in more southern regions.

At the same time, the increase in the number and intensity of weather risks in these regions, namely, showers and wind, cause enormous material damage. The softening of the temperature regime and the decrease in the number of weather risks in the Northern and

Far Eastern regions in the medium term is unlikely to contribute to the shift of large-scale agricultural production there. Structural adjustment will be expressed in an increase in the share of households and PFHs in potato and sunflower cultivation.

Thus, the results of the conducted analytical study confirmed the hypothesis that unfavorable hydrometeorological phenomena have a significant weight in the system of climatic factors. It has been proved that weather risks are one of the most significant and meaningful trends that simply need to be taken into account when making forecasts in order to form an export-oriented model of the agro-industrial complex. The factor of hazardous weather events and the structural shifts that they provoke should be taken into account when justifying adaptation measures of regional and sectoral development strategies. For this, it is important to develop a methodological toolkit that allows accounting in the statistical base and assessing weather risks with its further consolidation in the regulatory framework.

REFERENCES

[1]Bakker, M., Govers, G., Ewert, F., Rounsevell, M., Jones, R., 2005, Variability in regional wheat yields as a function of climate, soil and economic variables: assessing the risk of confounding, Agric. Ecosystems Environ., 2005, 110:195-209.

[2]Challinor, A., Ewert, F., Arnold, S., Simelton, E., Fraser, E., 2009, Crops and climate change: Progress, trends, and challenges in simulating impacts and informing adaptation, J. Exp. Bot. 2009, 60:2775-2789.

[3]Changnon, S., 2003, Measures of economic impacts of weather extremes, Bull. Am. Meteorol. Soc., 2003, 84:1231-1235.

[4]Chugunkova, A., Pyzhev, A., Pyzheva, Yu., 2018, Influence of global climate change on economy of forestry and agriculture: risks and opportunities, Actual problems of economics and law, 2018, 3:523-537. (Чугункова, А.В., Пыжев, А.И., Пыжева, Ю.И. Влияние глобального изменения климата на экономику лесного и сельского хозяйства: риски и возможности // Актуальные проблемы экономики и права. 2018, 3:523-537.) (In Russian).

[5]Doroshenko, S., Posysoeva, K., 2021, Econometric estimation of strategic development factors of Russian border regions, Economy of region, 2021, 17:431-444. https://doi.org/10.17059/ekon.reg.2021-2-6, Accessed on October 29, 2021.

[6]Food security doctrine of the Russian Federation (Doktrina prodovol'stvennoy bezopasnosti Rossiyskoy Federatsii), (In Russian), http://kremlin.ru/acts/bank/45106, Accessed on December 14, 2021.

[7]Frolov, A., 2014, Second assessment report of Roshydromet on climate changes and their consequences on the territory of the Russian Federation (Vtoroy otsenochnyy doklad Rosgidrometa ob izmeneniyakh klimata i ikh posledstviyakh na territorii Rossiyskoy Federatsii), Moscow, 61 p. (In Russian), https://cc.voeikovmgo.ru/images/dokumenty/2016/od2/od2.pdf, Accessed on September 21, 2021.

[8]Iashalova, N., Molchanova, T., Ruban, D., 2019, Prerequisites for effective management of climate risks in agriculture in Russia: investment and innovation aspect, Vestnik UrFU. Series economy and management, 2019, 18:637-655. (Яшалова, Н., Молчанова, Т., Рубан, Д., 2019, Предпосылки эффективного управления климатическими рисками в сельском хозяйстве России: инвестиционно-инновационный аспект, Вестник УрФУ. Серия экономика и управление, 2019, 18:637-655.) (In Russian).

[9]Kadomtseva, M., Osovin, M., 2020, Prospects for the development of the Russian system of agricultural consulting under the conditions of the digital transformation of agrarian economy, BIO Web of Conferences, 2020, 17:00134.

[10]Kadomtseva, M., Bogdanov, A., 2021, Rationale of climate risk management mechanisms in the regions of the Russian federation with crop specialization, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 2021, 21:317-330.

[11]Kattsov, V., Shkolnik, I., Pavlova, V., Khlebnikova, E., Efimov, S., Konstantinov, A., Pavlova, T., Pikaleva, A., Rudakova, Yu., Sall, I., Baidin, A., Zadvornykh, V., 2019, Development of the technology of probabilistic forecasting of the regional climate in Russia and the construction on its basis of scenario forecasts of changes in climatic influences on the sectors of the economy. Part 2: Climate Impact Assessments, Proceedings of the A.I. Voeikov Main Geophysical Observatory, 2019, 593:6-52. (Катцов, В., Школьник, И., Павлова, В., Хлебникова, Е., Ефимов, С., Константинов, А., Павлова, Т., Пикалева, А., Рудакова, Ю., Салль, И., Байдин, А., Задворных, В., 2019, Развитие технологии вероятностного прогнозирования регионального климата на территории России и построение на ее основе сценарных прогнозов изменения климатических воздействий на секторы экономики. Часть 2: Оценки климатических воздействий, Труды Главной геофизической обсерватории им.А.И. Воейкова, 2019, 593:6-52.) (In Russian).

[12]Khaptsev, Z., Bogdanov, A., Kadomtseva, M., Smutnev, P., Isaicheva, L., 2021, Opportunities and prospects for the development of complex biocompatible plant protection products based on some natural nitrogen compounds for solving agricultural

problems, IOP Conference Series: Earth and Environmental Science, 2021, 723:032069.

[13]Kobysheva, N., Akent'eva, E., Galyuk, L., 2015, Climate risks and adaptation to climate change and variability in the technical field. (Klimaticheskiye riski i adaptatsiya k izmeneniyam i izmenchivosti klimata v tekhnicheskoy sfere.), Kirillitsa, Saint-Petersburg, 2015, 256 p. (In Russian).

[14]Ksenofontov, M., Polzikov, D., 2020, On the question of the impact of climate change on the development of agriculture in Russia in the long term, Problemy prognozirovaniya, 2020, 3:82-92. (Ксенофонтов, М., Ползиков, Д., 2020, К вопросу о влиянии климатических изменений на развитие сельского хозяйства России в долгосрочной перспективе, Проблемы прогнозирования, 2020, 3:82-92.) (In Russian).

[15]Order of the Government of the Russian Federation of April 12, 2020 N 993-r "On approval of the Strategy for the development of the agro-industrial and fishery complexes of the Russian Federation for the period up to 2030" (Rasporyazheniye Pravitel'stva RF ot 12 aprelya 2020 goda N 993-r «Ob utverzhdenii Strategii razvitiya agropromyshlennogo i rybokhozyaystvennogo kompleksov Rossiyskoy Federatsii na period do 2030 goda»), (In Russian) https://docs.cntd.ru/document/564654448?marker=6540IN, Accessed on October 11, 2021.

[16]Ortiz-Bobea, A., Just, R., 2012, Modeling the structure of adaptation in climate change impact assessment, Amer. J. Agric. Econ., 2012, 95:244-251.

[17]Popescu, A., Dinu, T., Stoian, E., Serban, V., 2020, Variation of the main agricultural crops yield due to drought in Romania and Dobrogea region in the period 2000-2019, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 2020, 20:397-415.

[18]Porfir'ev, B., Makarova, E., 2014, Economic evaluation of damage from natural disasters, Her. Russ. Acad. Sci., 2014, 84:395-406. https://doi.org/10.1134/S1019331614060136, Accessed on November 18, 2021.

[19]Regions of Russia. Socio-economic indicators", 2020, Statistical Book, Moscow, Rosstat, 2020, 1242 p. («Регионы России. Социально-экономические показатели», 2020, Статистический сборник, Москва, Росстат, 2020, 1242 с.) (In Russian). http://meteo.ru/data/310-neblagopriyatnye-usloviya-pogody-nanjosshie-ekonomicheskie-poteri#%D0%B4%D0%BE%D1%81%D1%82%D1%83%D0%BF-%0%BA-%D0%B4%D0%B0%D0%BD%D0%BD%D1%8B%D0%BC, Accessed on October 06, 2021.

[20]Report on the peculiarities of the climate in the territory of the Russian Federation for 2020, Moscow, 2021, 104 p. (Доклад об особенностях климата на территории Российской Федерации за 2020 год. Москва, 2021, 104 p.). (In Russian). http://cc.voeikovmgo.ru/images/dokumenty/2021/doklad_klimat2020.pdf, Accessed on November 27, 2021.

[21]Romamenko, I., Siptits, S., Evdokimova, N., Egorova, O., 2015, The impact of emergencies on the food security of the Russian Federation: Scientific works of the A.A. Nikonov VIAPI (Vliyaniye chrezvychaynykh situatsiy na prodovol'stvennuyu bezopasnost' Rossiyskoy Federatsii: Nauchnyye trudy VIAPI imeni A.A.Nikonova), ERD, Moscow, 2015, Iss. 43, 142 p. (In Russian).

[22]Shpakova, R., 2019, General targets for strategic development Russian Federation regions, Public administration. Electronic bulletin, 2019, 77:316-317. (Шпакова, Р., 2019, Генеральные цели стратегического развития регионов Российской Федерации, Государственное управление. Электронный вестник. 2019, 77:316-317.) (In Russian).

[23]Siptits, S., Romanenko, I., Evdokimova, N., 2021, Conceptual aspects of developing a system of models for the development of regional agri-food systems taking into account the climatic factor, Russian Agricultural Economics, 2021, 6: 83-92. (Сиптиц, С., Романенко, И., Евдокимова, Н., 2021, Концептуальные аспекты разработки системы моделей развития региональных агропродовольственных систем с учетом климатического фактора, Экономика сельского хозяйства России, 2021, 6:83-92.) (In Russian)

[24]Sirotenko, O., Abashina, H., Pavlova, V., 1997, Sensitivity of the Russian agriculture to changes in climate, CO2 and tropospheric ozone concentrations and soil fertility, Climatic change, 1997, 36:217-232.

[25]Strategy for the socio-economic development of the Russian Federation with low levels of greenhouse gas emissions until 2050. Order of October 29, 2021, No. 3052-р. (Стратегия социально-экономического развития Российской Федерации с низким уровнем выбросов парниковых газов до 2050 года. Распоряжение от 29 октября 2021 года №3052-р). (In Russian). http://government.ru/news/43708/, Accessed on December 02, 2021.

[26]Svetlova, N., Shishkina, E., 2021, Scenario analysis of the consequences of climate change for Russian agriculture, Economy, labor, management in agriculture, 2021, 6:74-85. [Светлова, Н., Шишкина, Е., 2021, Сценарный анализ последствий изменения климата для сельского хозяйства России, Экономика, труд, управление в сельском хозяйстве, 2021, 6:74-85]. (In Russian).

[27]The Global Risks Report 2021 (16th Edition) is published by the World Economic Forum. URL:http://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf, Accessed on September 22, 2021.

[28]The Nobel Prize in Physics, 2021, https://www.nobelprize.org/prizes/physics/2021/summary/, Accessed on December 03, 2021.

[29]World Meteorological Organization. Weather. Climate. Water. https://public.wmo.int/ru, Accessed on November 15, 2021.