Climate Change and Russian Agriculture

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Contributor: Roman Gordeev

Russian weather trends such as winter softening and increase in summer heat have a significant but opposite effect on yields. An interesting finding is a significant and mostly positive influence of global climatic variables, such as the CO2 concentration, El Niño and La Niña events on both harvests and yields. Although technological factors are the main drivers of growth in Russian agricultural performance over the past 20 years, we found a strong positive effect on yield and gross harvest only for mineral fertilizers. The influence of the other variables is mixed, which is mainly due to data quality and aggregation errors.

agriculture Russia crop yields climate change global warming panel data fixed effects regression

1. Climate Change and Performance of the Russian Agricultural Sector over Past Years

The impact of climate change on agriculture is controversial. The past two decades have witnessed both the highest global temperatures and the greatest number of natural disasters. Increasingly frequent extreme weather events are one of the main reasons for the rising number of undernourished and food insecure people [1]. Lobell and Field [2] showed that climate change observed in 1981–2002 caused a decrease in global yields of wheat, maize and barley, but not for soybeans. However, estimated climate-driven losses of global agriculture over this period were overcompensated by agricultural technological advances and by fertilization effects of increased CO_2 levels.

In addition, the impact of climate on agriculture is uneven across the world. Increased drought will reduce agricultural production in Africa, the Middle East and South and Southeast Asia. On the contrary, it is expected that higher latitude regions such as Russia will benefit from climate change by extending the vegetation period [3]. At this point, there is much evidence to support this assumption for comparable countries. Due to global warming, an increase in grain yields is expected to occur in Ireland [4], Finland [5][6], the USA [7][8] and Canada [9][10].

However, climate change in Russia can affect crop yields in several dimensions. The main negative effect is an increase in the number of abnormal adverse weather events, especially droughts. Severe and extensive droughts can cause a 40–50% reduction in gross grain yields in major grain-producing regions [11]. Another risk factor is the increased negative impact of pests and crop pathogens. Climate warming and thawing of permafrost lead to the expansion of pest habitats and population growth. Increases in the annual sum of active temperatures of the surface air layer caused the boundaries of the Italian locust distribution to shift significantly northward in 1996–2015 compared to 1956–1976 [12]. Estimates of the potential distribution of the Colorado Potato Beetle under further climate warming in the 21st century indicate that its habitat will expand substantially in the northern, northeastern, and eastern directions [13].

Nevertheless, the Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet) identifies three main effects of climate warming that could at least partially lead to positive effects on agriculture: (1) an increase in the heat availability of crops and the duration of the growing season; (2) an increase in winter air temperatures, determining the conditions for overwintering of crops; (3) changes in moisture conditions, which are caused by an increase in precipitation in the cold season and a decrease in precipitation in the warm season [11].

The 1975–2008 period revealed a climate-driven increase in the yield of grain and leguminous crops on the entire territory, except for the regions of the Central federal district (18 sub-federal Russian territorial entities located around Moscow, the capital of Russia). The greatest positive effect was observed for winter grain crops. In some regions of the North Caucasus and the Volga region, the increase peaked at 10–15% within 10 years [14]. Still, there is evidence that the effects can be contradictory. In the territory of the European part of Russia for 1998–2017, there was no growth of climate-driven yields due to aridification and increasing tension of the thermal regime. At the same time, the increase in thermal resources and the duration of the growing season stimulated the growth of bioclimatic potential [15].

For such a large country as Russia, regional differences in the response of crop production to climate change can be very significant. The regions of Volga and Southern federal districts were national champions in terms of the growth rate of grain yield (2.2–2.6% over 10 years). However, the threat of drought is also most likely in the southeastern part of European Russia [11].

On the contrary, Central Siberia would likely benefit from the climate warming trend. For regions such as Krasnoyarsk Krai, Republic of Khakassia and Tyva Republic, agricultural production could double as the climate warms in the 21st century. In this case, the cultivation of traditional crops such as grain, potatoes and corn for silage may gradually shift 500 km to the north, and in the south of the territories, may be introduced new crops such as apricots, grapes and gourds [16].

Another feature of spatial heterogeneity is revealed in the yield dynamics of different crops. Between 1975 and 2010, the yield of grain and leguminous crops in Russia increased by an average of 4.5%. A decrease in yields was recorded only in the south of the Volga federal district, as well as in the southern and central regions of the Central federal district. Spring barley yields during the same period increased only in the Urals and Siberia, while negative trends were observed in the European part of Russia [17].

Notably, the risks for winter wheat are lower than for spring wheat [15]. Consequently, winter wheat was in favorable growing conditions in 1975–2010; the maximum growth was observed in the North Caucasus and the south of the Volga region. Between 1996 and 2010, there was also a climate-driven increase in the yield of sunflower and sugar beet for the European part of Russia. Corn yields increased in the Volga and Central federal districts but declined in the Southern federal district due to increased drought in the summer [17].

During the past two decades, Russia became one of the major exporters of agricultural production. By 2017–2018, Russia was supplying 10–13% of global exports of total grain and 20–23% of wheat [18]. An important point is that this successful performance on the global market was not driven by extensive development. Russia's grain harvested area fell from 58 mln ha in 1987–1991 to 41 mln ha in 2017–2019, but at the same time, yields rose significantly from 1.63 tons per ha in 1987–1991 to 2.81 tons per ha in 2017–2019 [18]. The reason was that the economic growth of the 2000s allowed for an increase in the use of fertilizers and higher-quality seeds and machinery, combined with an increase in farm management efficiency [19][20]. All these factors led to the large increase in yields for all main agricultural products over the past twenty years (**Figure 1**).

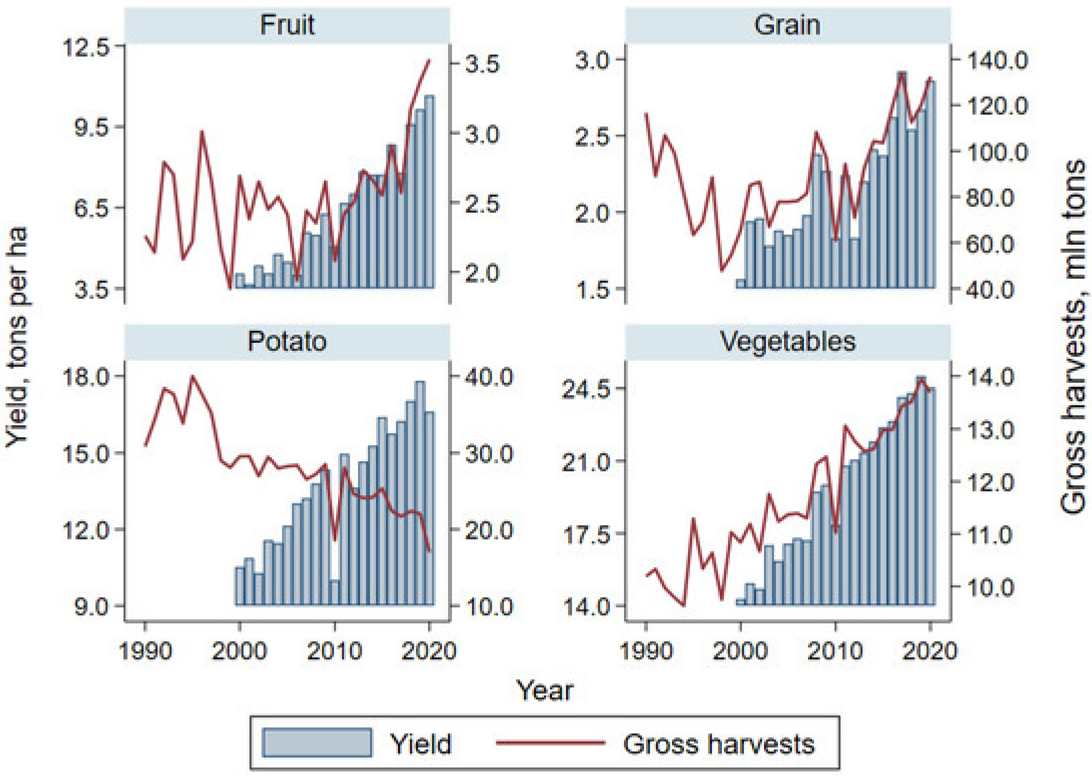

Figure 1. Yield and gross harvest dynamics of fruits, grain, potato, and vegetables in Russia, 1990–2020.

Since 2000, the yield of potatoes and vegetables has increased by 1.7 times, grain by 1.8 times and fruit and berry by 2.6 times. Gross harvests are also rising, except for potatoes, which still have not exceeded the level of 1990. The best outcome has been in grain, whose gross harvests have doubled since the 2000s.

The most export-oriented regions of Russia are in the southwest of the country: Krasnodar Krai, Rostov Oblast, and Stavropol Krai. The global warming trend may decrease their grain export volumes by 4–5 mln tons [21]. To overcome these negative effects, it is necessary to carry out some measures of adaptation to future climate change. Development options may include increasing the area of reclaimed land, and changing the structure of crops and tillage methods [21].

2. Assessing the Impact of Climatic Conditions on Agricultural Productivity in Russia

The influence of climatic factors on crop yields is considered by representatives of multiple scientific fields: agronomists, meteorologists and economists, who focus on various drivers of crop productivity [22]. Despite the different points of view, most of the studies employ the methods of econometric modelling. The common specification is the regression on yields as a dependent variable with several climatic characteristics as predictors. The most common climatic variables considered are temperature and precipitation. Further differences in the choice of variables are usually due to the growing conditions of a particular crop. For instance, the winter wheat might be more sensitive to autumn and winter temperatures, while the spring grains might be more strongly affected by extreme heat days [23].

The choice of methods for testing the presence of a causal relationship between climate change and agricultural productivity is also highly dependent on the object of study. Focusing on the country level makes it easier to use time series analysis due to the availability of larger datasets. In contrast, regional analysis is usually bound with more data restrictions. This problem is especially crucial for studies on the Russian economy. Socio-economic data on the same territories of Russia and the USSR are not fully compatible. In addition, the economic crisis and hyperinflation of the 1990s made all monetary indicators incomparable to other periods. Most time series of socio-economic indicators of Russia's development are limited to 20 years of the 21st century or even less. Multiple changes in statistical classifiers during the mentioned period make some of the data inconsistent. This pattern is inherent in many Russian industries [24] and agriculture is not an exception.

Belyaeva and Bokusheva [23] developed a panel fixed-effects regression on crop yields for 69 Russian regions over the period of 1955–2012. Using several variables describing seasonal temperature and precipitation, they found that large yield losses were caused by significant heat when daily temperatures exceed 25 °C. The hot days influence the spring wheat and spring barley the most. There was also the positive linkage of grain yields with summer precipitation, though it could not reduce the damage of extreme heat. They also conclude that global warming will lead to a decrease in agricultural productivity in Southern regions of Russia along with a positive effect on spring barley, winter and spring wheat in the Northern and Siberian territories [23].

Siptits et al. [25] built projections of the yield and gross harvest of grain and leguminous crops in the 79 regions of Russia until 2100. They used monthly average temperatures and precipitation level as predictors of yields in 1995–2016. The authors showed that the volume of grain and legume production in Russia will increase up to 170 mln tons by 2100 due to improved agricultural conditions in the Volga and Central Siberia regions.

Ksenofontov and Polzikov [21] made scenario forecasts of grain production and consumption by federal districts of Russia until 2030. The results confirm the negative consequences of global warming on the Southern regions of Russia, but expect the growth of gross harvests of grains and other crops in the Central and Northwestern parts of European Russia.

Pavlova and Sirotenko [17] used multiple linear regressions with differences in yield, temperature and precipitations first developed by Lobell and Field [2] to analyze the influence of climatic change for the 54 Russian regions over 1975–2010. Climatic changes caused an increase in winter wheat yield from 1% in the south of the Central federal district to 17% in the south of the Volga region. In much of European Russia, a tendency to a slight decrease in the yield of spring barley and cereal crops of about 1% in 10 years was revealed. This is compensated by the increase in yields in the Ural and Siberian federal districts.

Tchebakova et al. [16] focused on three regions of central Siberia that might benefit from the global warming trend: Krasnoyarsk Krai and the Republics of Khakassia and Tyva. The authors employed multiple linear regression models on crop yields using the number of days when temperature grew above a base of 5 °C and the ratio of this indicator to the annual precipitation as predictors for the period of 1966–2009. In the next step of the analysis, the forecast for 2090 showed that southern areas of Central Siberia such as forest-steppe, steppe, and semidesert would expand by up to 40% and may become climatically suitable for farming. In addition, Babushkina et al. [26] also proved that the temperature and precipitation conditions in May–July contribute the most to the variability of crop yields in the Khakassia Republic.

Most of the aforementioned econometric studies use only the temperature and precipitation levels as the major predictors and did not consider economic and agronomic variables. In some cases, they were only controlled by the fixed effects terms. Although the results are consistent and generally show a significant increase in yields due to climate change, the absence of other factors may create a significant bias in the estimates. For instance, Ahumada and Cornejo [22] suggested that there are three major groups of factors influencing the soybean yields. The climate group of factors covers variables describing global warming trends and their consequences such as CO_2 concentration and extreme events. Technological factors are captured with the use of fertilizers, modified seeds, machinery, labor and agricultural practices, for example, irrigation. Economic factors include prices on crops, fertilizers, and land.

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