ECONOMIC ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN RUSSIA

NATIONAL AND REGIONAL ASPECTS

GEORGIY SAFONOV

Director of Environmental and Natural Resource Economics, National Research University Higher School of Economics

YULIA SAFONOVA

Member of the research team, Environmental and Natural Resource Economics, National Research University Higher School of Economics

Climate change is already having a negative impact on agricultural production in Russia, especially grain production, since this sector is perhaps the most dependent on weather and climate factors. This report presents an economic evaluation of the impact of climate change on crop production at the national level and a long-term economic evaluation of the losses, profits, and risks for agriculture throughout Russia. It analyses the situation in the two the major agricultural regions, where the negative effects of climate change are especially pronounced, and examines the prospects for adapting Russia's agriculture to climate change.

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EXECUTIVE SUMMARY

Already climate change is having a negative impact on agricultural production in Russia. Forecasts until 2050 and beyond are rather pessimistic: Russia's climate is expected to change at a quicker pace and more drastically than at any time in the last 100 to 150 years. This will not only result in a higher surface temperature, but also in changes in precipitation and in a greater number of hydrometeorological hazards such as floods, drought, heat and cold waves, uncharacteristic freezing temperatures during vegetation periods, etc.

Russia's agriculture has already been confronted with the initial consequences of climate change. In 2010 and 2012, drought caused a significant drop in grain production in the country, as well as a consequent increase in grain prices. The total losses resulting from poor harvests exceeded RUB 300bn in those years. Meanwhile, the cost of these losses was pushed onto people who had to pay significantly higher bread prices – meaning that the most vulnerable populations were hit the hardest. The scale of the effect of climate change on agriculture is massive. Risks for producers and consumers of agricultural products are high and will continue to increase as weather and climate conditions deteriorate. Losses for the economy in general include not only losses from lower crop yield, but also price spikes on agricultural products.

Climate change knows no boundaries. While all leading grain-producing regions in Russia were affected by the drought, the negative impact was more widespread. In 2010, grain production dropped in Europe, the USA, Canada, Australia, and many other countries, which resulted in a 25 per cent reduction in global grain reserves. Consequently, global grain prices went up.

Are Russian agricultural companies really ready to face the challenges posed by climate change? Research shows that, against the background of climate change, the availability of technical, energy, and financial resources is not sufficient for the sustainable development of agriculture in Russia. Agricultural companies' accounts payable are increasing, the financial standing of over 30 per cent of large and medium-sized companies is flimsy, and their technical facilities are deteriorating, as is the social standing of residents in villages. Faced with such conditions, it is unlikely that companies will be able to withstand the negative impact of climate change on their own. We conclude that Russia's agriculture is extremely vulnerable both financially as well as to any of the potential negative effects of climate change. In addition, agricultural companies are also poorly equipped to withstand the negative effects of climate change.

Without adequate measures to adapt agriculture to climate change, the annual economic loss from a decrease in climate-determined crop yield in Russia is estimated at RUB 108bn (approximately $3.5bn) by 2020 and over RUB 120bn (approximately $3.9bn) by 2050.

Potential adaptation measures differ significantly from region to region in Russia. This report contains an in-depth analysis of two leading 'grain' regions. The Altai region is a perfect example of a region that already experiences significant problems related to soil erosion by wind and water, the recent drought, uncharacteristic freezing temperatures and snowfalls during the vegetation period, not to mention other climate anomalies. Agricultural producers in the Altai region are suffering major losses from poor harvests, and black storms could ruin the fertile soil layer in the region's steppes where the majority of key grain-producing districts are located. Another example is the Voronezh region, one of the few Russian regions that has managed to weather the droughts of 2010 and 2012 thanks to a well-thought-out agricultural policy and effective measures. Yet even this region can expect to see climate aridization and a significant drop in harvests unless additional adaptation measures are taken. Climate-determined losses of grain producers in the Voronezh region could reach RUB 1.4bn (approx. $46m) by 2020 and RUB 3.5bn (approx. $114m) by 2050.

Adaptation measures must be systematic and comprehensive in nature. They must also be integrated into the development strategy for the country's agricultural complex and into the

national climate policy. It is not only the immediate impact of climate and weather factors on agricultural production (crop yield) that must be taken into account, but also risks related to the impact of climate change on the transportation infrastructure, power production, processing facilities, the social sector, etc.

According to the latest data, annual global expenses related to the adaptation of agriculture are required in the amount of $7bn, $200m of which must be invested in Europe and Central Asia, including Russia.

The state programme for the development of the agricultural industry and market regulation of agricultural products, food staples, and food products markets for 2013–2020 provides for expenses in the amount of RUB 466.6bn (approx. $15.3bn), which includes spending on soil improvement, the introduction of new crops, measures to curb risks for agricultural producers, etc. Adaptation measures could be implemented as part of this programme, and they also fall within the scope of the Climate Doctrine.

Recommended measures to increase the resilience of Russian agriculture for adaptation to climate change

The management of risks stemming from climate change is complex and requires a comprehensive analysis not only of issues related to the proper cultivation and harvesting and processing of crops, but also aspects such as:

- the vulnerability of systems of production, delivery, and food storage (logistics);
- the impact on the price of food and consumption, especially on the lowest-income groups of the population;
- the risk assessment of the entire production chain associated with the production and processing of agricultural products, including transportation, energy, communications, and other infrastructure affected by climate change;
- the high risks for the survival of farmers and households engaged in growing subsistence crops in areas prone to adverse climate and weather conditions;
- the risks associated with the growing period as well as the harvest, when there may be extreme weather phenomena as a result of which, crops may be lost or their quality significantly diminished;
- the offsetting of agricultural yields from the south to the north, and the disposal of land in the more southern areas of agricultural activity;
- moisture is essential for sustainable agricultural production, and it depends on climatic factors, etc.[1]

It is believed that the basis of a strategy for adapting agriculture to climate change in Russia could be formed by the following measures:

- conducting integrated regional studies to assess the risks and vulnerability of agricultural production to the negative impact of climatic and weather factors (some of this work has already been done, but not in all regions of Russia);
- evaluating the sensitivity of the regional and national markets for agricultural products and foodstuffs to price shocks and supply reduction caused by climatic and weather factors;
- developing and implementing large-scale regional programmes aimed at creating field-protective forest belts and other measures to prevent and reduce soil erosion and loss of topsoil;
- accelerating the development of the agricultural sector in the non-Black Earth belt, primarily in the central, northwest, and other regions where there is sufficient moisture to ensure stability for crop production;

- optimizing the ratio of winter and spring crops to account for changes in the conditions of autumn and winter;
- expanding the cultivated area for more thermophilic and fruitful crops, providing the intensification of agricultural production (such as corn, sunflower, sorghum, soybeans, etc.);
- expanding crop acreage (the second) of crop growth for thermal resources;
- developing irrigated agriculture to improve the sustainability of agricultural production and utilization of additional thermal resources;
- expanding subtropical agriculture in southern Russia and accelerating the development of industries such as horticulture, viticulture, cotton, and rice, the effectiveness of which can increase significantly during the expected climate change;
- improving the effectiveness of husbandry by increasing food supply as a result of bioclimatic potential and reducing the period of confinement of cattle in a warming climate;
- introducing moisture-saving technologies, selecting more resistant crops or varieties, creating reserve stocks of food to reduce losses from possible climate aridization, thereby ensuring food security.

Further modernization of the industry, with a transition to innovative technology, will reduce the degree of its dependence on weather conditions and will correspondingly increase production.

A special study of the cost of adaptation, done at the level of regions and rural areas and across regions, should be produced. Such work may be performed as part of the Climate Doctrine of the Russian Federation, and also as part of the State Agricultural Development Program and Regulation of Agricultural Products, Raw Materials and Food for 2013–2020 (approved by the Russian government resolution No. 717 dated 14 July 2012).

INTRODUCTION

This report undertakes a long-term economic evaluation of the losses, profits, and risks for agriculture connected to climate change throughout the territory of the Russian Federation. The analysis focuses primarily on grain production, since this sector is perhaps the most dependent on weather and climate factors. Issues connected with the impacts of climate change on the production of other crops, as well as on animal husbandry, require additional research.

The report focuses mainly on an economic evaluation of the impact of climate change on crop production at the national level, and it features an analysis of the situation in the country's agricultural regions where the negative effects of climate change are especially pronounced. The final part of the report examines the prospects for adapting Russia's agriculture to climate change.

This research relied on open sources of data and information, publications by Russian science and research institutes, international organizations, and the opinions of experts and specialists.

1. ECONOMIC EVALUATION OF THE IMPACT OF CLIMATE CHANGE ON GRAIN PRODUCTION IN RUSSIA

1.1. Methodological aspects

The following questions and observations often arise when researchers are given the task of conducting an economic evaluation of the impact of climate change on Russia's agriculture:

1. It is unclear how extensive climate change is, as there are some experts who believe that there are recurring fluctuations in temperature, precipitation, and other parameters, but as yet no long-term trends for such changes.

2. Global warming generally has had a positive effect on agricultural crop yield; it has shifted the boundaries of risk-laden agriculture and resulted in significant economic benefit for Russia's agriculture. To some extent, it has even fuelled optimism and provided assurance in undertaking ambitious plans, for example, for boosting grain production and turning Russia into one of the largest global net exporters of agricultural products.

3. A deeper analysis of this goal entails a shift in emphasis from the general impact of climate change on agriculture to the question of how acute this problem is for Russia, and how climate-determined crop yield is changing as a result of climate change. Thus, the primary issue is the seriousness of the problem in terms of production metrics (such as crop yield, harvest size, etc.), as well as the amount of agricultural products the country (region) loses – or may lose – as a result of unfavourable climate change.

4. Further analysis leads to questions about the territorial distribution of the effects of climate change (that is, which regions are more or less affected); which crops' yields are more affected, the time span of changes, etc.

Some of these questions have already been answered quite comprehensively by Russian scientists. Yet, in cases when Russian data is insufficient – and also for purposes of cross-checking – we will use the results of international studies.

In this report, we examine the problem of how climate change affects agriculture in terms of **economic indicators**. To provide an adequate economic evaluation, natural metrics (such as crop yield, harvest size, etc.) are vital, as are parameters such as agricultural product prices, production cost, production volume, and, more importantly, the distribution of profit or losses between market players (the grain producers, the government, consumers, etc.) and the actions of price setters (enterprises) – all against the background of a higher risk of bad harvests, adaptation costs, new land use, etc.

1.2. Is Russia's climate changing, and in what way?

According to a report by the Russian Federal Service for Hydrometorology and Environmental Monitoring (Roshydromet) for 2011, monitoring data and model calculations show that Russia's climate is more susceptible to global warming than the climate of many other regions of the world. Climate warming in Russia has been registered as taking place at a much faster pace than the warming seen in the rest of the world: anomalies in average annual temperatures in Russia reach 3–4°C [7°C or more, based on 2012 data], while the average global anomalies only slightly exceed 1°C. According to Roshydromet data, over the past 100 years (1907–2006), total warming in Russia stood at 1.29°C, while average global warming, based on the

Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), was at 0.74°C over a span of 150 years.[2] At the same time, in many regions, such as the Altai region, the temperature increase in the last 100 years has exceeded 3°C.

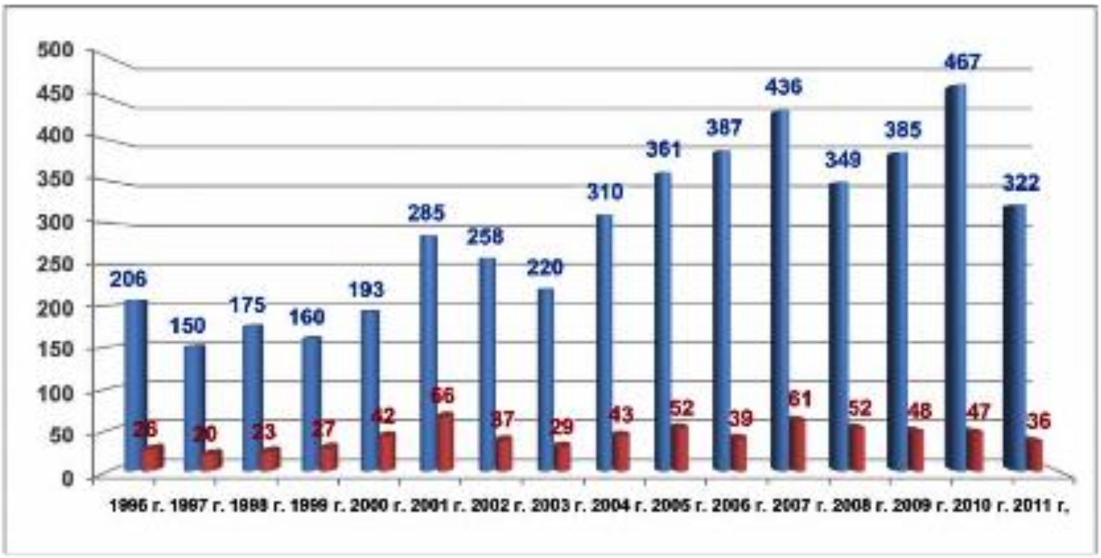
Over the last 25 years, the annual average temperature in Russia rose at a rate of **1.6°C per decade in certain areas.** This is an extremely high figure. While changes were distributed unevenly between regions, the major agricultural regions of the country are located in zones experiencing rising annual average temperatures. Thus, they are more sensitive to climate change.

Certainly, apart from temperature factors, such as humidity and precipitation, which are also seeing significant changes, other weather and climate conditions have had a major impact on agriculture.[3]

Hazardous hydrometeorological events also cause economic losses (see Figure 1.1). According to Roshydromet, in 2012 a record number of 469 cases of dangerous weather events and complex weather events, which resulted in measurable material losses, was registered as having taken place in the last 14 years.[4] The number of registered weather events rose nearly one-and-a-half times year-on-year. Most often, these extreme and complex weather events took place between the months of May and September: 314 such events or 67 per cent of the total number.

In 2012 periods of extreme heat occurred 80 per cent more often than in 2011. Similarly, heat waves were registered in Russian regions nearly three times more often than in the previous year, and the number of cold waves during the vegetation period rose 70 per cent year-on-year. In 2012, there was a total of 86 cases of temperatures hitting the absolute daytime maximum and 23 cases of the absolute night-time minimum being reached.

Figure 1.1. Breakdown of hydrometeorological events by year: the total number is indicated in blue and the number of unexpected dangerous weather events in red



Source: Roshydromet (2012), p 62.

In general, we agree with the opinion of many experts that climate change in Russia is already taking place and often has a negative impact on agriculture, economy, and the social sphere.[5] However, we are interested in more than just this conclusion – we are concerned with the economic effects of climate change. Before moving onto an assessment, however, let us make it clear: the observed changes are just the beginning. We can expect significantly more adverse consequences of climate change in the future.

Without exception, all models demonstrate a measurable warming for Russia in the twenty-first century. Temperature changes considerably exceed standard deviations in all regions, even in the cold months, when natural temperature fluctuations are especially high.

We would like to draw attention to another authoritative set of opinions from the experts at the Voeikov Main Geophysical Observatory, who estimate the temperature increase in Russian regions in accordance with the scenarios developed by the IPCC. Figures 1.2A and B below show the zones of rising annual mean temperatures for the periods of 2041–2060 and 2061–2099, respectively.

Figure 1.2A. Map of changes in annual mean temperatures in the Russian Federation for the period 2041–2060 for IPCC SRES A2 scenario, compared to the current situation

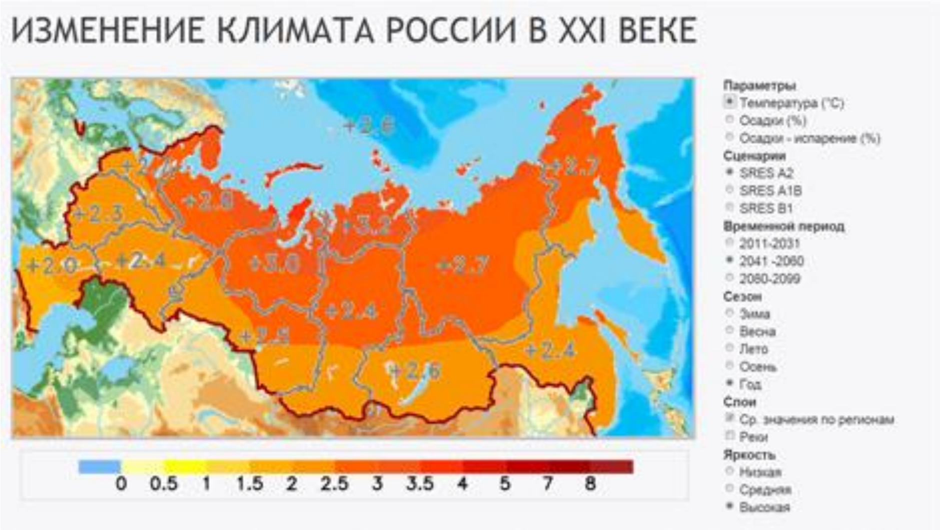
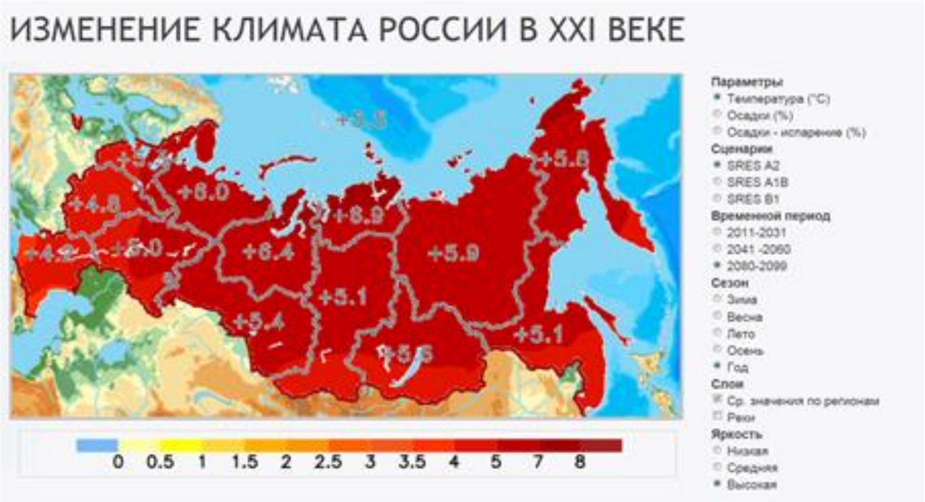


Figure 1.2B. Map of changes in annual mean temperatures in the Russian Federation for the period 2061–2099 for IPCC SRES A2 scenario, compared to the current situation



Source: Voeikov Main Geophysical Observatory: http://voeikovmgo.ru/ru/izmenenie-klimata-v-rossii-v-xxi-veke.

Translation of key:

Parameters	Scenarios	Time period	Season	Layers	Brightness
Temperature (C)	SRES A2	2011–2031	Winter	Mean for regions	Low
Precipitation (%)	SRES A18	2041–2060	Spring	Rivers	Medium
Precipitation – evaporation (%)	SRES B1	2080–2099	Summer		High
			Autumn		
			Year		

At the same time, we must keep in mind that the images demonstrate an **average** rise in temperatures, whereas in reality changes could actually be much higher in different regions and areas, meaning the impact on agriculture could be much more pronounced.

There should be no doubts regarding the fact that the Russian Federation’s agriculture is in for **very substantial** climate change. Could it be avoided? This would be extremely hard and practically impossible. Could the impact be downplayed and losses curbed? Yes, this is possible, and will be discussed later.

First of all, we need to determine what experts think about what the immediate effects are that climate change will have on agriculture in terms of crop yield.

1.3. Impact of climate on agricultural production (natural output indicators)

Highly interesting results were obtained during a study on the quantitative evaluation of the impact of climate change on crop yields in Russia conducted by the Russian Research Institute of Agricultural Meteorology under the patronage of the Environmental Ministry of Russia and Roshydromet, which has been doing scientific research in this area for many years.

Table 1.1. features an assessment of changes in crop yield in accordance with the IPCC A1F1 global development scenario and respective climate change. This scenario provides for rapid economic growth accompanied by an intensive use of fossil fuel.

It should be noted that the overall yield of grain crops in Russia is expected to drop by as much as 17 per cent by 2050. At the same time, in the Central, Volga, and Ural Federal districts the plunge in crop yield is described as ‘**catastrophic**’ at 14, 30, and 38 per cent by 2050, respectively.

The Russian Research Institute of Agricultural Meteorology also carried out in-depth studies in the Russian regions separately. Specifically, the Institute is studying the impact of observed and projected climate change in the twenty-first century on the bioclimatic potential and efficiency of the Kaluga region's agriculture, taking into account potential adaptation, a strategic climate change forecast, and the assessment of its effect on the state and efficiency of agriculture in the Central Federal District of Russia.

To what extent can these studies be trusted? Can they be verified by actual data and other assessments?

Table 1.2 features the Russian Statistics Service’s (Rosstat) data on gross yield of grain and leguminous crops in 12 leading regions of Russia in 2012 compared to the average yield from 2006 until 2010, and in the 2012 change from 2011.

Table 1.1. Crop yield dynamics in accordance with the IPCC A1F1 global development scenario and respective climate change (change from current level, %)

Federal districts of Russia	Grain crops			Fodder		
	Forecast period, years					
	2010	2030	2050	2010	2030	2050
Central	–3	–5	–14	–1	1	–7
Northwestern	4	8	9	7	16	20
Southern	–12	–8	–2	–11	–14	–17
Volga	–9	–13	–30	–1	–1	–12
Ural	–22	–26	–38	–4	1	–9
Russia overall	**–8**	**–9**	**–17**	**–2**	**–0**	**–7**

Source: Russian Research Institute of Agricultural Meteorology: http://www.agromet.ru/index.php?id=77.

(Authors’ note: The most significant changes in yield are highlighted in yellow.)

Table 1.2. Gross yield of grain and leguminous crops in the 12 largest grain-producing regions of Russia in 2012 compared to the average yield in 2006–2010 and in 2011

Region	**2006–2010 (on average per year), m tons**	**2012, change from 2006–2010**	**2012, change from 2011**
Krasnodar	9473	93%	77%
Stavropol	7101	68%	59%
Rostov	6498	94%	79%
Altai	4389	57%	64%
Tatarstan	3951	76%	61%
Republic of Bashkortostan	3239	52%	56%
Volgograd	3222	75%	91%
Omsk	2899	58%	50%
Saratov	2878	77%	107%
Voronezh	2603	118%	101%
Novosibirsk	2475	50%	50%
Orenburg	2416	61%	50%
Russian Federation, total	**85190**	**83%**	**75%**

Source: Rosstat’s website, section on agriculture, hunting, and forestry: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/enterprise/economy/# (accessed 20 February 2013).

(Note: Regions in which grain production shrank between 20 and 25% are highlighted in yellow, and a drop of 35 to 50% is highlighted in red.)

In 2012 (which was a rather good year compared to drought-stricken 2010), gross yield of grain and leguminous crops shrank by 17 per cent compared to the country average in 2006–2010, and 25 per cent compared to 2011. At the same time, all of the leading grain-producing regions (which account for over 60 per cent of total grain output), with the exception of the Voronezh region, saw a considerable decrease in grain production, in some cases reaching 50 per cent of the total output for 2006–2010.

The actual numbers for 2010 and 2012 show that dwindling production, which was triggered primarily by drought, could exceed the forecast published by the Russian Research Institute of Agricultural Meteorology. It is more important, however, that the forecasts are consistent with the actual data; the changing climate is already affecting grain production in Russia.

This conclusion is also in line with the estimates presented by Roshydromet, according to which climate-related grain crop yield in the North Caucasus, the Urals, and the Central Black Soil Region (the main crop-producing regions) is expected to shrink considerably by 2020. At the same time, annual losses in Russia could reach between 10m and 12m tons or nearly 13 per cent of gross grain yield in 2011 (see Table 1.3).

The chosen climate change scenario is also an important issue. In the worst-case scenario –the arid scenario – the impact would be the most adverse. Meanwhile, from an economic point of view, it is vital to evaluate the consequences of worst-cast scenarios, strategies, and measures. And who can really say with any certainty that the worst-case scenario will never take place in Russia?

Table 1.3. Climate-related crop yield and grain crop yield variability as a result of climate change: arid scenario

Region	**Total grain harvest, in average per year, per 1,000 tons**	**Share of region in the total grain harvest, %**	**Changes in climate-related crop yields, % of average level of 2001–2005**		**Changes in climate-related crop yields in comparison with average harvests of 2001–2005, (1,000 tons)**	
	2001–2005	**2001–2005**	**2010**	**2020**	**2010**	**2020**
Northern	220.3	0.3	4.8	7.1	10.6	15.6
Northwestern	117.1	0.1	4	7.9	4.7	9.3
Kaliningrad	218.6	0.3	2	4	4.4	8.7
Central	5,110.5	6.5	–1.9	–0.8	–97.1	–40.9
Volgo-Vyatsky	3,250	4.1	–5.6	–6.8	–182.0	–221.0
Central Black Soil area	8,905.9	11.3	–6.9	–14.1	–614.5	–1255.7
Volga	15,074.4	19.1	–13.3	-13.5	–2,004.9	–2,035.0
North Caucasus	20,503.7	26.0	–22.1	–23.8	–4,531.3	–4,879.9
Urals	10,396.7	13.2	–14.2	–15.9	–1,476.3	–1,653.1
Northern Siberia	11,751.4	14.9	–7	–12	–822.6	–1,410.2
East Siberia	2,830.3	3.6	–12	–18	–339.6	–509.5
Far East	387.3	0.5	4	7	15.5	27.1
Total	**78,766.2**	**100.0**	**–12.7**	**–15.2**	**–10,033.3**	**–11,944.5**

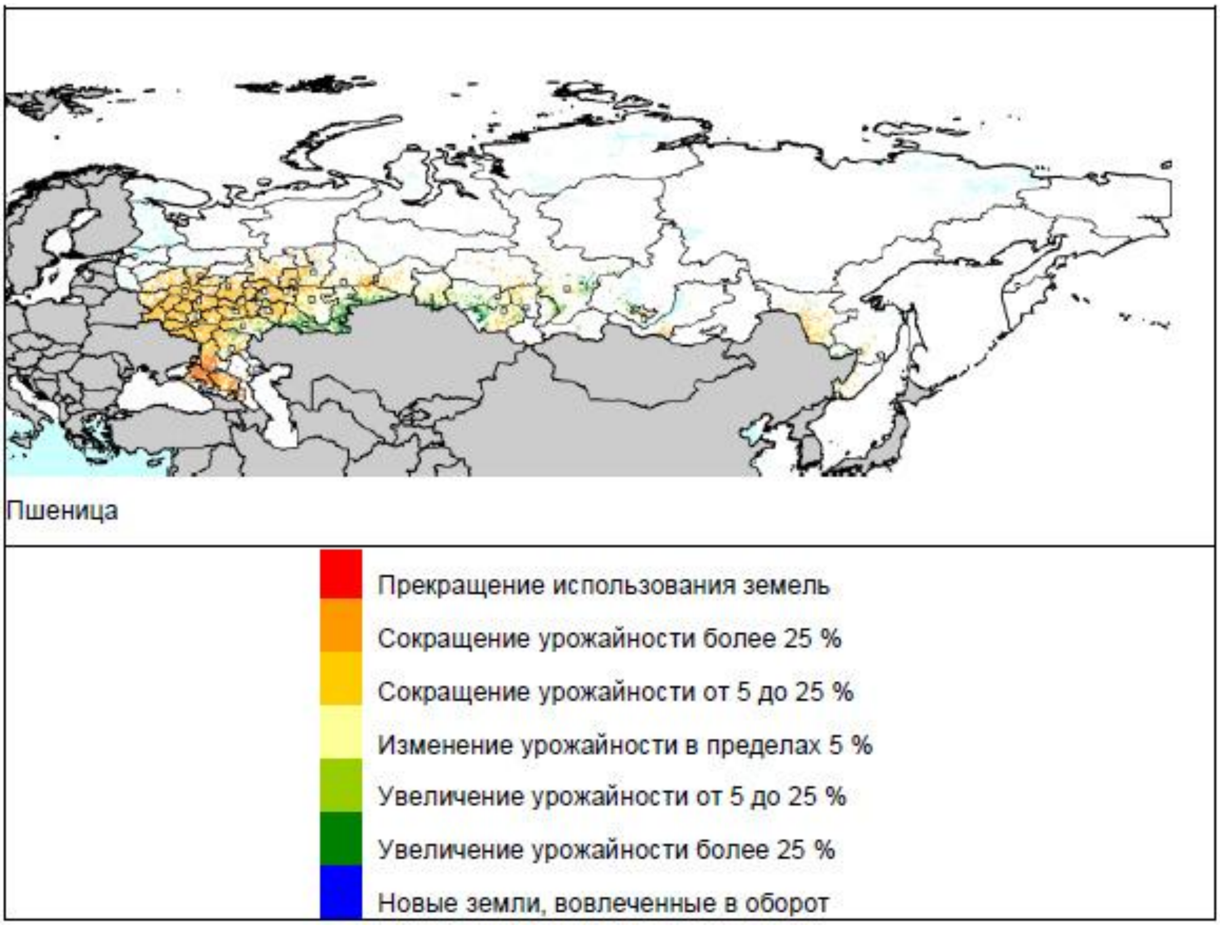
Source: Roshydromet (2005), page 53. Also based on Bobylev, S. *et al*. (2012), p. 23

International studies draw similarly pessimistic conclusions. Specifically, according to the International Food Policy Research Institute, climate change within the range of 2–4°C by 2100 (and this is quite optimistic!) will result in major harm for global agriculture. Wheat yield is projected to decline by 1.3–9 per cent by 2030, 4.2–12 per cent by 2050, and 14.3–29 per cent by 2080.[6]

Such a large-scale decrease in grain crop yield in the world would inevitably fuel grain price hikes and cause an aggravation in the problem of food security in various regions all over the world. The economic outcome of such changes is a topic that warrants a separate study. We will, however, discuss the issue of the effect of climate-related agricultural crises on prices.

Another key aspect is the geographical peculiarities of climate-related changes in agricultural production in Russia. The International Food Policy Research Institute, using its own research, provided an assessment of changes in Russia’s wheat yield (and some other crops) by 2050 compared to 2000 (see Figure 1.3).

Figure 1.3. Yield change map for rain-fed crops in 2050 compared with 2000, under climate change scenario A1B based on GCM of the Center of Climate System Research, Japan



Source: Bobylev *et al*. (2012), page 22, based on IFPRI materials.

Translation of key:

Baseline area lost
Yield lost more than 25% of baseline
Yield lost 5% to 25% of baseline
Yield change within 5% of baseline
Yield gain 5% to 25% of baseline
Yield gain more than 25% of baseline
New area gained

The following conclusions on the state of croplands in 2050 can be drawn, based on this data:

- A complete suspension of cropland use for growing wheat may take place in Russia’s southernmost regions.
- Extensive districts of the country’s south-western region will face a 25 per cent drop in crop yield.
- Crop yield will decline less than 25 per cent in different areas of the south of Russia’s European part, the southern Urals, and East and West Siberia.
- A 5–25 per cent rise in climate-related wheat yield can be seen in areas bordering on Kazakhstan and in the south of West Siberia.
- The phase-in of new croplands for agricultural production of wheat will be insignificant.

To sum up the ideas presented in this section, we can say that most Russian and international science and research institutes project a significant drop in grain harvests in the Russian Federation triggered by climate change. Quantitative estimates of the decrease will be used to analyse the economic loss in the following sections.

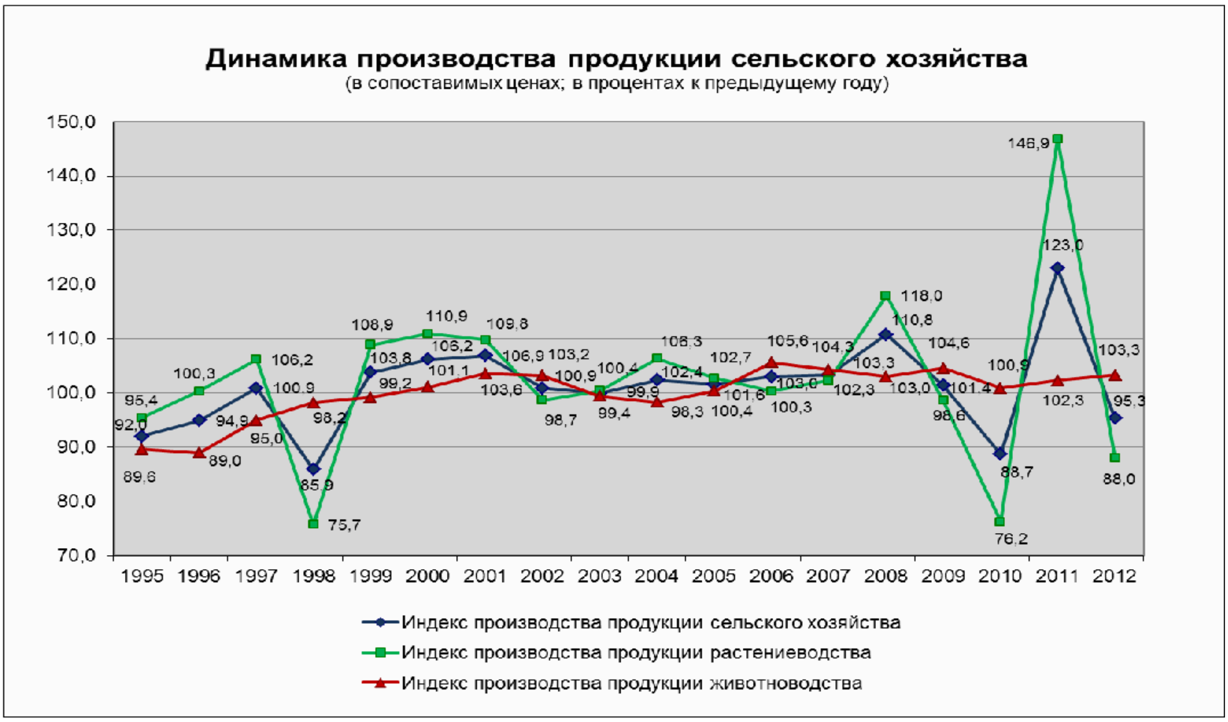
1.4. Impact on price metrics

Changes in grain production and supply on the grain market caused by climate change have a direct effect on grain prices. Domestic and global grain prices are undoubtedly affected by other factors as well, and to a different extent, but we are interested in pinpointing climate-related price fluctuations and determining the ‘climate’s contribution’ to price metrics.

Figure 1.4A shows the dynamics in the production of agricultural commodities in Russia on a like-for-like basis for 1995–2012. Notably, the years of severe droughts were characterized by bottomed-out crop production (at the same time, output in the animal husbandry sector remained nearly unchanged): in 2010, the production index slumped 24 per cent and in 2012, 12 per cent. As mentioned earlier, grain production shrank significantly more during these two years than crop production overall, since the industry’s losses were partly compensated for by the greater harvests of other cultures.

Figure 1.4B shows fluctuations in grain prices (wheat, barley, and rye) and wheat flour in Russia in 2000–2012. Notably, the droughts in 2010 and 2012 resulted in price spikes on the Russian market with a small lag of several months following the harvest period.

Figure 1.4A. Fluctuations in prices on agricultural commodities in Russia



Source: Rosstat’s website, section on agriculture, hunting, and forestry: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/enterprise/economy/# (accessed 20 February 2013).

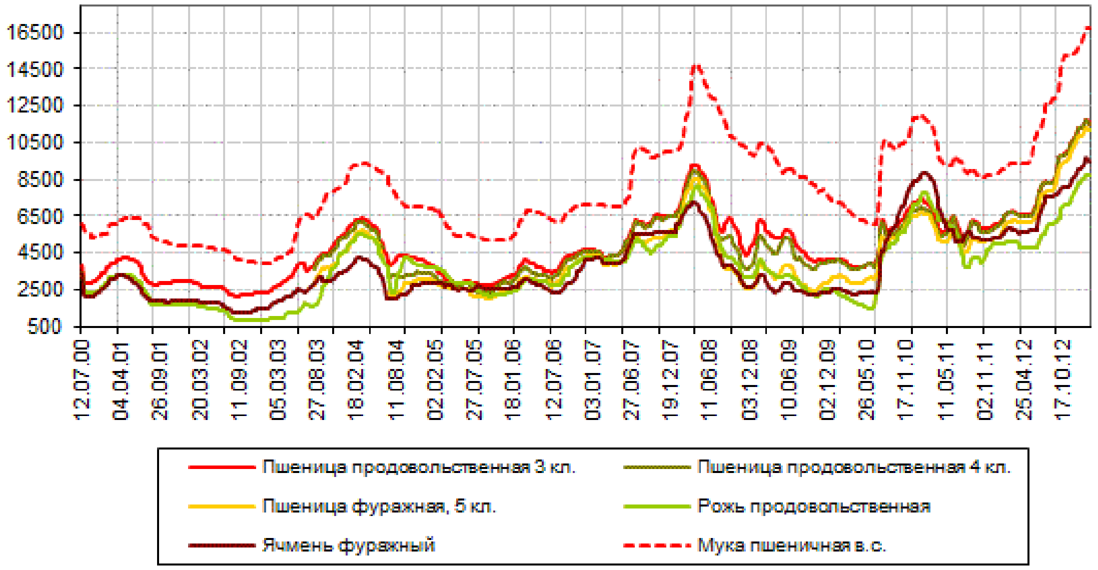
Translation of key:

Index of agricultural output production

Index of crop production

Index of animal industry output production

Figure 1.4B. Fluctuations in grain prices (wheat, barley, and rye) and wheat flour in Russia. (The index reflects the average asking price in the European part of Russia (EXW, RUB/ ton, including VAT)



Source: SovEcon, monitoring of Russian agricultural markets: http://www.sovecon.ru/prices/ (accessed 20 February 2013).

Translation of key:

Milling wheat, class 3

Feed wheat, class 5

Feed barley

Milling wheat, class 4

Milling rye

Wheat flour (extra quality)

According to SovEcon data, which are based on the monitoring of Russian agricultural markets, the drought in 2010 in the European part of Russia caused the following price increases:

- the price of wheat rose 2.2 times
- the price of rye rose nearly five times
- the price of feed barley rose 3.4 times
- the price of wheat flour rose 1.9 times.

Following the drought in 2012 and throughout the ensuing dwindling in grain yield:

- prices on milling wheat prices jumped 1.8 times
- prices on milling rye rose 1.9 times
- prices on feed barley rose 1.6 times
- prices on wheat flour rose 1.7 times.

(These figures are from the end of 2012, when the price increase was still in progress.)

Average country statistics reflect a slower rate of price increase. Table 1.4 features Rosstat data on prices of agricultural products in Russia from 2009–2012. It should be noted that the drought in 2010 caused prices of all main grain crops to rise significantly. The year-on-year price spikes ranged from 30 to 150 per cent. In 2012, the price of all grain crops, with the exception of buckwheat, continued to rise.

Could the drought alone be responsible for such sharp price spikes? Could this also be related to the situation on the global grain and food staples market? Is this perhaps not connected to climate change?

Table 1.4. Prices of agricultural products in Russia in 2009–2011 and in December 2012 (RUB/ ton)

	2009	**2010**	**2011**	**Dec 2012**
Grain and leguminous crops including:	**4,412**	**4,017**	**5,348**	**9,009**
wheat	4,260	3,867	5,108	8,875
rye	3,810	3,411	3,924	5,440
buckwheat	5,771	8,153	15,676	10,086
maize	4,361	4,681	5,917	7,697
barley	3,812	3,395	4,986	7,731
oat	3,957	3,596	4,495	5,504

Source: Rosstat (2013).

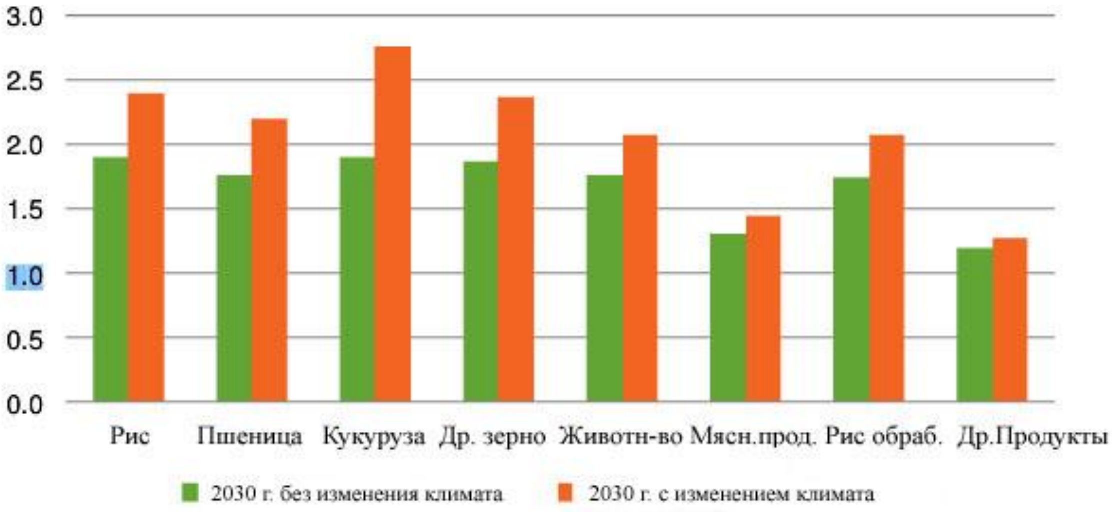
In this respect, 2010 is highly indicative of the overall situation. Using 2010 as an example, it is possible to illustrate global price shocks on the grain market triggered by climate factors. Severe drought in Russia and parts of the Ukraine and Kazakhstan put a dent in the production of all grain crops in 2010. Meanwhile, adverse growing conditions in the summer of 2010 affected US corn, while heavy rains in grain-producing areas in Canada and north-western Europe slashed the quality of much of the crop to feed grade. A drought and high temperatures associated with the La Niña weather pattern across Argentina in November 2010 reduced the yield of corn and soybean crops. Rains in Australia in late 2010 and early 2011 downgraded much of eastern Australia's wheat crop to feed quality. Due to weather-related production shortfalls, cereal stocks of the traditional developed country exporters are estimated to have fallen by nearly 25 per cent.[7]

With all of this in mind, climate change that is, by all appearances, global in nature triggered price shocks on the global grain and food staples market in 2010. This is especially significant for Russia, considering the country's ambitions with regard to hiking grain exports, on the one hand, and, on the other hand, Russia's potential dependency on food staples imports (for example, in the case of a series of years of poor harvests or droughts). Also, Russia's accession to the World Trade Organization (WTO) should also be factored in.

In this respect, it is interesting to see the results of studies featuring simulations of the impact of climate change on price fluctuations on the grain market. There are several leading international research centres that carry out this type of research.

According to a study conducted by the Institute of Development Studies at the University of Sussex in cooperation with Oxfam (Willenbockel, 2012), model calculations show that prices on grain crops and food staples will rise considerably as a result of a projected negative impact of climate change (see Figure 1.5). For grain cultures, the impact of the climate factor in the year 2030 is estimated as follows: 33 per cent for rice, 29 per cent for wheat, and 47 per cent for maize. These estimates are high, and they underline the vital role of climate factors for the global grain market.

Figure 1.5. Average price fluctuations on the grain and food staples market affected (orange) and not affected (green) by climate change by 2030 (2010=1.0)



Source: Willenbockel (2012), page 22.

Translation of key:

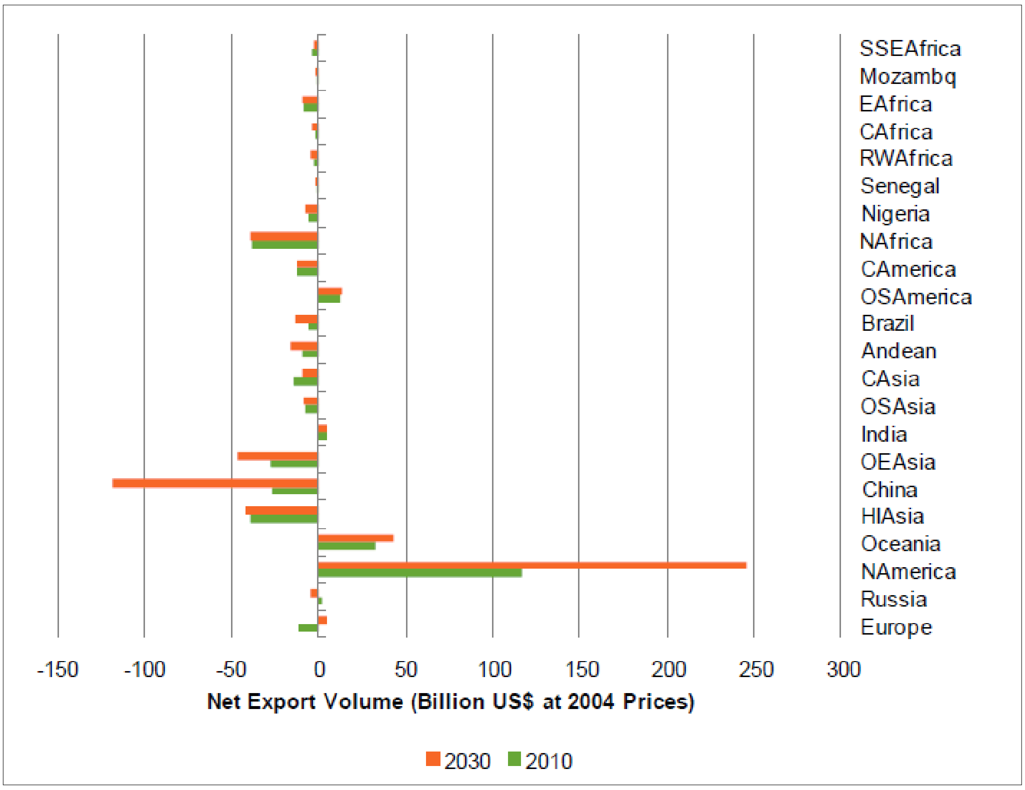
Rice
Wheat
Maize
Other crops
Animal husbandry
Meat production
Rice processing
Other products

Apart from general assessments, the study features models for the impact of climate change on different countries (see Figure 1.6). Based on the results of the study, the following conclusion can be drawn: in terms of price, net export/net import volumes of key grain crops will change considerably as a result of climate change. For major grain exporters — in countries and regions like North America and Asia — the increase is expected to reach 20 per cent or more.

The study shows that in Russia the tendency for wheat exporters to turn into wheat importers will increase between 2010 and 2030, and its net imports of wheat may reach $2bn–3bn (in 2004 prices). The net import of maize and rice is also likely to increase.

These findings are in sharp contrast to Russia's desire to become the world's largest grain and food staples exporter, and they call into question the country's ability to produce enough grain for domestic consumption and decrease its dependency on external food staples supplies.

Figure 1.6. Net export volume of wheat in 2030 (orange) and 2010 (green), $ (2004 prices)



Source: Willenbockel (2012), page 25.

One of the key conclusions of this section is that climate change is a factor that will contribute to considerable price growth on the grain market both in Russia and the rest of the world. The Russian agricultural products market, which has become more open after the country's accession to the WTO, will now become more sensitive to more prominent price changes on the global food staples market, which, in turn, will be affected by climate factors more and more.

Can these trends be ignored? What effect will price fluctuations have (or are already having) on Russia's agriculture and economy in general? Before answering these questions, we will turn our attention to the state of Russia's agricultural sector, including grain production.

1.5. State of the industry

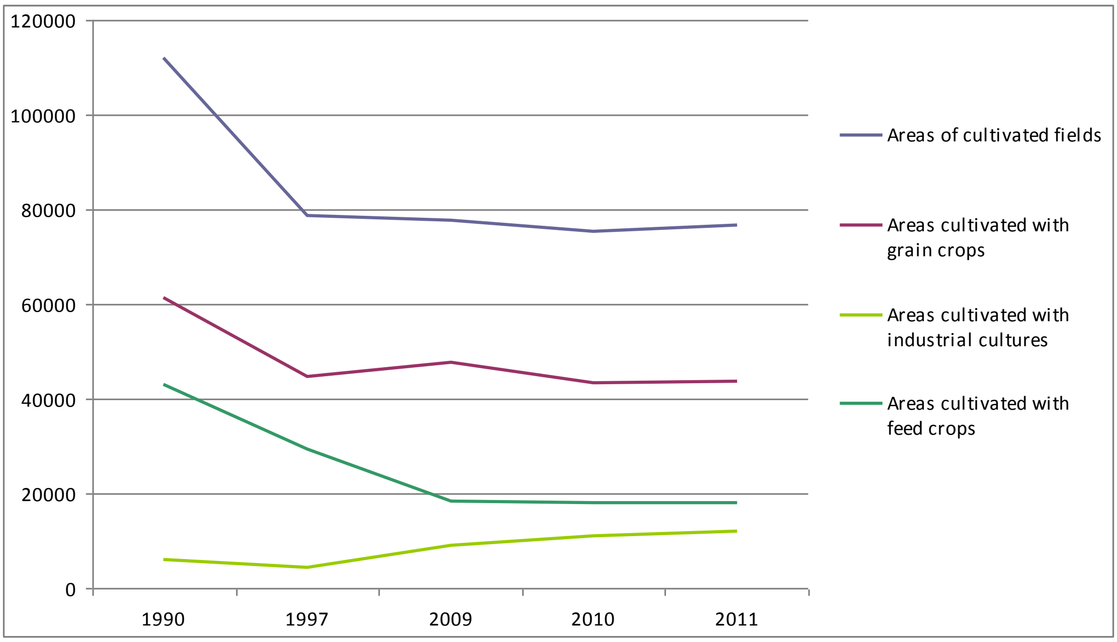
This report does not afford us the opportunity to conduct an in-depth analysis of the state of Russia's agriculture. It is vital, however, to have some idea of what is going on in this sector of the country's economy, to understand who climate change will affect in the near future, as well as what chances agricultural producers will have to overcome potential losses (or, in contrast, make a profit) from climate-related changes in crop yield and other metrics.

We will evaluate the state of grain crop production in Russia using several economic indicators.

The area of cultivated fields in Russia has shrunk by about one-third since 1990 (see Figure 1.7). At the same time, areas cultivated with grain crops have dropped by 29 per cent and account for 57 per cent of the total cultivated area. The area cultivated with feed crops has more than halved, and that of industrial cultures has nearly doubled. In recent years, the change in the total volume of cultivated land was insignificant. It should be noted that most cultivated lands not currently in use were affected by wind and water erosion, and have become overgrown and almost inaccessible due to destroyed surrounding infrastructure. Rehabilitating agricultural production on such lands would be complicated and require major investment – these lands comprise nearly 33.3 million hectares of formerly cultivated areas throughout Russia.

More than 6,000 big and medium-sized agricultural companies (according to Rosstat) are currently operating in Russia. Many of them produce various crops, including grain and leguminous crops. In 2009–2011, the number of such companies fell by 20 per cent. Table 1.5 shows some of the characteristics of the country's agricultural producers.

Figure 1.7. Dynamics of cultivated land in Russia (per 1,000 hectares), 1990–2011



Source: Rosstat (2013).

Table 1.5. Financial and economic metrics describing the state of big and medium-sized agricultural companies in Russia, 2009–2011

	2009	**2010**	**2011**
Total number of companies, per 1,000	7.5	6.9	6.0
Companies with overdue accounts payable, per 1,000	3	2	2
Total liabilities, RUB bn	991	1,113.5	1,252.6
Debt/equity ratio*	42.3	41.5	35.3

* Debt/equity ratio means the ratio of total liabilities of a business to its shareholders' equity.

Source: Rosstat, agriculture, hunting, and forestry section: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1140096652250.

One-third of all companies working in the agricultural sector are experiencing financial troubles and have overdue accounts payable. The total amount of overdue liabilities is constantly rising in this sector, and in 2011 it exceeded RUB 1.2 trillion. According to the Russian Grain Union, agricultural companies owed **RUB 1.7 trillion** (approximately $56bn) to their creditors at the beginning of 2013.

The debt/equity ratio of companies is rapidly shrinking, and in 2011 it equalled 35.3. This means that the proportion of equity in the companies' total financial resources is a mere 35 per cent! In a sector characterized by high financial risks (stemming from various, sometimes uncontrollable, factors), this means that the financial stability of Russian agricultural companies is pretty inadequate. Any price spikes, volatility, climate or other shocks present threats to the financial stability of such companies.

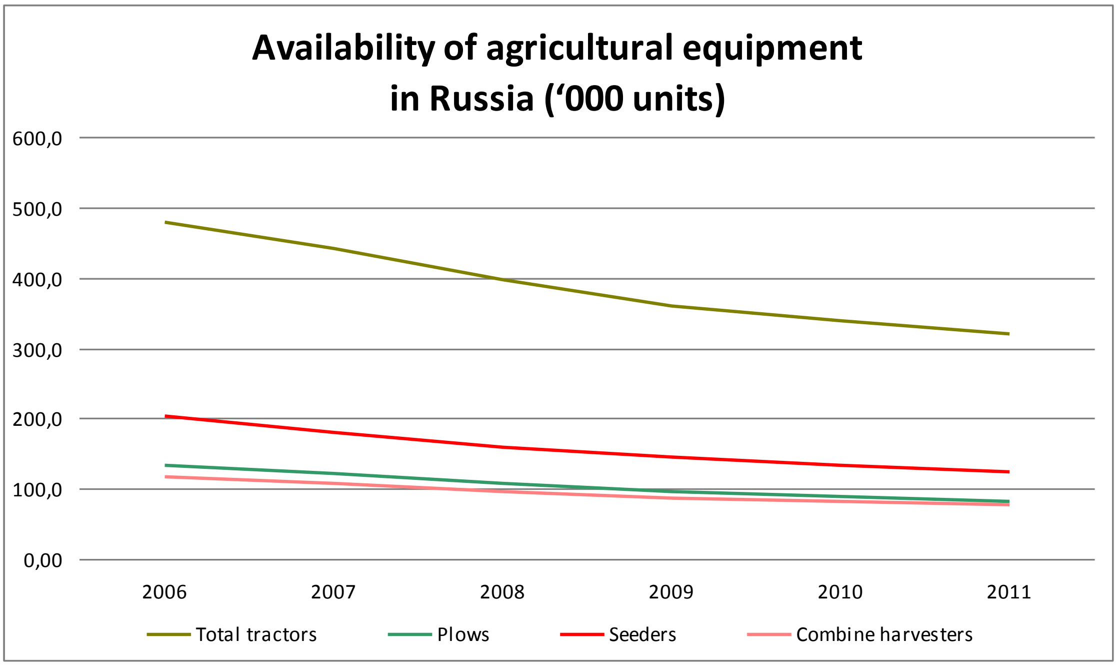
We can conclude that Russia's agriculture is **extremely** vulnerable financially and sensitive to any potential negative effects of climate change.

Another important indicator is the availability of equipment to agricultural companies. What technical equipment can help Russian agricultural companies withstand climate change?

Figure 1.8 shows the dynamics in the decrease in the total amount of agricultural equipment in the period from 2006–2011. Specifically, the total number of tractors dropped by 33 per cent, combine harvesters by 35 per cent, and seeders and ploughs by 62 per cent.

Unfortunately, any hopes of an active, ongoing process of replacing outdated equipment with new, more efficient equipment have been crushed by disheartening statistics. The phase-in period of new equipment is considerably lower than the retirement period of old equipment.

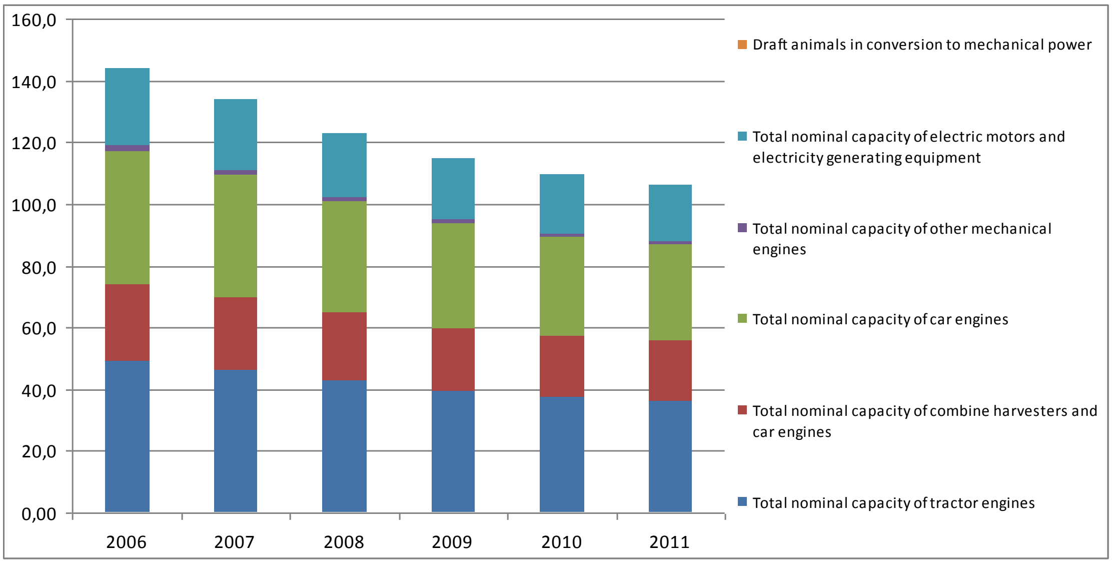
Figure 1.8. Availability of agricultural equipment in Russia (per 1,000 units) and dynamics in the total amount of agricultural equipment owned by companies in Russia in 2006–2011



Source: Rosstat (2013).

Negative dynamics can also be seen in the availability of power to agricultural producers. Figure 1.9 demonstrates the dynamics of this metric in 2006–2011.

Figure 1.9. Availability of power to agricultural companies in Russia (million horsepower), 2006–2011



Source: Rosstat (2013).

Over this period, the total power capacity of agricultural companies in Russia slumped by 26 per cent – meaning that in six years, a quarter of the total capacity in the agricultural sector was retired.

Power capacity declined quite evenly for all types of agricultural equipment: combine harvesters, machinery, cars, tractors, electric engines, and electricity generating equipment.

Therefore, agricultural companies are not only financially vulnerable, but are also poorly equipped to withstand the negative effects of climate change.

These metrics are crucial in analysing the stress resistance of companies and the agricultural sector in general. Let us illustrate this with an example.

Let us assume that climate change results not just in several one-year drought periods, as we saw in 2010 and 2012, but to a series of consecutive seasons (three to five years) with extremely unfavourable conditions for growing and harvesting grain crops. What would happen to Russian agricultural producers? How competitive would they be compared to foreign corporations?

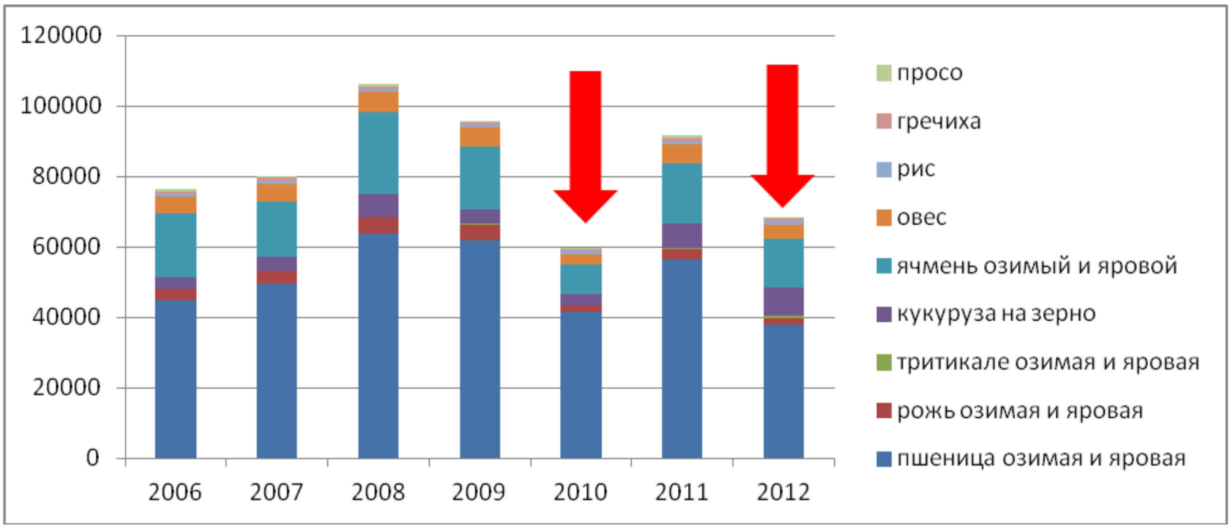
It is highly likely that due to a lack of financial resources, many companies would face bankruptcy and be forced to shut down. Meanwhile, experience shows that opportunities for hiking prices on their harvests (thus making end consumers compensate for companies' losses) are not infinite. In this case, it is unclear where the resources would be found to compensate for losses: should it be government (that is, taxpayer) funds or insurance funds? Have such matters really been put under the microscope in Russia? It is most likely that for now agricultural producers will have to rely entirely on themselves.

On the other hand, companies would not be able to use favourable weather conditions to their advantage if they are poorly equipped. With this in mind, there are certain limitations in the possibility of hedging risks against 'bad' seasons through 'favourable' years in terms of the climate.

1.6. Integrated economic assessment

First, let us analyse the effect of climate and weather events that have taken place in recent years, specifically the droughts of 2010 and 2012. We will assess the economic effects solely from the decrease in grain crop production in these years (see Figure 1.10), as a kind of resulting metric, but in our analysis we will not consider the effect on infrastructure, transportation systems, storage, grain processing, and other aspects, though we will factor in changes in grain prices (see Figure 1.11).

Figure 1.10. Gross grain crop yield in Russia, per 1,000 tons

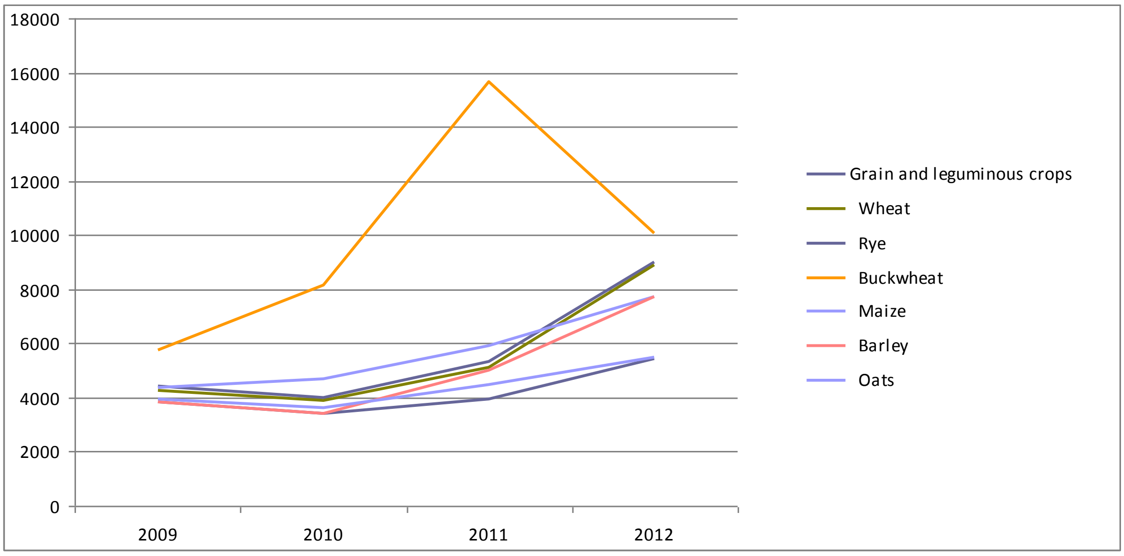


Source: Rosstat (2013).

Translation of key:

Millet
Buckwheat
Rice
Oats
Winter and spring barley
Grain maize
Winter and spring triticale
Winter and spring rye
Winter and spring wheat

Figure 1.11. Grain crop prices in Russia, RUB/ ton



Source: Rosstat (2013).

According to official Rosstat data on grain prices, the assessment of economic loss showed the following (see Table 1.6):

- In **2010**, the total loss from the drought exceeded 30m tons of grain crops (weight before processing) compared to the average metrics in 2006–2009. Economic losses are estimated at over **RUB 113.2bn** (approximately **$3.7bn** based on the current exchange rate).
- In 2012, the total loss equalled nearly 20m tons of grain crops (compared to the average metrics in 2006–2009 and 2011). Yet, due to a price spike, economic losses exceeded **RUB 182.3bn** (approximately **$6bn**).

Meanwhile, there are other metrics contributing to total economic losses. Specifically, the effects felt most by consumers (the country's population) were spikes in grain prices and products made from grain.

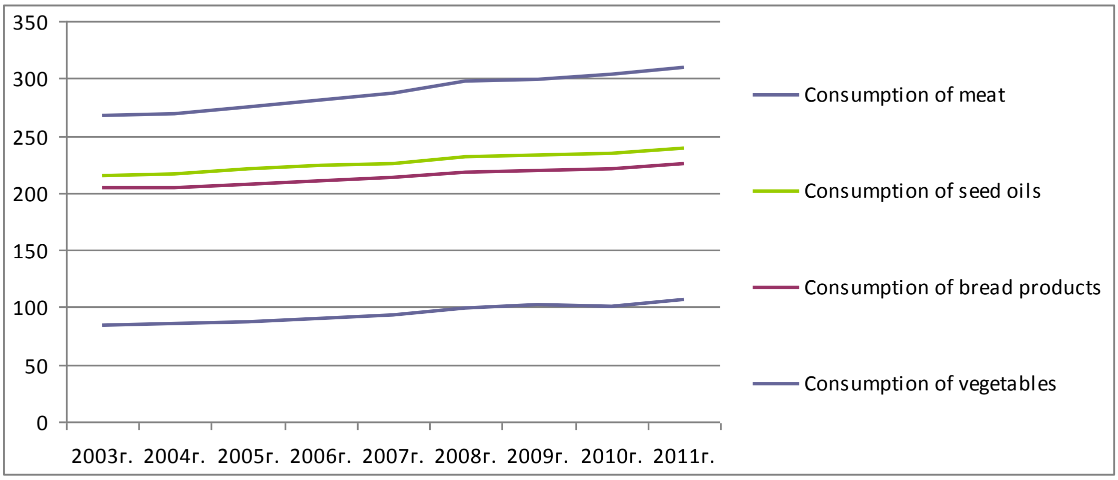
Table 1.6. Assessment of economic loss from droughts in 2010 and 2012 for grain crop production in Russia

Crop	Average yield in 2006–2009, per 1,000 tons	Drop in yield in 2010 compared to average metrics in 2006–2009, per 1,000 tons	Average price in 2010, RUB/ ton	Losses from failed harvest in 2010, RUB million	Average yield in 2006–2009 and 2011, per 1,000 tons	Drop in yield in 2012 compared to average metrics in 2006–2009 and 2011, per 1,000 tons	Price in December 2012, RUB/ ton	Losses from failed harvest in 2012, RUB million
Wheat	54,950	13,442	3,867	51,982	55,208	17,491	8,875	155,236
Rye	3,927	2,291	3,411	7,815	3,736	1,603	5,440	8,719
Maize	4,489	1,404	4,681	6,573	4,983	-3,011	7,697	-23,172
Barley	18,656	10,306	3,395	34,989	18,313	4,373	7,731	33,809
Oats	5,370	2,150	3,596	7,733	5,362	1,336	5,504	7,351
Buckwheat	839	500	8,153	4,078	832	35	10,086	355
Total				**113,170**				**182,298**

Source: Assessment of losses, using Rosstat data, by the authors.

Based on Figure 1.12, consumption of bread products in Russia is high – over 200 kilograms per person per year – and it is gradually rising, despite price spikes and other factors (such increases in incomes, etc.).

Figure 1.12. Consumption of different food products by the Russian population, kilogram per person per year

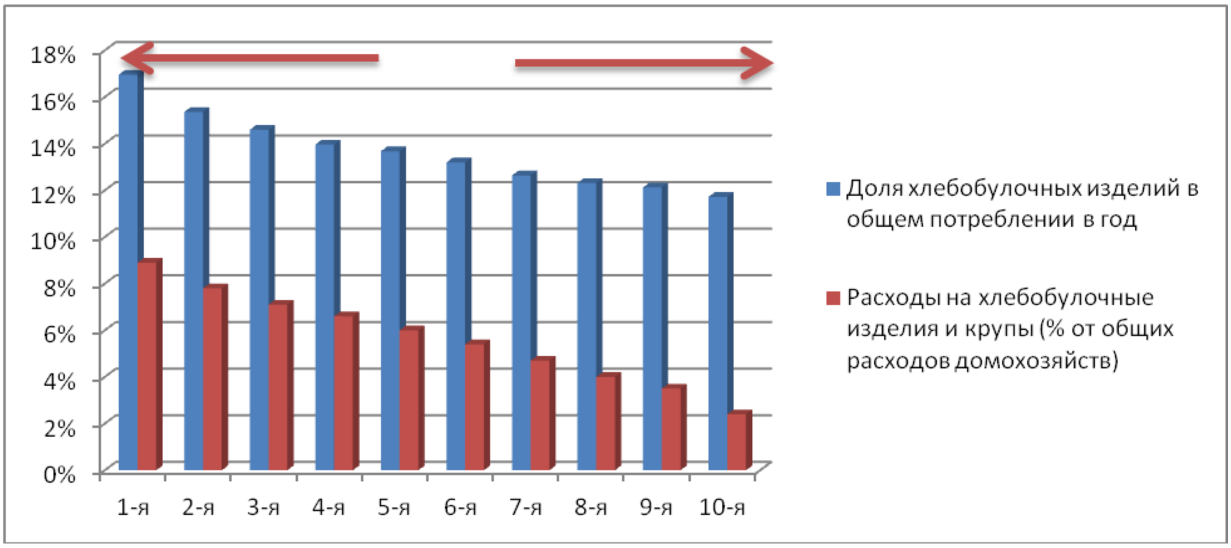


Source: Rosstat (2013).

In other words, flexibility in the consumption bread products in relation to prices is very low, meaning that bread consumption will remain high even if prices go up considerably. Taking into account grain price spikes caused by poor harvests in 2010 and 2012, it becomes obvious that the population was forced to bear high additional expenses (incurred losses).

Meanwhile, Russia's most vulnerable populations are still the main consumers of bread products (see Figure 1.13). According to Rosstat, in 2011, spending on bread in 10 per cent of the poorest households stood at 8.9 per cent of the total spend on food products, whereas bread products accounted for just 2.4 per cent of the total spend for 10 per cent of the most affluent Russians. The share of bread products in the diets of the poorest Russians stood at 17 per cent and at 12 per cent for the most affluent. This leads us to conclude that price spikes in bread products as a result of droughts and other extreme weather events hit the most vulnerable populations the hardest. When this is taken into consideration, shortfalls in policy on adapting to climate change could also create losses for the most vulnerable populations and lead to greater social discontent.

Figure 1.13. Consumption of bread products by Russians in 2011: the share in total annual consumption and the share in household spend on food products, with breakdown by decile groups



Source: Rosstat (2013).

Translation of key:

Share of bread products in total annual consumption

Expenses on bread products and cereals ($ of total household expenses)

Clearly, we cannot attribute all price fluctuations to poor grain harvests alone, but the scale of such losses for the population is quite interesting:

- In **2010**, an increase in grain prices resulted in additional expenses for the population totalling **RUB 80bn** (approx. **$2.6bn**).
- In **2012**, additional expenses for the population equalled **RUB 196bn** (approx. **$6.3bn**).

Clearly, these enormous additional expenses become the earnings of agricultural companies that are able to cover their losses from poor grain crop harvests during drought years. The government is able to compensate for some of these additional expenses through social support measures, price regulations on bread, provision of loans and subsidies to agricultural producers, etc. However, the losses are great, and most of them end up becoming a burden on Russian consumers.

Is it fair to say that poor harvests in 2010 and 2012 are accidents that we are unlikely to occur in the future? Or can it be said that Russian agricultural producers will adapt easily and without major expenses to changing weather conditions? Our analysis shows that the answer to both of these questions is negative.

We can assess potential future losses from a decline in crop yield based on available data. Such an assessment is complicated by a lack of reliable grain price forecasts until 2050, but certain estimates can be given:

- By **2020**, losses from a decline in climate-related crop yield will amount to **RUB 108bn** (in 2012 prices) or $3.5bn.[8]
- By **2050**, based on the aridization scenario, losses from a decline in climate-related crop yield will amount to **RUB 120bn** (approximately $3.9bn) in 2012 prices.[9]

For a more thorough assessment of losses we would need to carry out additional research, do model calculations, analyse risks, determine probable losses not only in agricultural production, but also in the transportation and processing industry, storage, product distribution, etc. These are topics for specialist research.

Based on materials presented in this report, however, we can conclude that the scale of the effect of climate change on agriculture is massive. Risks for producers and consumers of agricultural products are high and will continue to increase as weather and climate conditions deteriorate. At this time, the industry is not fully prepared to withstand and adapt to climate change.

Losses for the economy in general include not only losses from lower crop yield, but also price spikes on agricultural products. Both agricultural producers and consumers are incurring losses.

This calls for adaptation measures that are systematic and comprehensive in nature, including regional measures to curb risks and damages from climate change, and the adaptation of the agricultural sector to changing climate and weather conditions.

The droughts and subsequent great losses – which exceeded **RUB 300bn** (approximately $10bn – of 2010 and 2012 are a clear sign that immediate measures must be taken to minimize similar losses in the future. (See Section 3 for more on possible adaptation measures to climate change.)

2. ANALYSIS OF THE EFFECT OF CLIMATE CHANGE ON THE AGRO-INDUSTRIAL SECTOR IN RUSSIA'S REGIONS

2.1. Case study 1: The Altai region

The Altai region is one of the top grain-producing regions in Russia. Its total area of cultivated land amounts to 5.4 million hectares, 3.5 million hectares of which are designated for grain and leguminous crops, including maize (see Table 2.1). The gross grain yield average for the period 2006–2010 is 4.4 million tons per year.

The Altai region is witnessing significant climate changes. At the Barnaul weather station, the oldest weather station in Russia, regular measurements of climatic parameters are carried out. Over the period 1838–2008, the average annual temperature increased by more than 3°C. That is four times higher than the global temperature increase (0.74°C), according to data from the IPCC.

It has been noted that the warming is mostly characteristic for winter and spring. Long-term trends are observed against the background of small-scale digressions of both positive and negative signs that possess a cyclical (rhythmic) character. The possibility of late spring frosts and early autumn with ascendant, extreme variability remains. In recent years, the frequency of very low absolute minimum air temperatures has been increasing. There has also been an increase in inter-annual variability (contrast) of seasons.

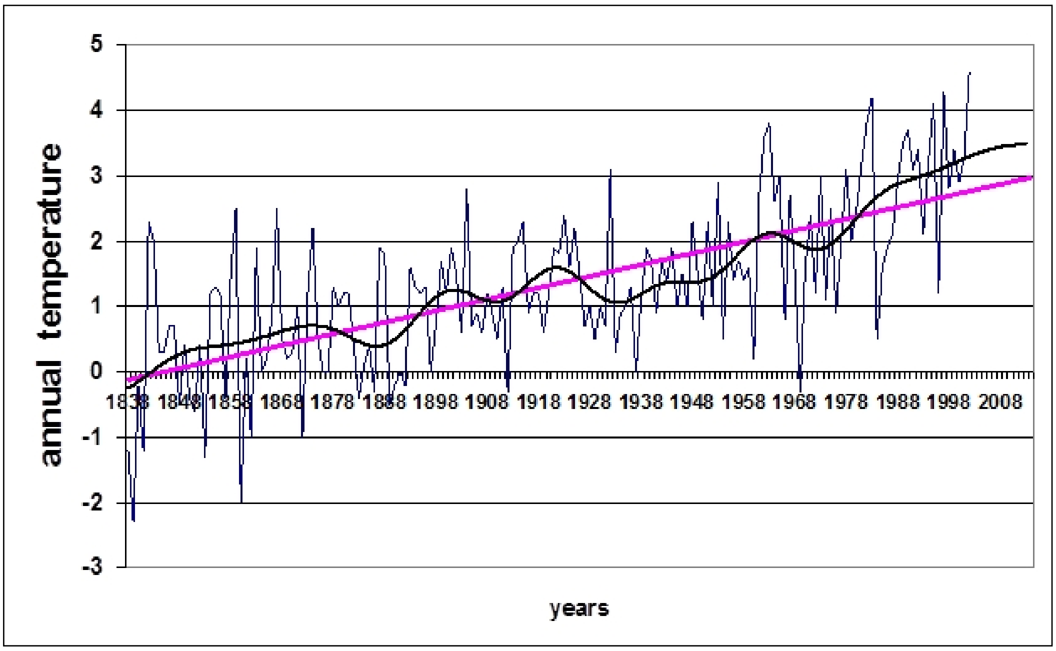
Data illustrating the tendency of relevant climatic parameters (the average annual temperature and precipitation) in the region are shown in Figures 2.1 and 2.2.

Table 2.1. Cultivated area of all categories of crops in the Altai region (per 1,000 hectares)

	Total area of cultivated land		**Grains and leguminous plants, including maize**		**Winter and spring wheat**		**Winter rye and spring crop**		**Grain maize**	
	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011
Altai region	5,449.9	99.0	3,539.2	9.5	2,040.3	87.4	35.5	118.0	0.5	80.6
Russian Federation	76,308.2	99.5	4,4428.8	102.0	24,682.4	96.6	1,558.9	100.5	2,055.2	119.8

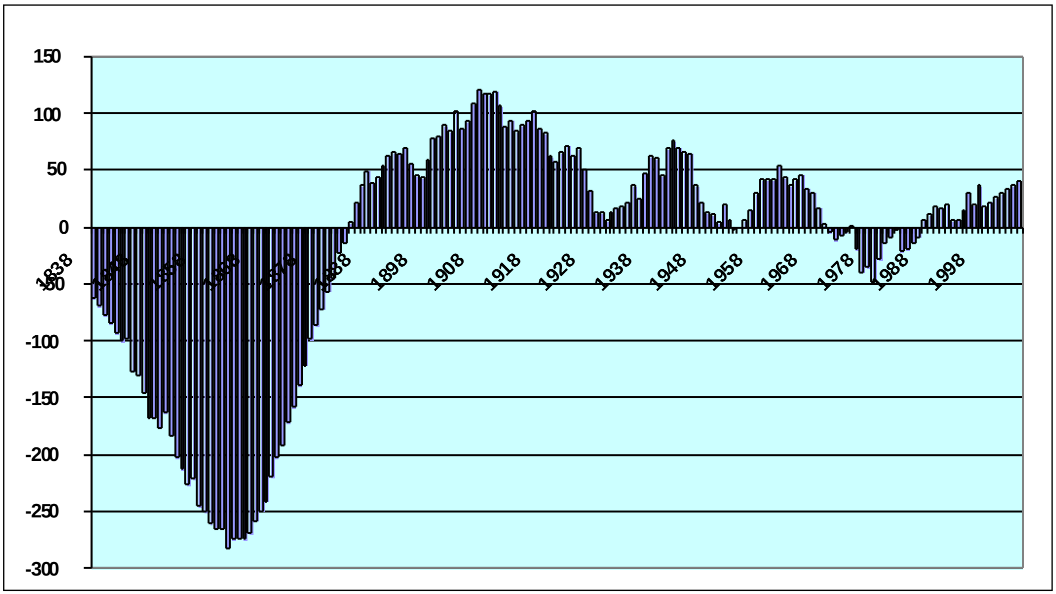
Source: Rosstat (2013).

Figure 2.1. Changes in average annual air temperature (in degrees Celsius), Barnaul weather station. Linear trend and deviations from the annual average.



Source: N.F. Kharlamova, Altai State University.

Figure 2.2. Deviation of annual rainfall from the average rate for 1961-1990, subdued 11-year moving filter



Source: N.F. Kharlamova, Altai State University.

Key:

Y axis: Anomalies in precipitation, mm

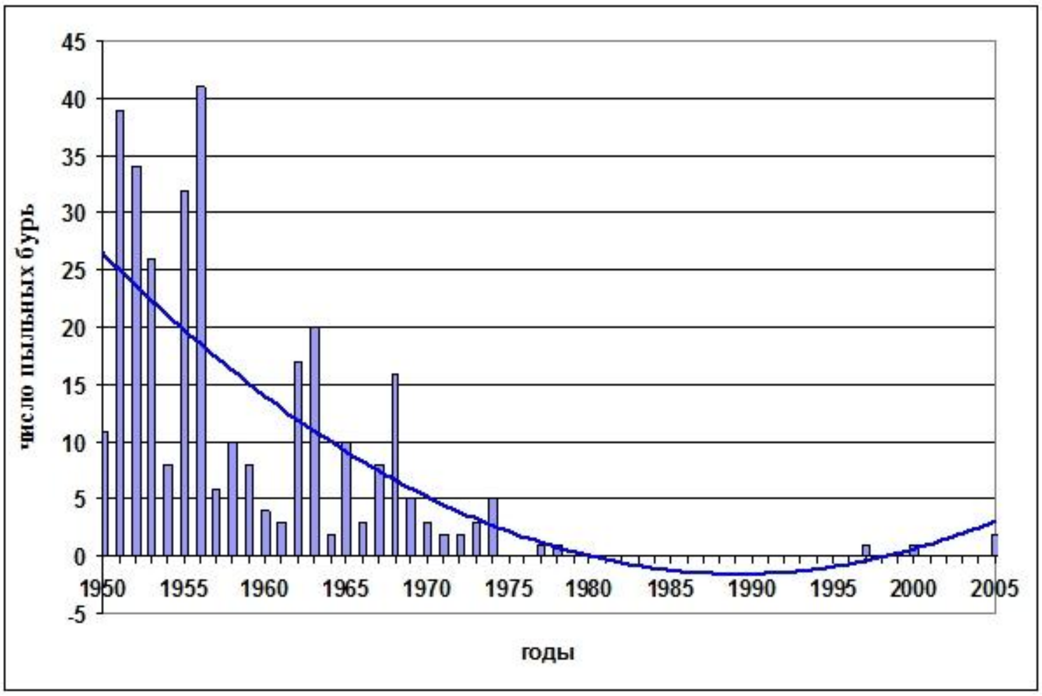
X axis: Years

According to the results of research done by the Altai State University (ASU), there is a general tendency for aridization in the territory of the Altai-Sayan Ecoregion, against a background of warming, which may not only continue, but also intensify in the next few decades. On top of that, particular importance is attached, above all, to the ratio of heat and moisture in the territory. Since the late 1970s, an almost universal increase in precipitation has been observed within the region, although it is not analogous to an ‘increase in moisture’. Only the ratio of the balance of heat and moisture can predetermine the conditions for the growth of vegetation and the dynamics of other components.

The repurification of sand as a result of wind movements and of ‘special processes of drying and decondensing the surface cover’ also reveals an escalation in the daily range of the temperature in conditions of drier air, contributing to the activation of processes of weathering, etc.

One extremely dangerous phenomenon connected with climate change in this regard is the aggravated situation regarding ‘black storms’ in the steppe and farmlands of the Altai region (see Figures 2.3 and 2.4). From 1963–1965, more than 1 million hectares of eroded land in the Altai region was taken out of economic circulation. In 1960–1970, a set of measures aimed at soil conservation was implemented, including the establishment of plantations and shelter belts, tillage, soil-protecting crop rotation, crop lane placement, mulch with straw, and so on. However, the problem of black storms that was resolved in the 1960s and 1970s is now reappearing. Black storms were recorded in the Altai region in the mid-1990s and the 2000s. The phenomenon poses a serious threat to agriculture in the region. In fact, there are already ongoing processes involving the complete loss of topsoil, which threatens the long-term sustainability of agricultural production in the region.

Figure 2.3. Polynomial trend in the number of days with dust storms, 1950–2005



Source: N.F. Kharlamova, Altai State University.

Key:

Y axis: Number of dust storms

X axis: Years

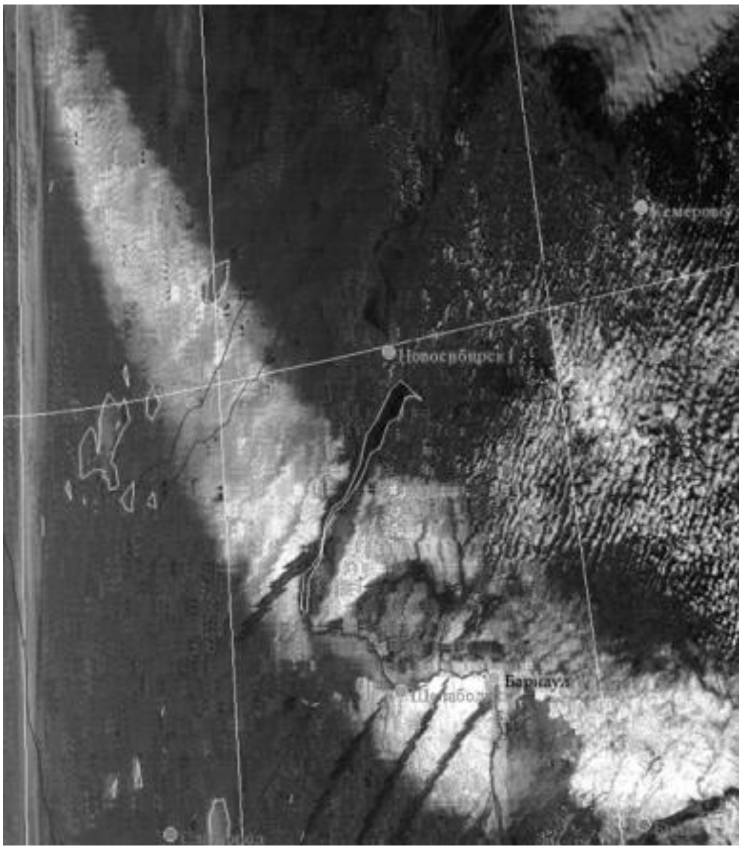
Figure 2.4. An illustration of a dust storm blowing in the Kulundinsky district, Altai, 1963

Source: Barnaul Local History Museum.

Also of great importance for the agro-industrial areas of the Altai region are the more prominent effects of climate change: the emergence of snow ‘trawl lines’ that are uncharacteristic for warm seasons, leading to the death of trees and agricultural crops (see Figure 2.5). This broad band of snowfall is most dangerous during the growing season or at harvest time. Not only is the ripening process disrupted but there is the possibility of subsequent crop failure or a deterioration of the plants' quality. In addition there are also problems associated with the harvest, transportation, production, storage, processing, etc. Such bristling weather and climate phenomena are not uncommon in West Siberia. However, it is difficult – if not nearly impossible – to predict and, more importantly, to protect crops from such events.

One of the most promising solutions to this problem is the modernization, reconstruction, and creation of new forest belts on farmland. However, over the past 20 years, the area of forest belts has decreased by approximately half, to 70,000 hectares, and the quality of the forest belts has deteriorated (see Figure 2.6). This is connected with the ageing of wooded areas and absent owners of forested areas, resulting in tree plantations simply being destroyed and falling victim to agricultural burning.

Figure 2.5. Satellite image of a snow band from 27 September 2004 in the Altai and neighbouring regions



Source: Prof. M.Shishin, Altai State Technical University (2012)

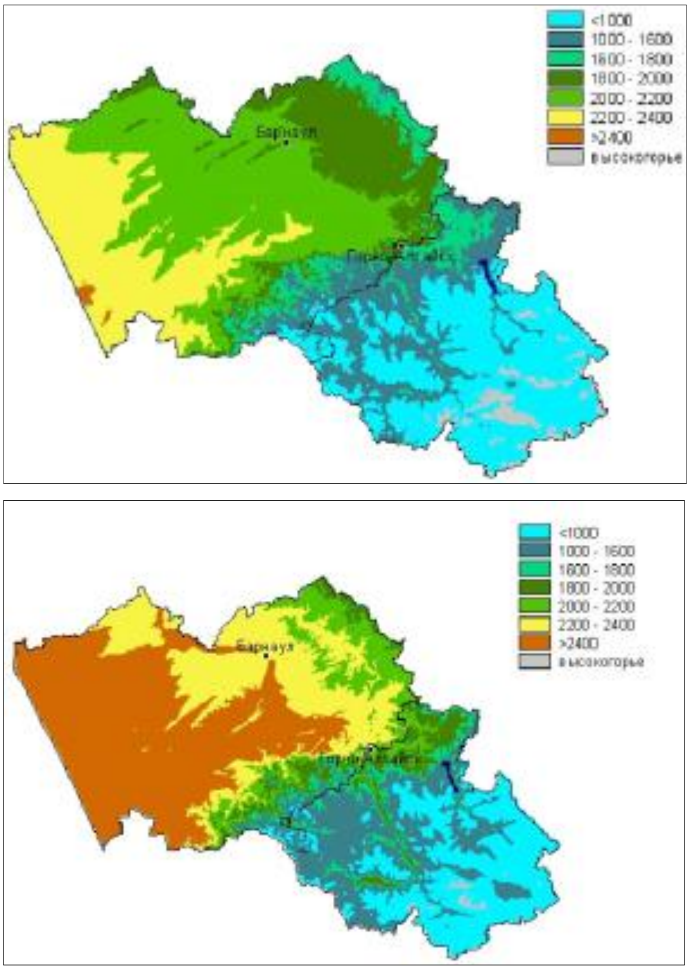
Figure 2.6. Failing afforestation belts in the Altai region

Source: Photo by the authors.

In 2012, at the initiative of the Altai region's governor, an inventory of the remaining forest belt area was conducted. The survey of a total of 74.3 thousand hectares of forest belts found that 57 per cent of forest plantations had reached a critical age and required either reconstruction or restoration. According to experts, it is crucial to create and restore more than 100 hectares of forest belts in the region, a move that would ensure the protection of 3.3 million hectares of agricultural land that is subject to long-term desertification, mainly in the steppe zone of the region. To this end, a regional programme was developed for the creation and reconstruction of field-protective forest ranges; it is expected to cost about RUB 6bn.

Projections of climate change (see Figure 2.7) conducted by ASU show that a further increase in temperature – even by a mere 1°C – would make more than half of the Altai region (the steppe, farmlands) subject to highly unfavourable thermal conditions (the sum of annual temperatures above +10°C is currently more than 2,400). Clearly, if the temperature in the region climbs 2.4°C by 2040 and 5.1°C by 2060, as the Voeinkov Main Geophysical Observatory predicts (see Figure 1.6), the consequences for agriculture in the Altai region would be catastrophic.

Figure 2.7. Thermal conditions (the sum of temperatures above +10 °C): Current (top) and after a 1°C increase in temperature (bottom) in the Altai region and the Altai republic[10]



Source: N.F. Kharlamova, Altai State University.

According to available data, it is estimated that the economic damage to agriculture in the arid region of Altai in 2012 will primarily affect the grain harvest. In September 2012 the decrease in the grain yield was expected to amount to approximately 20 per cent of that for 2011 year[11] – it actually amounted to 36 per cent.[12]

The increase in prices for grains in the Altai region for 2012 amounted to 80.9 per cent (according to the regional Rosstat branch). On top of that, the regional monoculture – wheat – became more expensive over the year, to RUB 9,134 per ton, an increase of 96.8 per cent. The price of rye for the period grew to RUB 8,298 per ton, a 46.1 per cent increase. The price of millet climbed 28.7 per cent to RUB 7,000, barley by 71.4 per cent to RUB 9,288, oats by 68.4 per cent to RUB 7,276, and peas by 45.5 per cent to RUB 9744. The price of sunflower seeds increased by 50.1 per cent to RUB 15,077 per ton, and soy beans by 38.3 per cent to RUB 16,949 per ton.

The only grain crop to show a decrease in price in 2012 was buckwheat. The market for buckwheat in Altai, the main producer of this crop in Russia, continues to endure a period of ‘rollback’ from soaring prices seen during the 2011 crisis. In 2012, the price of buckwheat in the Altai region fell 28.7 per cent to RUB 9,734 per ton.

In value terms, the climate-induced reduction of the grain harvest in 2012 (compared to the average data for 2006–2010) can be estimated at RUB 17bn or $0.6bn.[13]

2.2. Case study 2: Voronezh region

The Voronezh region is one of the largest constitutional entities of the Russian Federation in terms of territory, population, and also economic potential within the Central Federal District. The region lies in the geographic centre of European Russia, along the transition between forest-steppe and steppe zones.

Voronezh is one of the 10 leading producers of staple grains. Its cultivated area consists of 76.3 million hectares, of which 44.4 million are used for the production of grain and legume cultures, including maize (see Table 2.2).

Table 2.2. Cultivated agricultural areas in all categories in Voronezh Oblast (thousands of hectares)

	Total area of cultivated land		**including:**							
			Grains and leguminous plants, including maize		**from them:**					
					Winter and spring wheat		**Winter and spring rye**		**Grain maize**	
	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011	2012	2012 in % to 2011
Voronezh region	2,492.0	100.7	1,383.6	105.4	622.8	113.5	32.8	125.0	126.7	96.1
Russian Federation	76,308.2	99.5	44,428.8	102.0	24,682.4	96.6	1,558.9	100.5	2,055.2	119.8

Source: Rosstat (2013).

The climate of the Voronezh region is moderate and continental, with a comparatively hot and dry summer and relatively cold winter. The approximate average yearly air temperature in the north of the region is in the range of 4.6°C–5.6°C, and in the south of the region is 6.9°C–7.0°C. In individual years, atmospheric peculiarities can result in a divergence of plus or minus 2°C–3°C from the norm.

The average long-term annual air temperature in the city of Voronezh in the period of 1949–1999 was 6.0°C.

Research by V.A. Dmitrieva at Voronezh State University shows that in the period 1949–1999 (see Table 2.3), the average annual air temperature in the city of Voronezh climbed by 1.0 C (indicated by the yellow line in Figure 2.8), which significantly exceeds the global temperature rise. The average annual temperature in 2001–2012 was 7.6°C (see Table 2.4), which testifies to the continuation of the rising trend and even an acceleration of the temperature rise.

Table 2.3. Air temperature at Voronezh Weather Station, 1949–1999

Средняя месячная температура воздуха, °C													
Период	1	2	3	4	5	6	7	8	9	10	11	12	Год
1949-59	-8,8	-9,8	-4,5	6,8	14,5	18,7	19,8	18,7	12,8	5,7	-2,1	-5,7	5,5
1960-69	-9,8	-8,7	-3,2	7,1	14,6	17,9	19,8	18,5	12,9	6,5	-0,2	-5,3	5,9
1970-79	-9,6	-7,8	-1,7	8,2	14,1	18,3	19,6	18,4	12,8	5,1	0,6	-5,2	6,2
1980-89	-7,2	-8,5	-2,4	7,4	15,0	18,7	19,6	18,4	12,9	6,2	-1,5	-4,6	6,1
1990-99	-5,7	-5,6	-1,1	8,0	14,3	18,7	20,1	18,4	12,6	6,6	-1,6	-6,1	6,5
Средняя	-8,2	-8,1	-2,3	7,5	14,5	18,5	19,8	18,5	12,8	6,0	-1,0	-5,4	6,0

Source: V.A. Dmitrieva, Voronezh State University.

Translation:

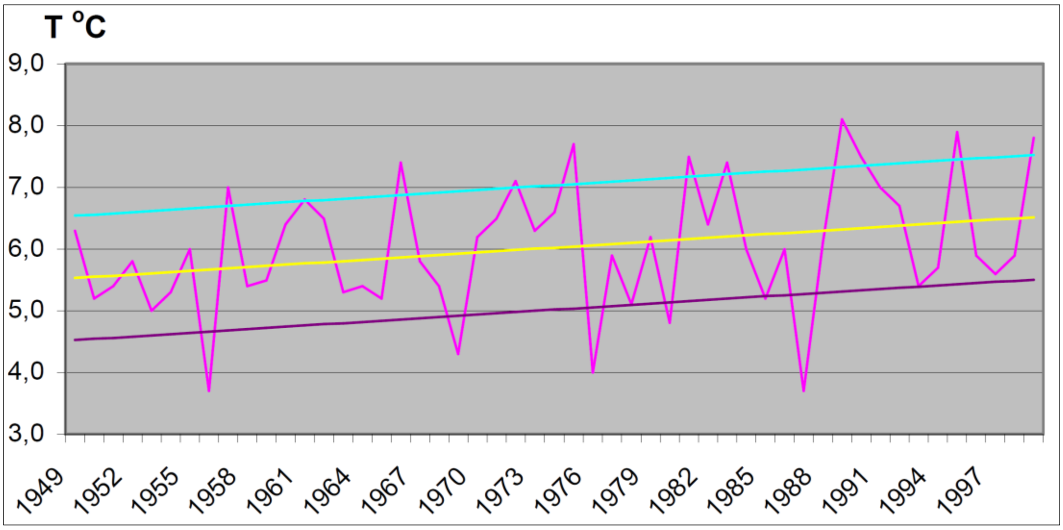
Average monthly temperature, C

Period (Период)

Year (Год)

Average (Средняя)

Figure 2.8. Average annual air temperature in the city of Voronezh, 1949–1999



Source: V.A. Dmitrieva, Voronezh State University.

Key:

Yellow line: The linear trend of temperate growth over the period of 1949-1999

Blue line: Upper level of assumed deviation of temperature trend (+1 C to linear trend) over the period of 1949-1999

Purple line: Lower level of assumed deviation of temperature trend (-1 C of linear trend) over the period of 1949-1999

Table 2.4. Air temperature at Voronezh weather station, 2001–2012

Average Monthly Air Temperature, °C													
Period	1	2	3	4	5	6	7	8	9	10	11	12	Year
2001	–2.4	–4.9	–0.2	11.1	14.0	16.8	24.1	20.1	13.3	5.6	1.4	–10.0	7.4
2002	–5.7	0.6	4.2	9.0	14.5	18.0	23.9	19.3	14.4	5.8	1.0	–11.7	7.8
2003	–6.2	–9.9	–3.6	6.1	16.8	15.0	20.2	18.7	12.7	6.8	1.6	–2.5	6.3
2004	–3.8	–4.9	2.3	7.1	13.5	16.8	19.1	20.0	14.1	7.4	0.7	–2.5	7.5
2005	–2.2	–8.5	–5.1	9.0	17.3	17.3	20.0	19.7	15.2	7.9	1.7	–2.9	7.5
2006	–11.4	–12.3	–2.8	8.1	14.6	19.9	18.9	20.9	14.4	8.4	1.5	0.6	6.7
2007	0.1	–7.6	3.8	7.1	17.0	19.2	21.0	22.4	14.1	8.5	–1.1	–4.2	8.4
2008	–8.5	–2.8	4.0	11.2	13.7	17.3	21.2	21.1	13.1	9.7	2.7	–3.3	8.3
2009	–5.4	–4.4	–0.2	7.4	14.6	20.2	21.6	17.5	16.6	8.8	2.8	–5.4	7.8
2010	–14.8	–6.4	–1.3	9.4	17.3	22.4	26.4	25.5	14.6	5.1	5.9	–3.3	8.4
2011	–8.7	–11.9	–3.3	7.3	17.3	20.6	23.7	20.2	14.0	7.0	–1.0	–0.2	7.1
2012	–6.9	–12.1	–2.5	11.9	18.4	20.2	22.1	20.3	14.3	9.8	2.7	–5.9	7.7
Average	–6.3	–7.1	–0.4	8.7	15.8	18.6	21.9	20.5	14.2	7.6	1.7	–4.3	7.6

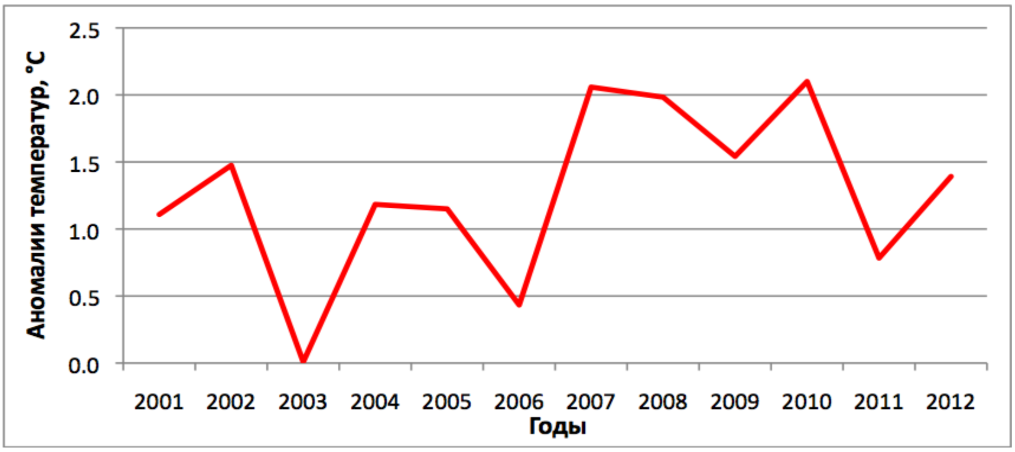
Source: Voronezh weather and climate: http://www.pogoda.ru.net.

The warmest month in Voronezh is July. The highest average July temperature – 26.4°C – was reached in 2010. The period 2001–2012 was also hotter than preceding years.

In the period from 2001 to 2012, nine record air temperatures were set: January 2001 (8°C), April 2012 (29.2°C), May 2007 (35.7°C), June, July and August 2010 (38.9°C; 40.1°C and 40.5°C respectively), September 2008 (32.1°C), and December 2010 (12.4°C).

An analysis of the range of annual temperature fluctuations shows that the warmest average annual temperature in the period from 2007 to 2010 was 8.4°C. Apart from 2003 (6.3°C), all years in the twenty-first century were hotter than the norm by between 0.4°C and 2.1°C (see Figure 2.9). This allows us to speak of how the figure for the average annual air temperature grows increasingly warmer than the norm in every decade.

Figure 2.9. Deviation of the average annual air temperature from the norm in Voronezh in 2001–2012



Source: V.A. Dmitrieva, Voronezh State University.

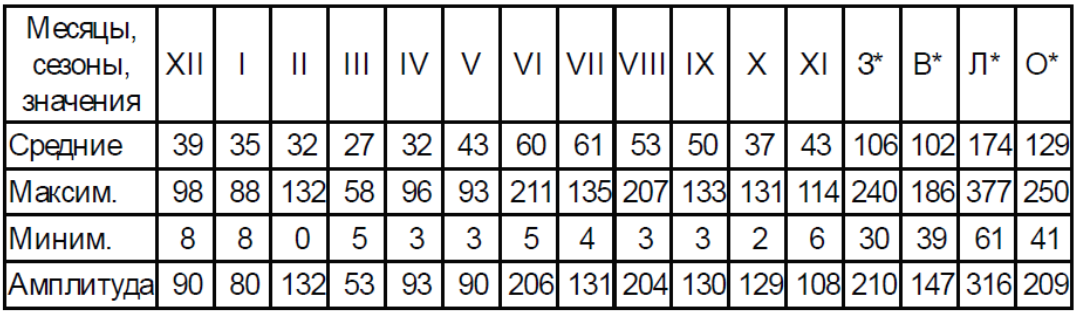
Translation:

Abnormalities of t, C (Аномалии температур, °C)

Years (Годы)

Irregularity is a characteristic feature of the yearly distribution of atmospheric precipitation (see Table 2.5). A total of 106 mm of winter precipitation falls, mainly in the form of snow. This plays an enormous role in humidifying the territory. In the absence of a deep thaw in winter, the snow forms a steady covering which protects the topsoil from freezing. In such circumstances, shrubs and crops with shallow root systems can cope winter more safely.

Table 2.5. Typical monthly precipitation in Voronezh Oblast



Месяцы, сезоны, значения	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	З*	В*	Л*	О*
Средние	39	35	32	27	32	43	60	61	53	50	37	43	106	102	174	129
Максим.	98	88	132	58	96	93	211	135	207	133	131	114	240	186	377	250
Миним.	8	8	0	5	3	3	5	4	3	3	2	6	30	39	61	41
Амплитуда	90	80	132	53	93	90	206	131	204	130	129	108	210	147	316	209

Source: V.A. Dmitrieva, Voronezh State University.

Translation:

Months, seasons, meanings (Месяцы, сезоны, значения)

Average (Средние)

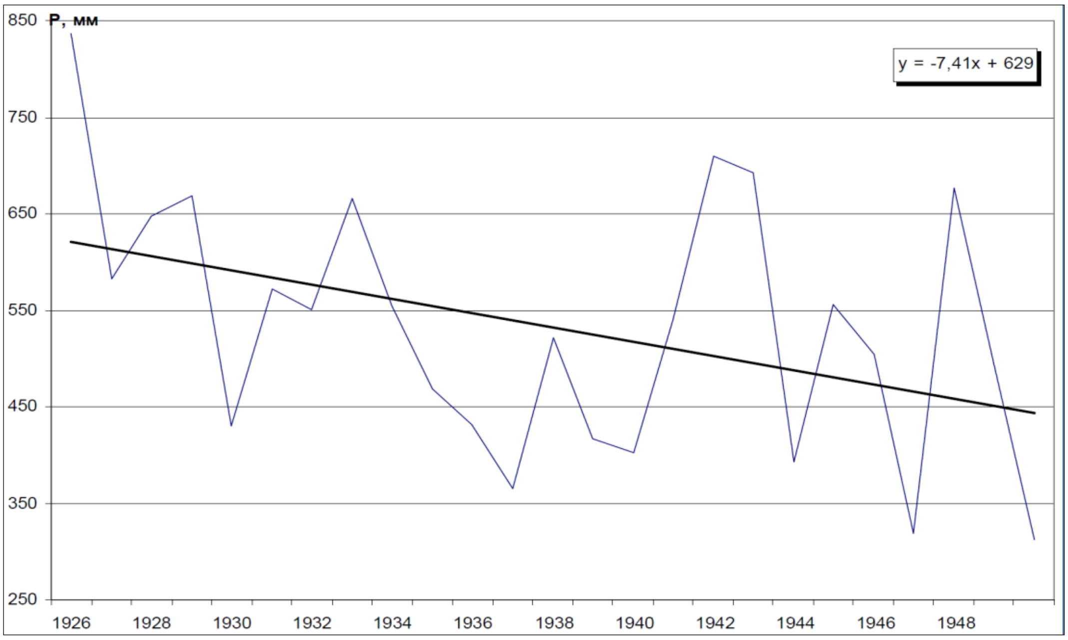
Maximum (Максим)

Minimum (Миним)

Range (Амплитуда)

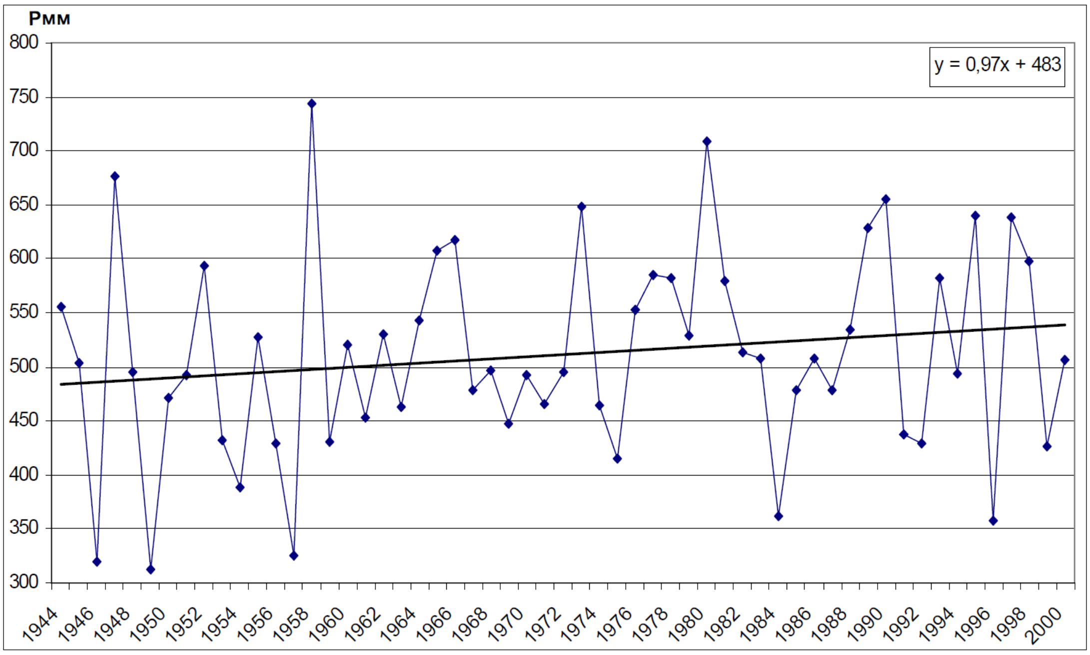
Notes: З* – Winter, В* – Spring, Л* – Summer, О* – Winter.

Figure 2.10. Yearly atmospheric precipitation in the city of Liski, 1925-1949



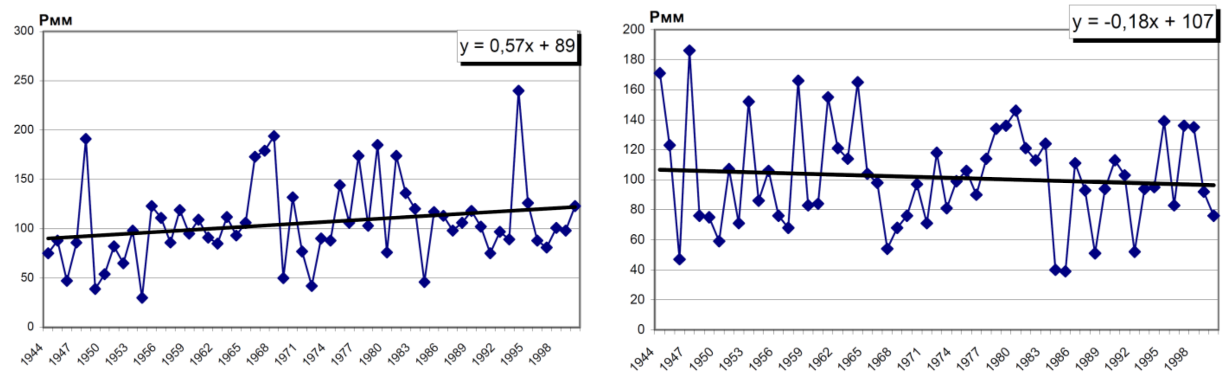
Source: V.A. Dmitrieva (Voronezh State University)

Figure 2.11. Yearly atmospheric precipitation in the city of Liski, 1944-2000



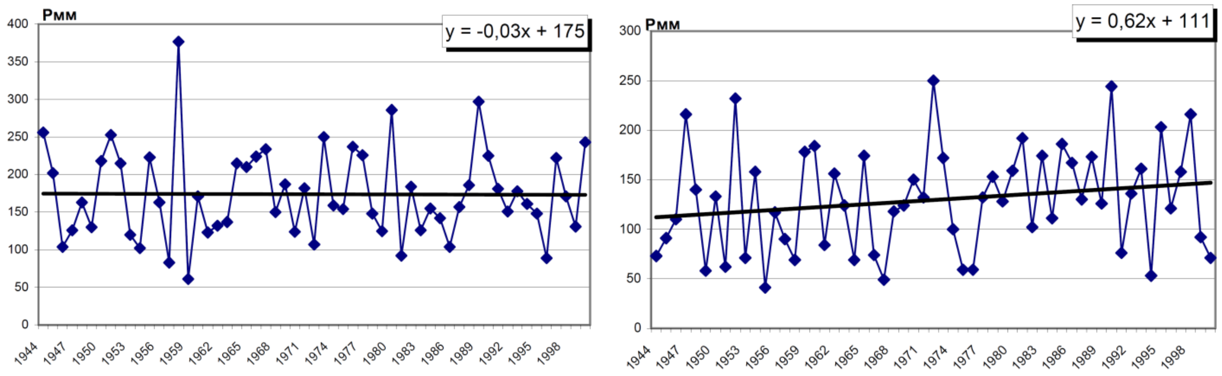
Source: V.A. Dmitrieva (Voronezh State University)

Figure 2.12. Yearly atmospheric precipitation in the city of Liski by seasons, 1944-2000



а) зима

б) весна



в) лето

г) осень

Source: V.A. Dmitrieva (Voronezh State University)

Translation:

a) Winter

b) Spring

c) Summer

d) Autumn

Precipitation levels reach their yearly maximum in the summer months. In particularly rainy years, precipitation levels can reach 211 mm (as in 1958), and in dry years can decrease to 3 mm (as in 1994). Total summer precipitation is 174 mm, 1.7–1.3 times higher than the precipitation levels of other seasons. However, the hydroclimatic role of this precipitation is not as significant, as 70 per cent of its volume evaporates. In autumn, precipitation decreases, and within the three months that season lasts, there is a 129 mm decrease.

If in 1925–1949 there was a noticeable trend towards declining annual averages of atmospheric precipitation, then in the following 60 years there was a tendency for the total yearly precipitation to increase (see Figures 2.10 and 2.11). The increase in the annual total comes from increased humidity in autumn and winter (Figure 2.12).

The average long-term quantity of yearly precipitation from 2001–2012 was 598 mm. The year 2012 went down in history for the record quantity of precipitation in Voronezh – 873 mm.

Voronezh is one of the country's largest food providers. Agriculture was developed here thanks to the fertile black earth, one of the main natural resources of the region.

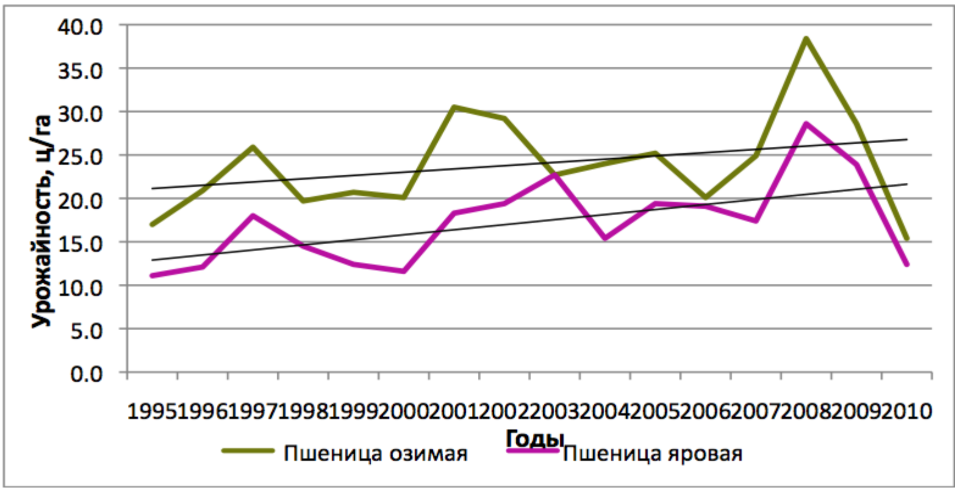
In terms of volume of production for grain, sunflowers, and sugar beets, the region traditionally takes the first place in the Central Federal District. For agricultural production, the region has 4 million hectares of agricultural land, including 3 million hectares of arable land. The structure of the cultivated areas is made up as follows: 50 per cent hold grains and legumes, 23 per cent industrial, and 13 per cent fodder.

In the last 30 years, there has been a growth in the climate-dependent yields of winter grain crops, sunflowers, sugar beets, and maize (up to 2.2 kg/ha in 10 years in the Central Federal District). Rosstat data on the dynamics of grain and industrial crops in the Voronezh region for 1995–2010 are presented in Figure 2.13. One can note the growth in yields of these crops in the period up to 2009, followed by a sharp fall in 2010 due to the record hot summer, drought, and wild fires.

According to the Rosstat data, in the comparatively dry year 2012, Voronezh was able to increase its harvest of grain and legumes by 1 per cent despite a 25 per cent overall fall in the national harvest.

Figure 2.13. Dynamics of wheat, beet, and potato yields in the Voronezh region from 1995–2010 with linear trends

A) Wheat



Translation:

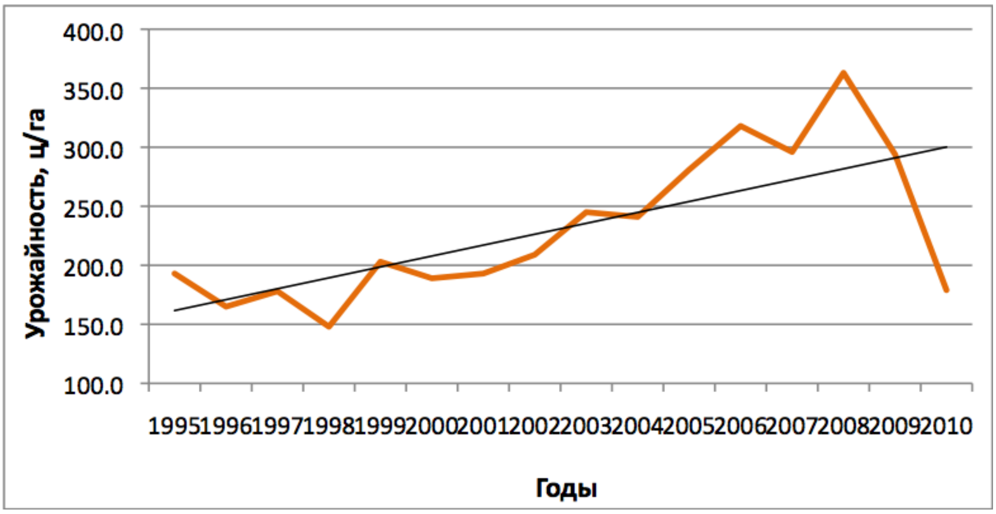
Yield, centner/ha (Урожайность, ц/га)

Years (Годы)

Winter wheat (Пшеница озимая)

Spring wheat (Пшеница яровая)

B) Beets

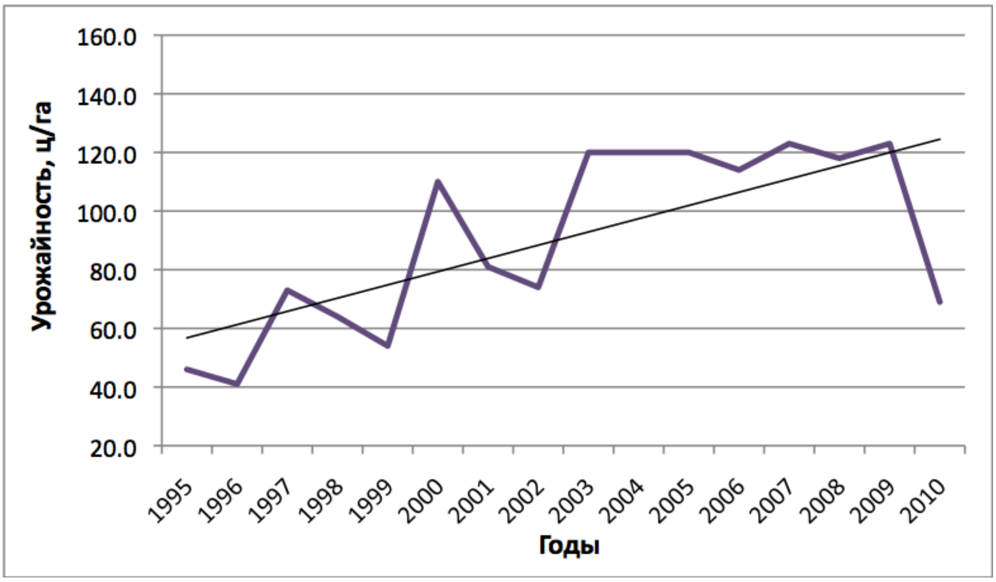


Translation:

Yield, centner/ha (Урожайность, ц/га)

Years (Годы)

C) Potatoes



Source for Figure 2.13A, B and C: Rosstat (2013)

Translation:

Yield, centner/ha (Урожайность, ц/га)

Years (Годы)

Table. 2.6 presents estimates of the expected impact of climate change scenarios on the productivity of important crops for the Voronezh region. Changes in yield are calculated taking into account the direct influence of the change in thermal conditions and humidity on the productivity of agrocenosis (1) and also taking into account the additional feedback of climate agrocenosis on labile soil organic matter (VOCs) (2).

Table 2.6. Estimated changes in yields for 2020–2040 with the implementation of an ensemble climatic scenario in the territory of Voronezh region

Culture	**Climate**							
	2011–2030				2041–2060			
	centre/ha		%		centre/ha		%	
	1	2	1	2	1	2	1	2
Grain	–0.8	–1.0	–4.7	–5.9	–1.9	–2.5	–11.2	–14.7
Winter wheat	–0.2	–0.6	–1.0	–2.9	–0.7	–1.5	–3.4	–7.3
Spring barley	–1.3	–1.4	–7.5	–8.0	–3.0	–3.4	–17.2	–19.5
Sunflower	+0.2	+0.2	+1.9	+1.9	+0.6	+0.5	+5.8	+4.8
Sugar beet	–4.6	–5.0	–2.9	–3.2	–7.8	–8.9	–4.9	–5.7
Designation: changes in yield without (1) and with climate-dependent changes BWO (2)								

Source: Generalized Data Report for 2010 on the joint research programmes of the Interstate Council on Hydrometeorology of the CIS for the period 2006–2010: http://sng.pogoda.by/?p=591 (accessed 26 February 2013).

Warming in the territory of Voronezh, which grows more noticeable by the year, leads to marked aridization. The growth in dryness in the spring/summer period leads to a decline in the yields of spring crops. Winter grains suffer from this considerably less as a result of the rise in precipitation in the cold periods of the year. According to estimates by Russian Research Institute of Agricultural Meteorology, yields for all grain crops in Voronezh will decrease by 5–6 per cent by 2020 and by 14–15 per cent by 2050.[14]

The expected economic loss for the production of grain crops in Voronezh in terms of 2012 values can be estimated at RUB 1.4bn (approximately $46m at the current exchange rate) in 2020 and **RUB 3.5bn** (approximately $114m) by 2050.

In the most dangerous climate warming scenario – arid warming – damage in the Voronezh region could be prevented by changing focus to more heat-friendly crops such as sunflowers. Overall, prospects for crops in the region should be tied to the implementation of innovative agricultural technologies, high-performance equipment, more productive varieties and hybrids of crops, new fertilizers, and plant protection products. With the use of resource-conserving technologies, up to 60 per cent of croplands in Voronezh can be utilized. Further modernization of the industry, with a transition to innovative technology, will reduce the degree of its dependence on weather conditions and will correspondingly increase production. Regional programmes for developing local agriculture and reclaiming agricultural lands in Voronezh will be oriented towards these goals of modernization and innovation in the period up to 2020.

3. ISSUES OF ADAPTING AGRICULTURE TO CLIMATE CHANGE IN RUSSIA

A systematic approach must be taken to adapt agricultural production to climate change. This approach must take into consideration the long-term scope for as well as the variety of negative impacts in different areas, and provide an adequate assessment of the risks involved and take steps to manage those risks.

At the moment, Russia does not have such a systematic approach. The development of adaptation policies is provided for, however. For example, the Russian government approved the Climate Doctrine (2009) and its Implementation Plan (Resolution No. 730-r, dated 25 April 2011). In particular, in accordance with paragraph 14 of the Plan, Russia's Agriculture Ministry and other relevant agencies have been tasked with minimizing the risk of reduced production of agricultural products (including reductions of livestock, yield, and gross output of agricultural crops), by developing methods for calculating risk and damage assessment of climate change on agriculture (for which the deadline is 2013) and the development and implementation of measures to adapt agriculture to climate change (from 2011–2020.). The Natural Resources Ministry is responsible for developing methodologies for calculating risk and assessing the impact of climate change and for the formation of industry, departmental, regional, and territorial plans for adapting to climate change (for which the deadline is 2011). The Regional Development Ministry is responsible for assessing the vulnerability of the regions to climate change and preparing proposals for the formation of a quick response to such changes (for which the deadline is 2012).

There are a variety of ‘emergency’ measures in use today. One example is the State Duma's appeal to Prime Minister Dmitry Medvedev to consider measures necessary to eliminate the consequences of abnormal weather phenomena in the spring and summer of 2012, in particular to:

- prepare amendments to the 2012 budget to provide budgetary loans to those regions of the Russian Federation hit by drought;
- allocate funds for purchasing seeds for the planting season;
- take measures, including chemical processing, to protect agricultural land from the spread of pests and locusts;
- postpone for two years payments on loans issued to regions affected by drought by the Agricultural Bank, Sberbank of Russia, and Vnesheconombank;
- consider the possibility of extending lease payments in relation to the drought situation;
- establish a reduced rate for the rail transportation of grain, forage, and seed;
- offset some of the costs of diesel fuel, gasoline, and fertilizer until farm work has been completed as well as during the autumn and the spring planting season, etc.[15]

In this way, by using a variety of measures, agricultural producers are trying to get grants from the state to compensate for damage caused by the drought. This is in addition to a significant increase in grain prices and, ultimately, bread prices, which seriously affects the population. Unfortunately, the authors do not have accurate data on the cost estimates of these measures, but it is clear that we are talking about tens of billions of rubles in subsidies (including in the form of lower rates on loans and benefits) to deal with effects from the 2012 drought year alone.

The management of risks stemming from climate change is complex and requires a comprehensive analysis not only of issues related to the proper cultivation and harvesting or processing of crops, but also aspects such as:

- the vulnerability of systems of production, delivery, and food storage (logistics);
- the impact on the price of food and consumption, especially on the most low-income groups of the population;
- the risk assessment of the entire production chain associated with the production and processing of agricultural products, including transportation, energy, communications, and other infrastructure affected by climate change;
- the high risks for the survival of farmers and households engaged in growing subsistence crops in areas prone to adverse climate and weather conditions;
- the risks associated not only with the growing period, but also the harvest, when there may be extreme weather phenomena, as a result of which, crops may be lost or their quality significantly diminished;
- the offsetting of agricultural yields from the south to the north, and the disposal of land in the more southern areas of agricultural activity;
- moisture is essential for sustainable agricultural production, and it depends on climatic factors, etc.[16]

It is believed that the basis of the strategy for adapting agriculture to climate change in Russia could be formed by the following measures:

- conducting integrated regional studies to assess the risks and vulnerability of agricultural production to the negative impact of climatic and weather factors (some of this work has already been done, but not in all regions of Russia);
- evaluating the sensitivity of the regional and national markets for agricultural products and foodstuffs to price shocks and supply reduction caused by climatic and weather factors;
- developing and implementing large-scale regional programmes aimed at creating field-protective forest belts and other measures to prevent and reduce soil erosion and loss of topsoil;
- accelerating development of the agricultural sector and the non-Black Earth belt, primarily in central, northwest, and other regions where there is sufficient moisture to ensure stability for crop production;
- optimizing the ratio of winter and spring crops to account for changes in the conditions of autumn and winter;
- expanding the cultivated area for more thermophilic and fruitful crops, providing the intensification of agricultural production (corn, sunflower, sorghum, soybeans, etc.);
- expanding crop acreage (the second) of crop growth for thermal resources;
- developing irrigated agriculture to improve the sustainability of agricultural production and utilization of additional thermal resources;
- expanding subtropical agriculture in southern Russia and accelerating the development of industries such as horticulture, viticulture, cotton, and rice, the effectiveness of which can significantly increase during the expected climate change;
- improving the effectiveness of husbandry by increasing food supply as a result of bioclimatic potential and reducing the period of confinement of cattle in a warming climate;
- introducing moisture-saving technologies, selecting more resistant crops or varieties, creating reserve stocks of food to reduce losses from possible climate aridization and ensuring food security.

What might the costs of such adaptation measures be? On the whole, the entire world, according to the International Institute for Studies in Food Policy (IFPRI)[16] would need to spend an additional $7bn annually on research and development, expansion, and improvement of the efficiency of irrigation, the transport infrastructure, etc. to avoid the disastrous consequences of climate change for agriculture. The countries of Europe and Central Asia (including Russia) would have to spend at least $198m–222m a year.

A more accurate assessment of the cost of adaptation requires a special study, conducted at the level of regions and rural areas, and across regions. Such work may be performed as part of the Climate Doctrine of the Russian Federation, and also as part of the State Agricultural Development Program and Regulation of Agricultural Products, Raw Materials and Food for 2013–2020 (approved by the Russian government resolution No. 717 dated 14 July 2012). Incidentally, the Program includes a special section called ‘Risk management in the sub-industry’, which may see measures taken for the risk management of climatic factors. The total cost of the Program for 2013–2020 years is estimated at RUB 466.6bn (approximately $15.3bn).

Adaptation costs are likely to be significantly less than costs to repair the damage that they can prevent. The damage from drought in 2010 and 2012, amounting to more than RUB 300bn, allows us to evaluate the scale of effects of a ‘short-sighted’ approach to the issue of climate change's impact on agriculture in Russia.

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NOTES

[1] The recommendations of Russian Research Institute of Agricultural Meteorology are often used. These are available on their website: http://sng.pogoda.by/?p=591 (accessed 28 February 2013).

2 Roshydromet: http://www.global-climate-change.ru/index.php/ru/climate-rf/78-about-climate-rf/180-doklad-o-klimate-rf-za-2011

3 A detailed review of climate metrics in respect of agriculture can be found in Bobylev *et al*. (2012).

4 Roshydromet: http://www.meteoinfo.ru/news/1-2009-10-01-09-03-06/6483-14012013-2012-14-

5 Including in Bobylev *et al*. (2012).

6 Nelson *et al*. (2012), p. 85.

7 Trostle *et al.* (2011); FAO-OECD, 2011; Development Committee, 2011.

8 Based on the Russian Research Institute of Agricultural Meteorology's data, the change in climate related crop yield in 2020 is projected at 11.9m tons of grain (see Table 1.3). This assessment is given in absolute figures, but it includes the average grain yield for 2000–2005. According to Rosstat data, average grain and leguminous crop prices stood at 9,009 RUB/ton in December 2012.

9 Based on the Russian Research Institute of Agricultural Meteorology data, a drop in grain crop yield will amount to 17 per cent or 13.4m tons of grain by 2050 (see Table 1.1). According to Rosstat data, average grain and leguminous crop prices stood at 9,009 RUB/ton in December 2012.

[10] In agriculture, the term ‘sum of temperatures over +10 degrees Celsius’ denotes how much solar (thermal) energy is provided for growth of the plants during the vegetation period. If this indicator's value is over 2,200 (calculated as a sum of average daily temperatures in the vegetation period of April-October), there would be too much solar and the droughts will occur. Figure 2.7 shows that a rise in the temperature of 1 degree Celsius would result in most of the territory of the Altai region being in conditions of drought, which will affect agricultural production. So there is a need for adaptation measures, e.g. creation of irrigation systems, change of growing species, etc.

[11] Scenario conditions for the socio-economic development of the Altai territory for 2013 to 2015. Confirmed by decree No. 383-r. of the Altai region’s administration from 17 September 2012.

[12] Rosstat data (2013).

[13] The index was calculated in view of the price of wheat and rye in the Altai region at the end of 2012.

[14] See: http://sng.pogoda.by/?p=591 (accessed 26 February 2013).

[15] According to materials from the website http://voronej.bezformata.ru/listnews/medvedeva-smyagchit-posledstviya-zasuhi/5365327/ (accessed 15 March 2013).

15 The recommendations of the Russian Research Institute of Agricultural Meteorology are often used. These are available on the website: http://sng.pogoda.by/?p=591 (accessed 28 February 2013).

[16] Nelson *et al.* (2009): http://www.ifpri.org/sites/default/files/publications/pr21.pdf/

ACKNOWLEDGEMENTS

The report was written by Georgiy Safonov and Yulia Safonova from Environmental and Natural Resource Economics, National Research University Higher School of Economics.

Oxfam acknowledges the assistance of Daria Ukhova, John Magrath, and Richard English.

For more information, or to comment on this report, email Yulia Yevtushok, Oxfam Programme Manager, at yyevtushok@oxfam.org.uk

Oxfam Research Reports

Published by Oxfam GB for Oxfam International under ISBN 978-1-78077-317-9 in April 2013.
Oxfam GB, Oxfam House, John Smith Drive, Cowley, Oxford, OX4 2JY, UK.

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