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# Russia's Food Security and Climate Change: Looking into the Future

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**Abstract**
Global climate change presents long-term risks to agriculture. In general, global climate change is expected to positively affect Russian agriculture. In high and middle latitudes, global warming would expand the growing season. Acreages of agricultural crops may expand toward the north, although yields would likely be lower due to less fertile soil. However, in the south there is a possibility of drier climate, which has a negative impact on crop yields and livestock productivity. In addition, climate change is expected to increase the scarcity of water resources and encourage weed and pest proliferation, and it is expected to increase the short-term risks associated with an increase in extreme weather events and natural disasters. This paper uses data on current conditions to simulate future scenarios and examine possible impacts on crop production in the Russian Federation. It also considers adaptive measures for agriculture in response to climate change.

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# 1 Introduction

The first part of this paper is an overview of the current food security situation, the underlying natural resources available in Russia and the drivers that lead to the current state, focusing on income and population growth. The second part reviews Russia-specific outcomes of a set of scenarios for the future of global food security in the context of climate change. These country-specific outcomes are based on IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade) runs from July 2011. Finally Russia's potential for mitigation of agricultural greenhouse gas emission and policy for adaptation of agriculture to climate changes are considered.

In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group reports that "climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years)"(Le Treut et al. 2007: 96).

The ongoing growth of greenhouse gas emissions is raising average temperatures. The consequences include changes in precipitation patterns, more and more extreme weather events, and shifting seasons. The accelerating pace of climate change, combined with global population and income growth, threatens food security everywhere.

Agriculture is vulnerable to climate change in a number of dimensions. Higher temperatures eventually reduce yields of desirable crops and tend to encourage weed and pest proliferation. Greater variations in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there might be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security. The impacts are:

- Direct, on crops and livestock productivity domestically;
- Indirect, on availability/prices of food domestically and in international markets;
- Indirect, on income from agricultural production both at the farm and country levels.

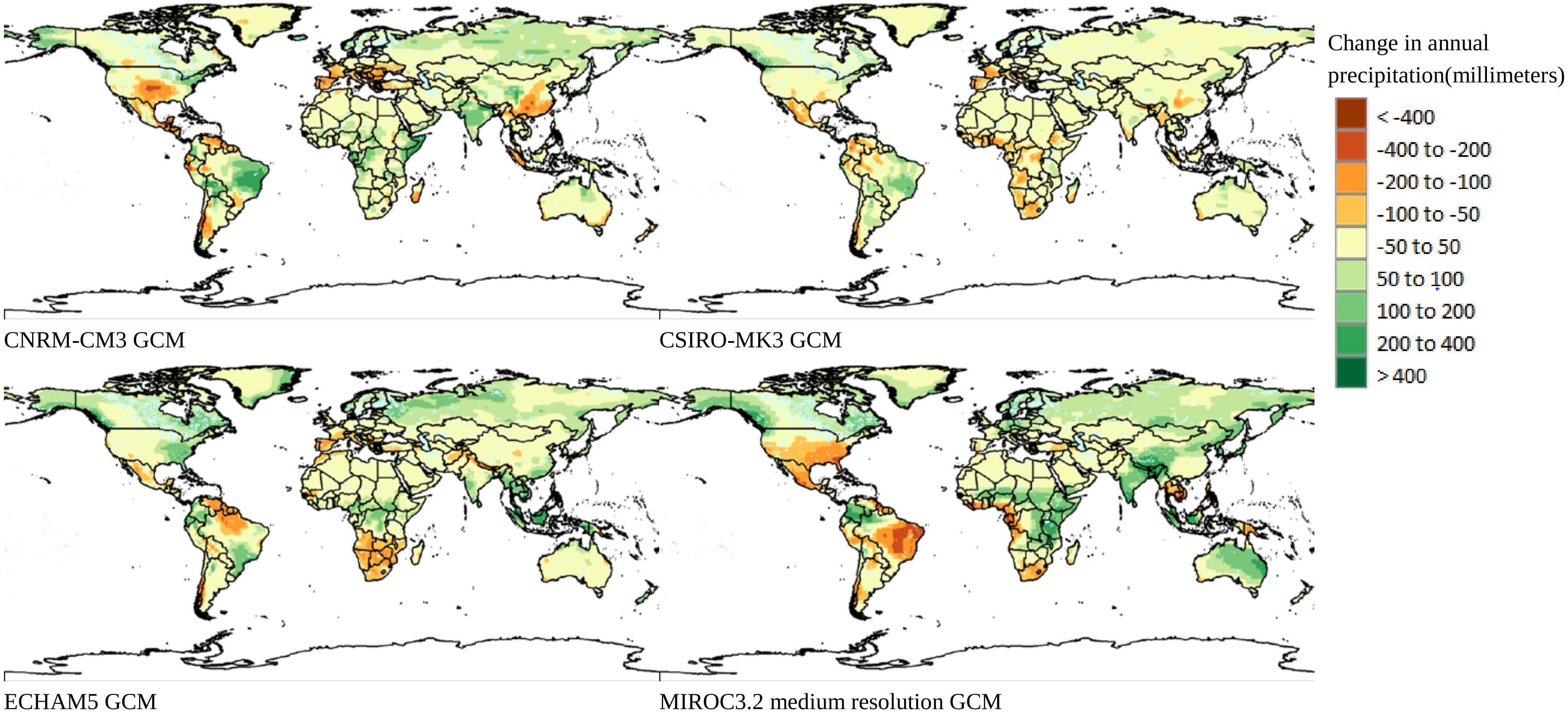
### *Regional Impacts of Climate Change*

While the general consequences of climate change are becoming increasingly well known, great uncertainty remains about how climate change effects will play out in specific locations.[1] Figure 1 shows changes in average precipitation globally between 2000 and 2050 for four General Circulation Models (GCMs), each using the A1B scenario (Special Report on Emissions Scenarios (SRES) of the IPCC 2000: 4, 28). Figure 2 shows the change in average maximum temperature. In each set of figures, the legend colors are identical; a specific color represents the same change in temperature or precipitation across the models.

A quick glance at these figures shows that substantial differences exist. For example, in Figure 1 the MIROC GCM predicts that Southeast Asia will be much drier, while the ECHAM model has the same region getting wetter. In South Asia, the MIROC GCM has an increase in precipitation, especially in the northeast, while the CSIRO GCM has a drier South Asia. In northeast Brazil, the CNRM GCM shows significant drying while the MIROC scenario has a sizeable increase in precipitation. In Figure 2, we see that the MIROC and ECHAM GCMs predict very big temperature increases for northeast South Asia, but they differ on whether northwest South Asia will also experience such a severe temperature increase. These figures illustrate qualitatively the range of potential climate outcomes using current modeling capabilities and provide an indication of the uncertainty in climate-change impacts. The differences across models are why policymakers

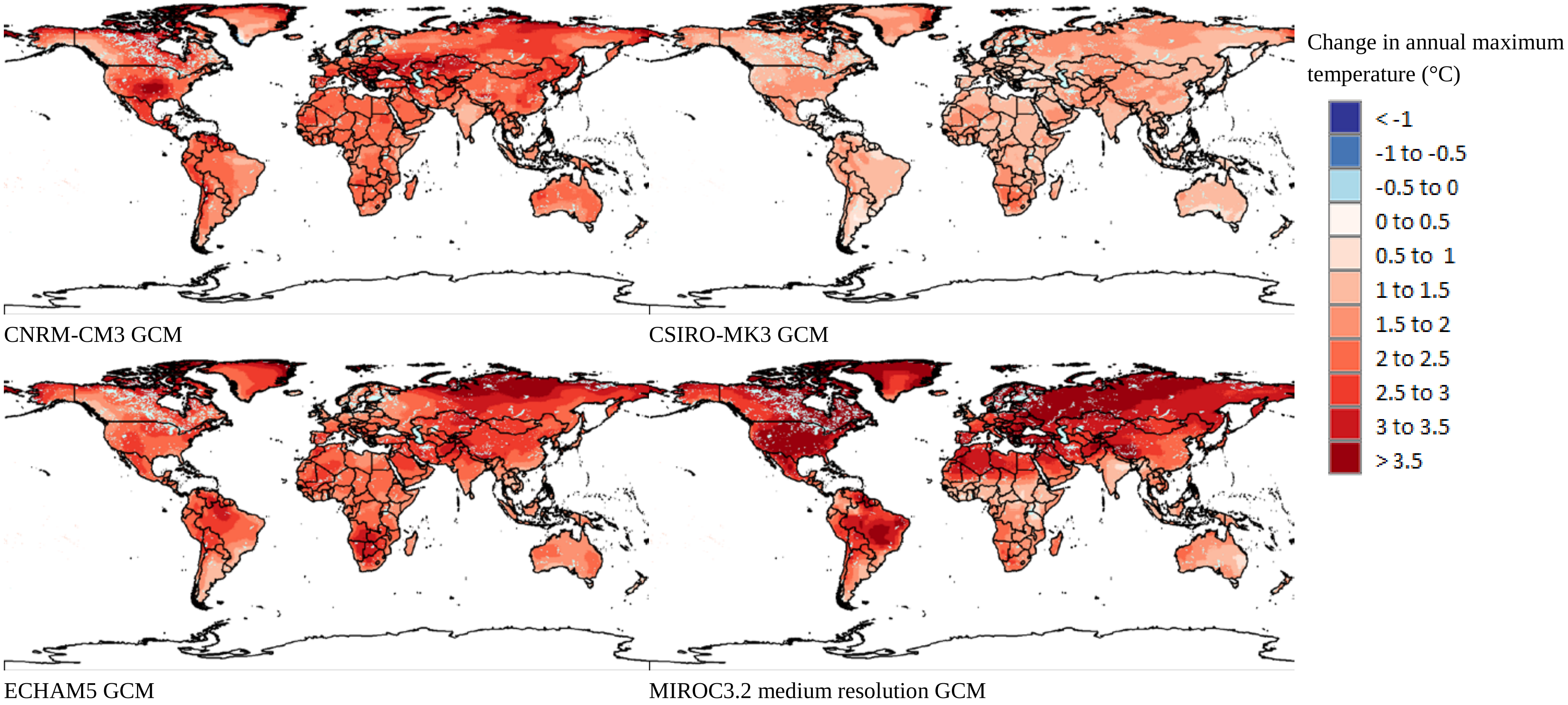
[1] To understand the significant uncertainty in how these effects play out over the surface of the earth it is useful to describe briefly the process by which the results depicted in the figures are derived. They start with global (or general) circulation models (GCMs) that model the physics and chemistry of the atmosphere and its interactions with oceans and the land surface. Several GCMs have been developed independently around the world. Next, integrated assessment models (IAMs) simulate the interactions between humans and their surroundings, including industrial activities, transportation, agriculture and other land uses and estimate the emissions of the various greenhouse gasses (carbon dioxide, methane and nitrous oxide are the most important). Several independent IAMs exist as well. The emissions simulation results of the IAMs are made available to the GCM models as inputs that alter atmospheric chemistry. The end result is a set of estimates of precipitation and temperature values around the globe often at 2 degree intervals (about 200 km at the equator) for most models. Periodically, the Intergovernmental Panel on Climate Change (IPCC) issues assessment reports on the state of our understanding of climate science and interactions with the oceans, land and human activities.

*Figure 1*. Changes in mean annual precipitation between 2000 and 2050 using the A1B scenario (mm per year)




Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org.

*Figure 2.* Changes in annual maximum temperature between 2000 and 2050 using the A1B scenario (°C)




Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

must avoid seeking specific solutions for specific locations – unless there is significant agreement across models. Rather, it is important to note general trends and to consider policies that are helpful and robust across the range of climate outcomes.

## 2 Agriculture, Food Security and Russian Development

The food security issues in Russia are in the focus of attention for policy–makers. Several official documents were adopted in recent years. One of the most important is the Food Security Doctrine, which was approved by the Decree of the President of the Russian Federation of January 30 2010, № 120. The Doctrine represents official views on the purposes, tasks and the main directions of Russia's economic policy for providing food security.

Food security is a central tenant of current agricultural policy. In the State Program of Development of the Agricultural Sector and Regulation of Markets of Agricultural Products, Raw Materials and Food for 2013–2020 provision of food independence within the parameters defined by the Food Security Doctrine of the Russian Federation is among the goals with the highest priority.

In Russia, there is a clear understanding of the strong impact of climate factors on yield and agricultural efficiency. Climate risks have been included in all major official documents as possible obstacles for achieving agricultural development.

Since 1999, Russia's agricultural performance has been positive, with the exception of 2010 when an extremely abnormal drought affected a majority of the regions of the Russian Federation. Growth in agricultural output has been influenced by an increase in prices for agricultural products, and growth of consumer demand for food due to rising real incomes.

The Russian Federation is a net food importer but the increase in imports has been accompanied by an increase in agro-food exports. Since 2002, Russia has significantly increased its grain supply to the world market. But the growth of agricultural production might not be sustainable, given the potential threats from climate change.

On the demand side, relatively low incomes, the resulting high share of food expenditure in the structure of consumer spending and a large income disparities indicate a high vulnerability of Russia's population to food price shocks that are likely to become more serious with climate change.

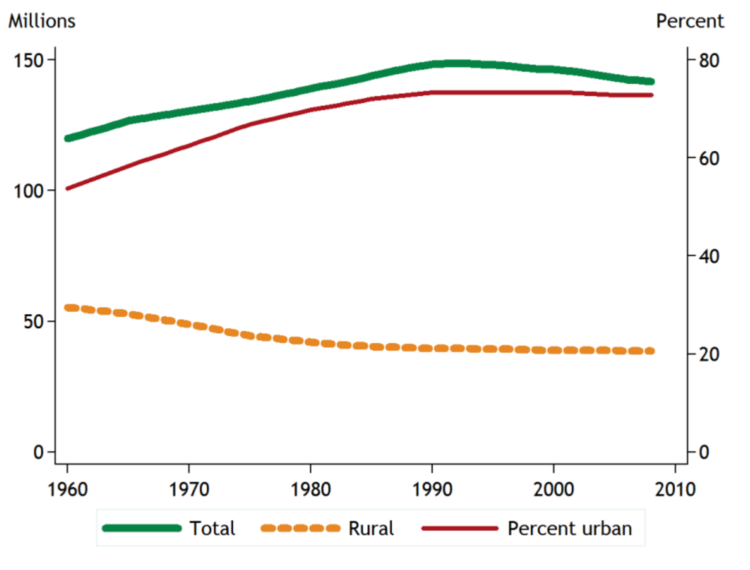
## 2.1 Review of the Current Situation

### *Population*

Figure 3 shows total and rural population (left axis) and the share of urban population (right axis) in total population of Russia. Since 1994 there has been reduction of population in Russia at the background of relatively stable percentage indicators of urban and rural population.

Table 1 provides additional information on the determinants of overall population growth trends. As with many other countries with relatively high per capita income, the population growth rate has been slowing. A brief hiatus in this process occurred in the early 1990s with an increase in the rural population due to substantial in-migration of a Russian-speaking population from the former Soviet

*Figure 3*. Population Trends: Total Population, Rural Population, and Percent Urban, 1960–2008




Source: World Development Indicators (World Bank, 2009).

*Table 1.* Average Annual Population Growth Rates, 1960-2009 (%)

| Decade | Total Population Growth Rate | Rural Population Growth Rate | Urban Population Growth Rate |
|---|---|---|---|
| 1960–1969 | 0.87 | –0.95 | 2.45 |
| 1970–1979 | 0.58 | –1.38 | 1.77 |
| 1980–1989 | 0.64 | –0.71 | 1.24 |
| 1990–1999 | –0.01 | 0.14 | –0.06 |
| 2000–2009 | –0.34 | –0.32 | –0.35 |

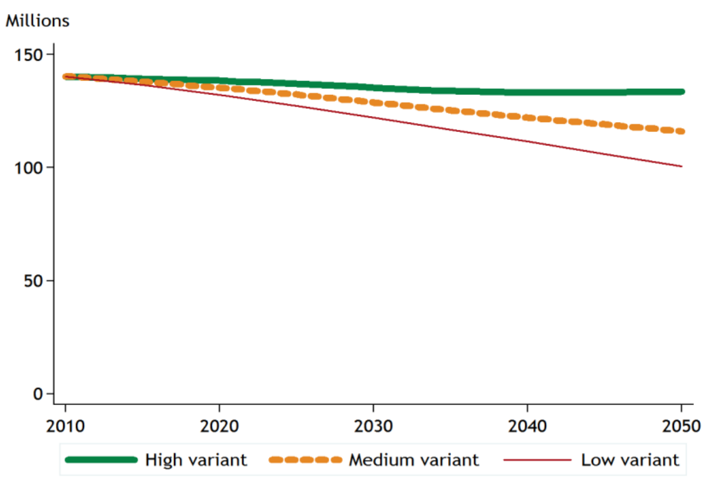
Source: Calculations based on Russian Federation Federal State Statistics Service data.

Republics. After 1995 the inflow of migrants into the rural areas declined sharply and rural population growth became negative again.

Figure 4 shows three population projections by the UN Population office through 2050. Under all of these scenarios, population in the Russian Federation declines.

These projections differ somewhat from the official Russian projections, which have a moderate population decline for the medium and low scenarios but a slight increase in the high scenario (Figure 5). This scenario seems implausible given current trends.

*Figure 4.* Population scenarios for 2010 to 2050




Source: UN Population Projections (United Nations 2008).

*Figure 5.* Population projections for 2011 to 2031


Source: Russian Federation Federal State Statistics Service.

***Income***

The income available to an individual is the single best indicator of their resilience to stresses in the agricultural and food markets. Figure 6 shows trends in GDP per capita and proportion of GDP from agriculture. The agricultural share is included both because its vulnerability to climate change impacts as well as an indicator of the level of development of the country. As development increases, the importance of agriculture in GDP tends to decline.

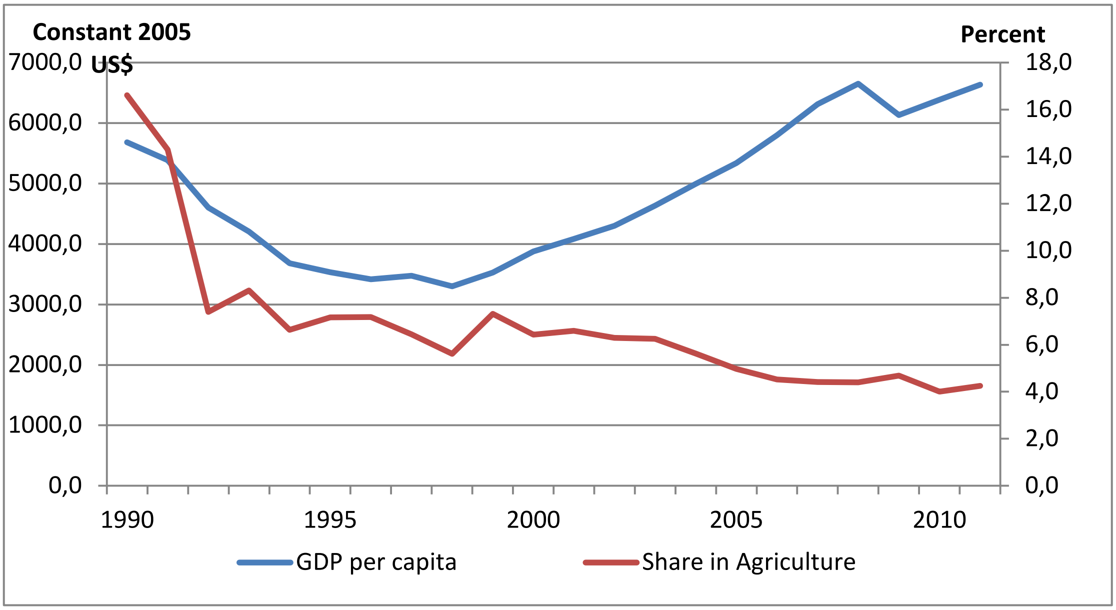
Since 1999, the Russian economy has been growing quite rapidly. During the period from 1999 to 2010, the average annual GDP growth rate was 5.4%. The cumulative GDP growth for the period following the default of 1998 amounted to 186.7%. Russia's agriculture also performed well during this period. The average growth rate of gross agricultural production for 1999–2010 was 2.4% per year. Agricultural production declined only in 2010 due to the abnormal drought. In that year, agricultural production declined by 11.3%.

Despite growth in domestic agriculture, import growth continued; a consequence of the real appreciation of national currency, growth in real disposable incomes, and an increase in domestic prices for agricultural products. In terms of value meat, dairy products and raw sugar are the most import-sensitive commodities.

During 2008–2010, the values of agricultural and food imports reached a record level. The average annual value of agricultural and food imports for this period totaled to 31.8 billion dollars. This is almost 52% more in comparison with the preceding three-year period.

Russia's agro-food export has been growing along with the import increase. Since 2002, Russia has been one of the largest suppliers of grain in the world market. In addition, the modernization of the food industry contributed to increasing Russia's export of beer, ice cream, dairy and meat products. Increasing exports reflect an increasing competitiveness of the domestic food industry and positively influence on agricultural producers incomes.

*Figure 6.* Per capita GDP (constant 2000 US$) and share of GDP from agriculture



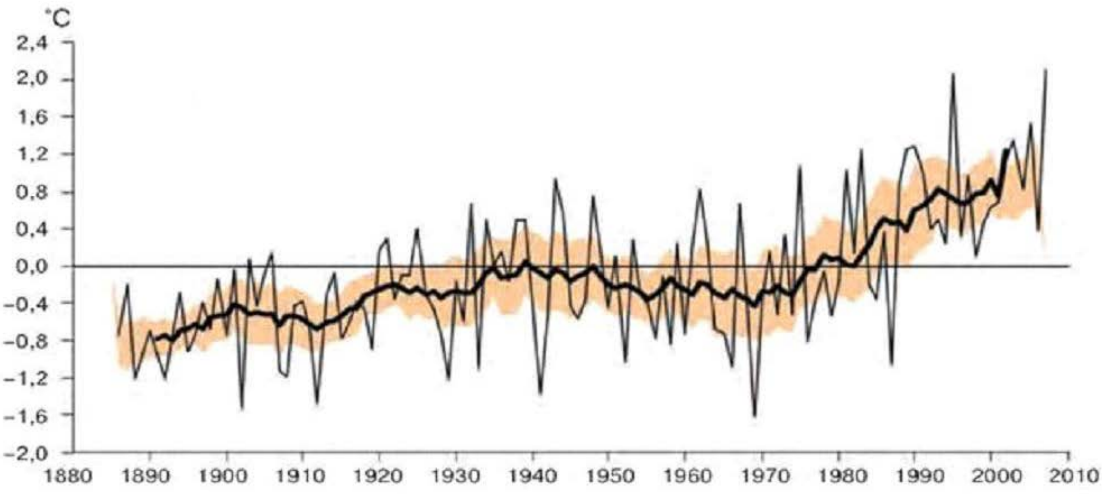

Source: World Development Indicators (World Bank 2012).

### *Climate Changes*

Climate change is clearly visible in Russia, as can be seen in the increase of average annual temperature (Figure 7) and precipitation. According to Roshydromet, between 1997 and 2006 the average temperature increased by 1.29°C in Russia, an increase that is almost twice as large as that for the world as a whole. This warming is more obvious in the spring and in the autumn.

The growing season has increased and the agricultural zone extended due to warming. However there are also the negative consequences of warming, especially the expansion of areas of plant pests and diseases. And according to the British ecologists, permafrost thawing may cause an additional emission of 85 billion tons of greenhouse gases in the atmosphere.[2] Compared to the total of 13 billion tons currently released into the atmosphere, the additional emissions from permafrost thawing would undoubtedly have serious consequences.

*Figure 7*. Temperature deviation from the average temperature of 1961–1990 in Russia (ºC)




Source: The RF Federal Meteorological Service data.
The smoothed curve was obtained by 11-year run averaging.

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2 All-Russia Ecological Portal (http://ecoportal.su/news.php?id=56271).

Warming will result in a longer fire season as well as increased intensity of forest fires. The RF Ministry of Emergency Situations estimates that the fire season in the middle latitudes of Russia may increase by 30–40% or by 50–60 days based on existing rates of warming. As a result of forest fires, the depth of soil frost penetration will increase, the surface drain and water erosion in vast territories will become larger, and the probability of floods will increase as a result of both plentiful precipitation and fast snow thawing. These processes will impact negatively on agricultural production and fertility of soils.

In addition to temperature, rainfall is important for agricultural production. By and large recent changes have been favorable for Russia – annual rainfall increased by 7.2 mm per 10 years over 1976–2006. This trend remained unchanged in 1976–2010, and annual rainfall increased by 8.5 mm per 10 years. From 1936, annual rainfall increased in the 50s, drier conditions prevailed in the mid-60s – 70s, and from the mid-70s an increase of annual rainfall has been observed.

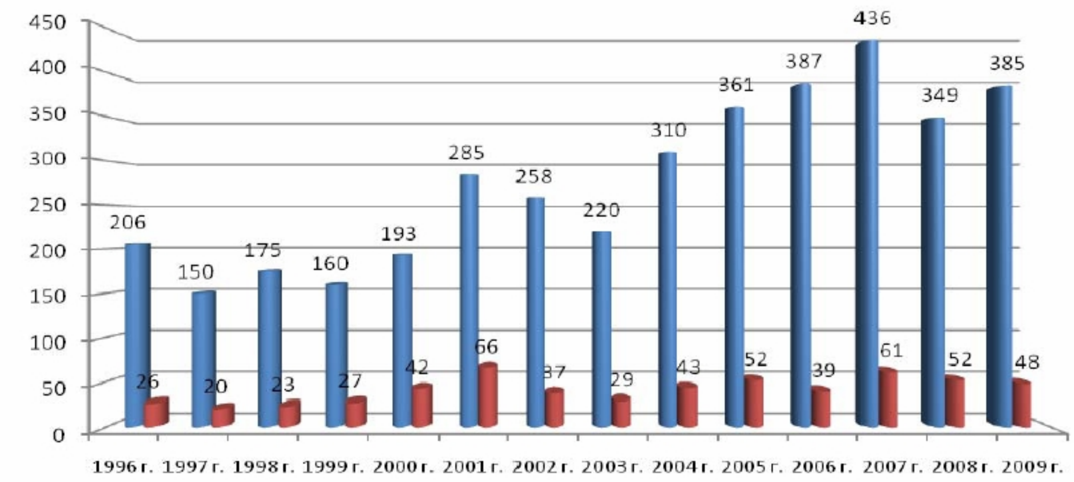
There are differences between seasons however. There is a distinct increase of precipitation amount in spring, a smaller increase in fall and winter, and no change in summer. The summer linear rainfall trend coefficient was 0.33 mm/month during the 10 year period from 1976 to 2009, and even became negative over 1976–2010 period, –0.01 mm/month per 10 years due to abnormal drought in 2010.

Thus, increase of spring precipitation in the vast territory of Russia has caused stronger spring high waters and floods. For the summer period the amount of precipitation changed little. In combination with higher temperatures, the result is adverse drying conditions for agricultural production in the summer.

Besides the droughts climate changes are also reflected by an increase of other dangerous meteorological events, such as high water, squalls, hails, sleet, hard frosts, heavy rains, and hurricanes (Figure 8).

According to the RF Ministry of Emergency Situations, 297 dangerous meteorological events were observed in 2011. This number exceeds the mean annual values of 262 dangerous meteorological events by 13.3% but is 36% less than the values of 2010 (467 dangerous meteorological events). As a whole the year 2010 was abnormal in terms of the dangerous meteorological events number, caused damages. As a rule, the greatest numbers of dangerous meteorological events in the Russian Federation occur during the period from May to August.

*Figure 8*. Annual numbers of dangerous meteorological events in the Russian Federation (blue – all events, red – unforeseen events) (in numbers)




Source: RF Federal Meteorological Service data.

Such activities as agriculture, transport, energy and power supply, housing and communal services experience the most negative influence of dangerous meteorological events. The annual damage from the impact of dangerous meteorological events in Russia estimated up to 60 billion rubles[3] (about 2 billion dollars). The tendency of increase of dangerous meteorological events will remain in the future, therefore losses from the hydrometeorological events will raise and expand to more and more territories.

As far as water resources is concerned, the popular belief is that Russia has water in abundance, and in the long term it can serve as a source of water resources for other countries. Lake Baikal is often mentioned in this context. As noted in Roshydromet publications, the increase in renewable water resources by 8–10% is expected in Russia. Taking into account decrease in population, water endowment per one inhabitant will increase by 12–14%.

However, this water endowment is shared very unequally among the regions. Increased water endowments will occur in the North and the Northwest of the

[3] See Korshunov et al. (2010).

European Russia, the Volga region, the Non-Black Soil Center of Russia, the Urals, and also the most part of Siberia and the Far East. Today these regions have more than 95% of water resources of the country.

At the same time a reduction of water resources by 5–15% and increase demand is expected in many densely populated regions (Central and Black Soil Zone, the South of Russia, the North Caucasus, the South of Siberia) that are already experiencing water shortages. As a result of climate change, accompanied by demographic shifts, the inequality of water resource distribution will increase. Water shortages will likely increase in the regions where the main part of crop production is located.

Thus, climate change will have both positive and negative effects on Russian agriculture. In spite of the fact that agricultural potential of many territories not currently suitable for agriculture now may increase in the future, the main agricultural areas will lose their positions unless serious adaptation measures are undertaken.

### *Vulnerability*

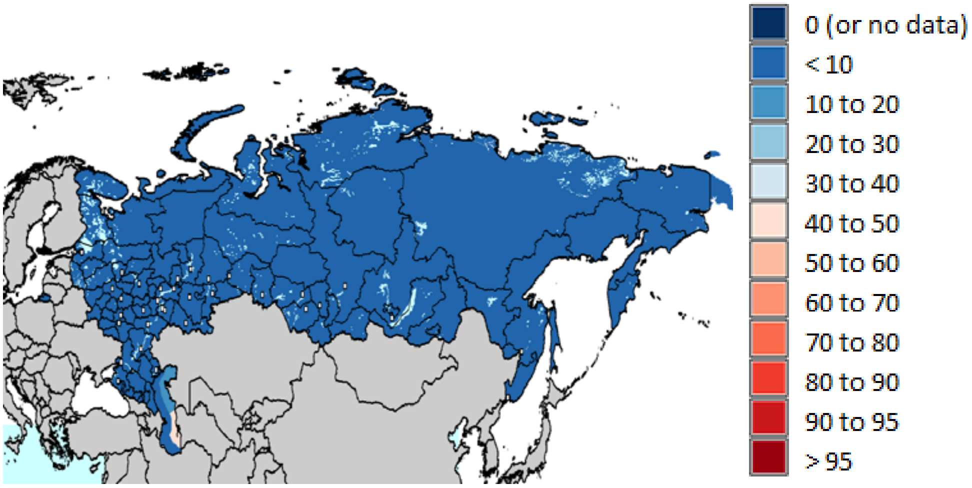
Vulnerability is the lack of ability to recover from a stress. Poor people are vulnerable to many different kinds of stresses because they lack the financial resources to respond. In agriculture, poor people are particularly vulnerable to the stresses of an uncertain climate. In this report the focus is on income, both level and sources. At the national level, vulnerability arises in the interactions among population and income growth and the availability of natural and manufactured resources. National per capita income statistics reported above show averages, but potentially conceal large variations across sectors or regions.

Figure 9 shows the distribution of the proportion of the population living on less than $2.00 per day. In Russia less than 10% of people can be considered as poor taking into account such criteria.

However, to characterize poverty in Russia another criterion is used in the national socio-demographic statistics. According to Russia's socio-demographic statistics, poor people are those, whose income is less than minimum cost of living (poverty line). Poverty lines are different across the regions. Average Russia's poverty line measured in dollars for 2008–2010 are presented in Table 2. The number of people with incomes below the poverty line is shown in Figure 10.

According to Figure 10, the number of poor people has declined steadily. 18.1 million persons or 12.8% of Russia's population had incomes below the poverty line in 2010. About 58% of poor people live in urban areas, while 42% live in rural areas.

*Figure 9.* Poverty (percent below US$2 per day)



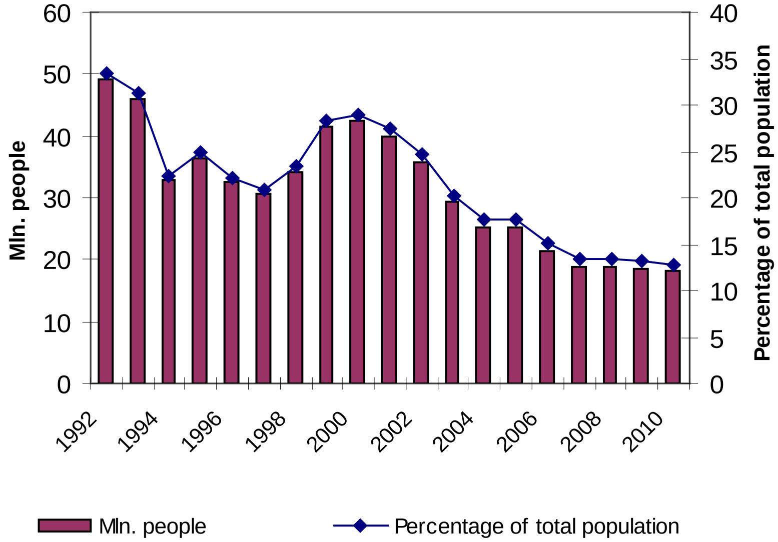

Source: Wood et al. (2010) available at labs.harvestchoice.org/2010/08/poverty-maps.

*Table 2.* Poverty lines in Russia (average per capita, dollars per month)

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| For all socio-demographic groups | 185.1 | 162.7 | 187.4 |
| For specific socio-demographic groups | | | |
| – working-age population | 200.4 | 175.9 | 202.2 |
| – pensioners | 146.9 | 129.4 | 148.9 |
| – children | 176.9 | 155.6 | 180.8 |
| | | | |
| Ratio of per capita income to minimum cost of living, percent | 325.3 | 326.8 | 326.2 |

Source: Calculations, based on the Russian Federation Federal State Statistics Service and Bank of Russia data.

*Figure 10.* People with incomes below the poverty line



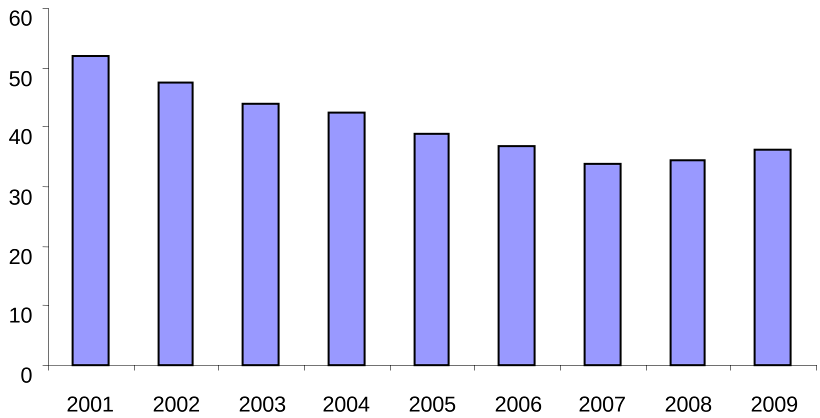

Source: Russian Federation Federal State Statistics Service.

There are significant regional disparities in terms of poverty level. The following regions of Russia are characterized by the lowest levels of poverty: Republic of Tatarstan (8.1%), Belgorod region (8.6%), The City of St. Petersburg (8.7%), Republic of North Ossetia-Alania (8.7%), and the Republic of Dagestan (9.3%). The most disadvantaged regions with high levels of poverty are the following: Republic of Kalmykia (36.2%), Republic of Tyva (26.3%), Republic of Mary El (24.5%), Amur region (24.4%), and the Altai territory (24.3%).

Low incomes, high share of food expenditure in total consumer spending (see Figure 11) and a huge differentiation in income (in 2009 the coefficient of income differentiation[4] was 16.7) indicate a high vulnerability of Russia's population to food prices shocks.

[4] The coefficient of income differentiation characterizes the degree of social stratification and is defined as the ratio between the average incomes of 10% of the population with the highest incomes and 10% of the population with the lowest incomes.

*Figure 11.* Share of food expenditures in total consumer expenditures




Source: Russian Federation Federal State Statistics Service.

Table 3 provides some data on additional indicators of vulnerability and resiliency to economic shocks: the level of education of the population, literacy, and concentration of labor in poorer or less dynamic sectors.

As for the level of primary and secondary education, Russia still holds rather high positions. The same is for high education. But the quality of education is variable, with special challenges in the rural areas.

In Russia, agriculture employs about 9% of the economically active population. Along with the reduction of rural population, growth in capital investments in the agricultural sector against the background of relatively low

*Table 3.* Education and labor statistics

| Indicator | Year | Value |
|---|---|---|
| Primary school enrollment: Percent gross (3-year average) | 2007 | 95.8 |
| Secondary school enrollment: Percent gross (3-year average) | 2007 | 84.3 |
| Adult literacy rate | 2007 | 99.5 |
| Percent employed in agriculture | 2007 | 9 |

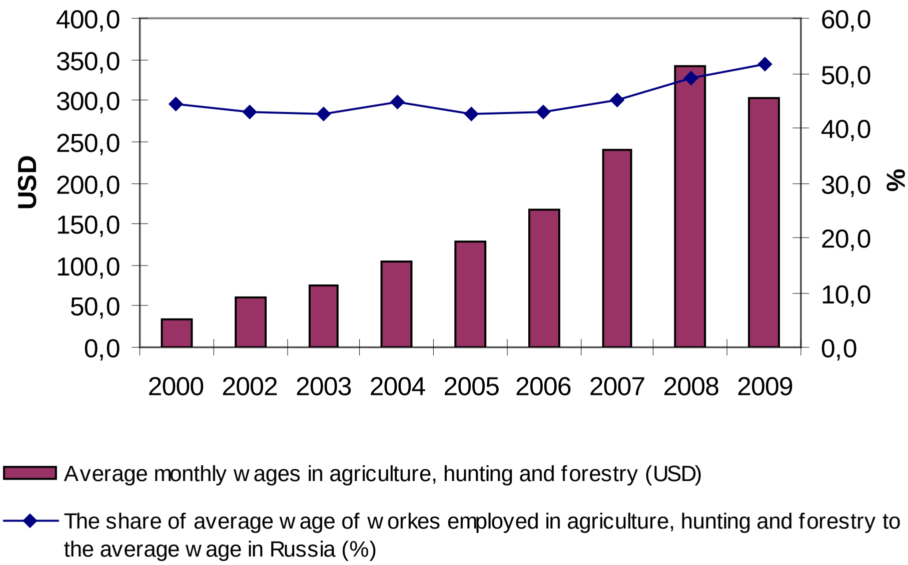
Source: World Development Indicators (World Bank 2009).

wages (see Figure 12), further declines in the number of people employed in agriculture is expected.

The outcomes of significant vulnerability include low life expectancy and high infant mortality. Figure 13 shows two non-economic correlates of poverty, life expectancy at birth and under-5 mortality.

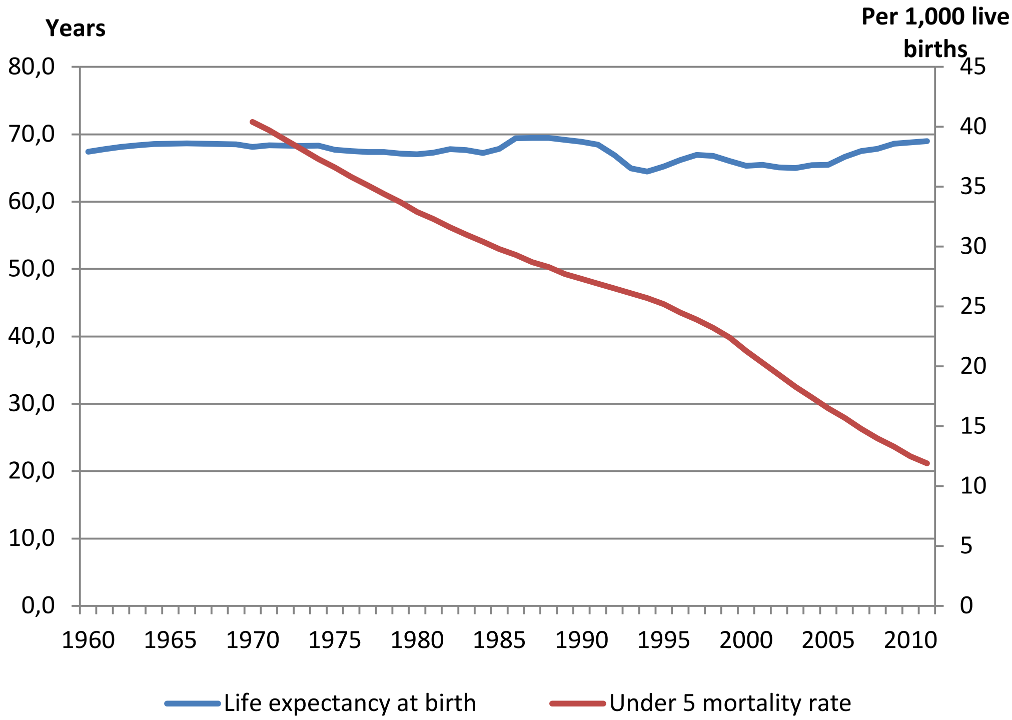
Life expectancy at birth in Russia is relatively low compared with developed countries (Figure 13). In 2010, life expectancy at birth in Russia was 69 years; for men it was only 63 years. A positive sign is the decline in the infant mortality rate.

*Figure 12.* Wages of workers employed in Russia's agriculture, hunting and forestry




Source: Russian Federation Federal State Statistics Service.

*Figure 13.* Well-Being Indicators in Russia: Life Expectancy at Birth and under 5 Mortality Rate




Source: World Development Indicators (World Bank, 2012).

## 2.2 Review of Land Use and Agriculture

Agricultural production is dependent on the availability of land that has sufficient water, soil resources and an adequate growing season.

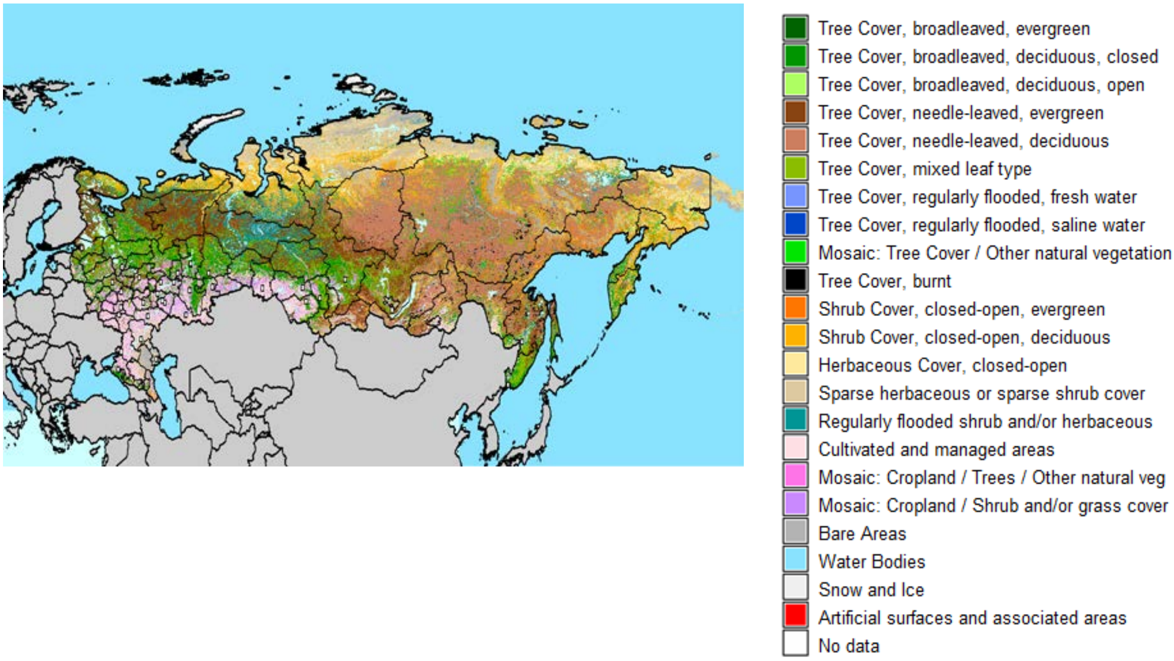
***Land Use Overview***

Russia is the most extensive country in the world. Its area reaches 1,710 million ha and occupies a large part of Eastern Europe and Northern Asia. Russia's territory is located in the arctic, subarctic and – most of it – in a temperate climatic zones. The climate is continental almost everywhere in Russia. The average annual surface temperature varies from +12÷14°C in the North Caucasus regions to –16÷–14°C in the Republic of Sakha (Yakutia). Permafrost constitutes more than 67% of Russian territory. Figure 14 shows Russia's land cover as of 2000.

The main components of the territory of Russia are forest lands and lands occupied by other vegetation (see Figure 15). Lands designated for agriculture occupy 400.0 million ha or 23.4% of the land area of Russia. In terms of agricultural production, especially valuable lands are the following types of agricultural lands: arable land, hayfields, pastures, fallow land and lands under perennial plants (orchards, vineyards, and others).

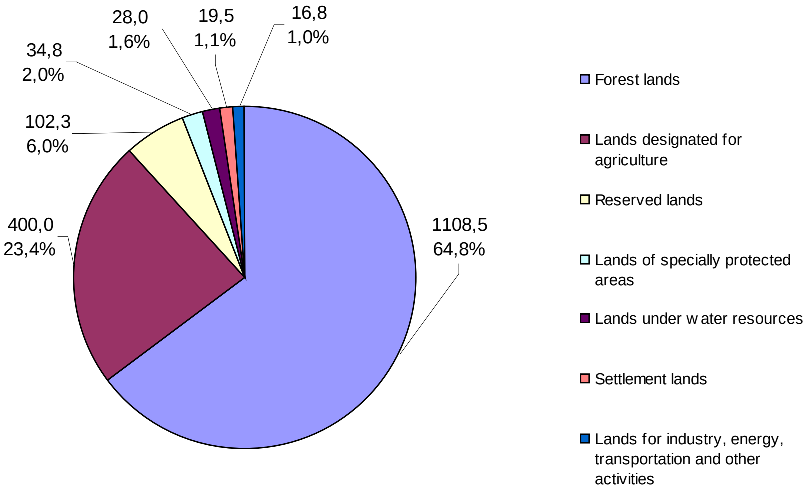
The share of agricultural land in the total is relatively small. Arable land is the most productive type of agricultural lands. The share of arable land amounts to about 7% of the total country area or 28.9% of the lands designated for agriculture (see Figure 16). However, Russia has one of the highest rates in the world supply of arable land (115.3 million ha) and arable land per capita (0.81 ha per capita).

*Figure 14.* Land cover, 2000



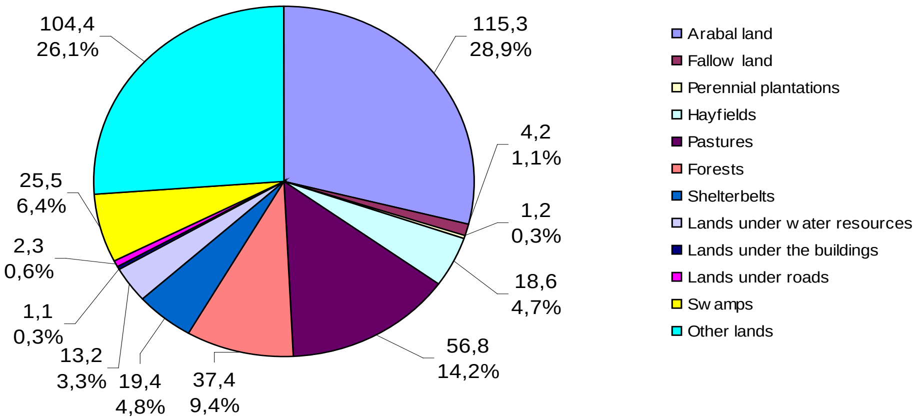

Source: GLC2000 (JRC 2000).

*Figure 15.* The composition and structure of the lands in the Russian Federation in 2010, million ha and %




Source: RF Ministry of Agriculture (2011).

*Figure 16.* The composition and structure of the lands designated for agriculture in the Russian Federation in 2010, million ha and %




Source: RF Ministry of Agriculture (2011).

As of 1 January 2010, a significant part of the lands designated for agriculture was state and municipal property – 270.7 million hectares or 67.7%. Individuals owned 119.5 million ha or 29.9%. 9.8 million hectares or 2.4 per cent of the lands designated for agriculture were in the ownership of legal entities.

By the beginning of 2010, agricultural enterprises and individuals used more than 190.7 million hectares or 86.5% of agricultural lands from all land categories. To produce agricultural products 64.4% of agricultural lands were used by agricultural enterprises, and 35.6% by individuals.

One of the main directions of the agricultural policy of the Russian Federation is to increase soil fertility and crop yields. Currently, soil quality continues to decrease. The annual removal of nutritive materials from the soils due to agricultural activity is three times higher than mineral and organic fertilizers application. Applications of organic and mineral fertilizers are less than 10% (53–54 million tons) and 30% (2.3 million tons) of science-based requirements respectively.

The use of mineral fertilizers per hectare of agricultural crops is increasing (Figure 17) but less than a half of agricultural lands are fertilized and fertilizer doses remain low. This situation threatens the sustainability of land-use due to a permanent decrease in natural soil fertility.

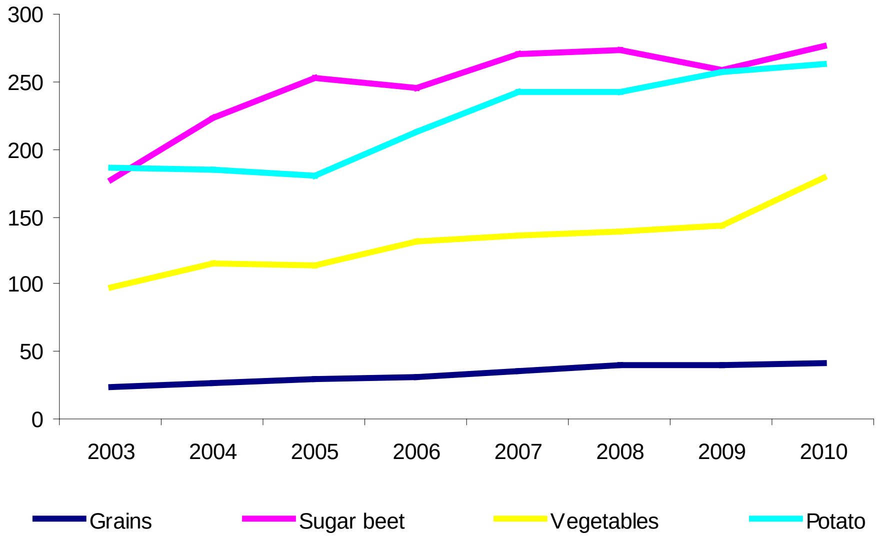
In order to preserve, restore and improve soil fertility Russia provides some fertilizer subsidies. Investments in land improvements are funded by regional authorities and agricultural producers. However, the funds for such activities continue to decrease due to a systematic reduction of regional budgets and the lack of financial resources of agricultural producers.

Russian agriculture operates in complicated natural and climatic conditions:

- 80% of arable lands are located in areas of unstable and insufficient moisture,
- over 10% of arable lands are located in areas of redundant moisture.

Reclaimed areas are of special value in these conditions, as their use facilitates stable crops production. Nowadays there are only 9m ha of reclaimed areas in Russia, 4.25m ha of which are irrigated, and 4.75m ha are drained.

*Figure 17.* Application of mineral fertilizers for agricultural crops, kg/ha




Source: RF Ministry of Agriculture (2011).

Reclaimed areas cover 8% of total cropland area and produce about 15% of gross crop production. Up to 70% of vegetables, all rice, more than 20% of succulent feeds, fodder and other products are produced on reclaimed.

As a result of the recent socioeconomic crisis about 1.9m ha of irrigated areas have been lost. Construction of new irrigation and drainage systems was virtually stopped. The technical state of reclamation system has also become worse. As a consequence of defective farm-irrigation systems, irrigation is absent on more than 1.8m ha of irrigated area or on more than one third of them.

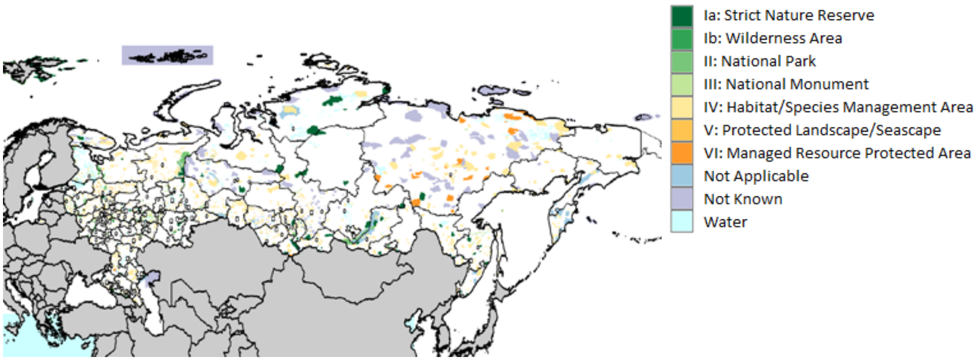
The estimated cost of irrigation system improvements is 6–8bn rubles, while actual financing is only 1.5–2bn rubles. The cost of needed current repairs is estimated at 2bn rubles with actual financing of only 0.3–0.6bn rubles. In these conditions the restoration of amelioration systems is a priority among the other measures for adaptation to climatic changes.

Thus, to ensure the sustainability of agricultural production on existing irrigated lands it is extremely important to provide necessary investment in reconstruction and modernization of hydraulic structures and expenditures on maintenance of on-farm irrigation systems.

Figure 18 shows the locations of protected areas, including parks and reserves. These locations provide important protection for fragile environmental areas, which may also be important for the tourism industry. Such non-agricultural activity is essential for providing the sustainability of development in some rural areas.

Urban areas provide potential markets for agricultural products. Policy makers need to keep in mind the importance of transport costs when considering agricultural expansion; that is, if fertile but unused land is far from markets, it represents potential land for expansion only if transportation infrastructure is put in place, and if the land does not conflict with preservation priorities seen in Figure 18.

*Figure 18*. Protected areas




Source: World Database on Protected Areas (UNEP 2009). Water is from Global Lakes and Wetlands Database (WWF) (Lehner and Döll 2004).

### *Agriculture Overview*

Table 4 to Table 6 show key agricultural commodities in terms of area harvested, value of the harvest, and food for people (this last item was ranked by weight) for the period centered around 2006–2008. Wheat, barley, sunflower seed are the most important crops in terms of area harvested. These three crops use more than 70 % of total harvested area. Potatoes, wheat and tomatoes retain the top three positions in terms of value of production. Barley is the fourth most important crop.

*Table 4.* Harvest area of leading agricultural commodities, average of 2006–2008

| Rank | Crop | % of total | Area harvested (000 hectares) |
|---|---|---|---|
| 1 | Wheat | 43.90% | 24,207 |
| 2 | Barley | 16.60% | 9,126 |
| 3 | Sunflower seed | 10.20% | 5,642 |
| 4 | Oats | 6.10% | 3,346 |
| 5 | Potatoes | 4.80% | 2,637 |
| 6 | Rye | 3.60% | 1,967 |
| 7 | Maize | 2.40% | 1,333 |
| 8 | Buckwheat | 2.00% | 1,091 |
| 9 | Sugar beet | 1.70% | 910 |
| 10 | Soybeans | 1.40% | 744 |
| | Total | 100.00% | 55,102 |

Source: FAOSTAT (FAO 2010).

*Table 5.* Value of production for leading agricultural commodities, average of 2006–2008

| Rank | Crop | % of total | Value of Production Value of Production (million US$) |
|---|---|---|---|
| 1 | Potatoes | 26.0% | 7,962.7 |
| 2 | Wheat | 19.8% | 6,071.4 |
| 3 | Tomatoes | 8.9% | 2,720.2 |
| 4 | Barley | 6.5% | 1,985.0 |
| 5 | Cucumbers and gherkins | 5.4% | 1,662.8 |
| 6 | Sunflower seed | 5.0% | 1,528.5 |
| 7 | Sugar beet | 3.0% | 1,066.0 |
| 8 | Cabbages and other brassicas | 2.9% | 875.2 |
| 9 | Apples | 2.7% | 826.1 |
| 10 | Vegetables fresh nes | 1.9% | 583.9 |
| | Total | 100.0% | 30,642.8 |

Source: FAOSTAT (FAO, 2010).

*Table 6*. Consumption of leading food commodities, average of 2003–2006

| Rank | Crop | % of total | Food consumption(000 mt) |
|---|---|---|---|
| 1 | Wheat | 27.53% | 18,999 |
| 2 | Potatoes | 27.15% | 18,736 |
| 3 | Other Vegetables | 14.16% | 9,768 |
| 4 | Sugar Refined Equiv | 8.23% | 5,676 |
| 5 | Root Tuber Dry Equiv | 5.43% | 3,747 |
| 6 | Tomatoes | 4.22% | 2,913 |
| 7 | Other Fruits | 4.19% | 2,891 |
| 8 | Apples | 3.86% | 2,662 |
| 9 | Onions | 3.15% | 2,175 |
| 10 | Sunflower seed Oil | 2.08% | 1,434 |
| | Total | 100.00% | 69,001 |

Source: FAOSTAT (FAO, 2010).

A substantial part of agricultural output (47.1%) is produced by household plots. Household plots mainly specialize in labor-intensive crop production (potatoes, vegetables), meat and milk (about 50% of gross output of these products), wool (60% of wool gross output), eggs (25% of eggs gross output). The shares of agricultural enterprises and private farms account for 45.4% and 7.5% of total agricultural production respectively.

Wheat, potatoes and vegetables are the three top food commodities in terms of consumption. These commodities account for more than 50 percent of total volume of food consumption.

The Food Security Doctrine of the Russian Federation defines that the share of domestically produced plant agricultural products in their total supply should be:

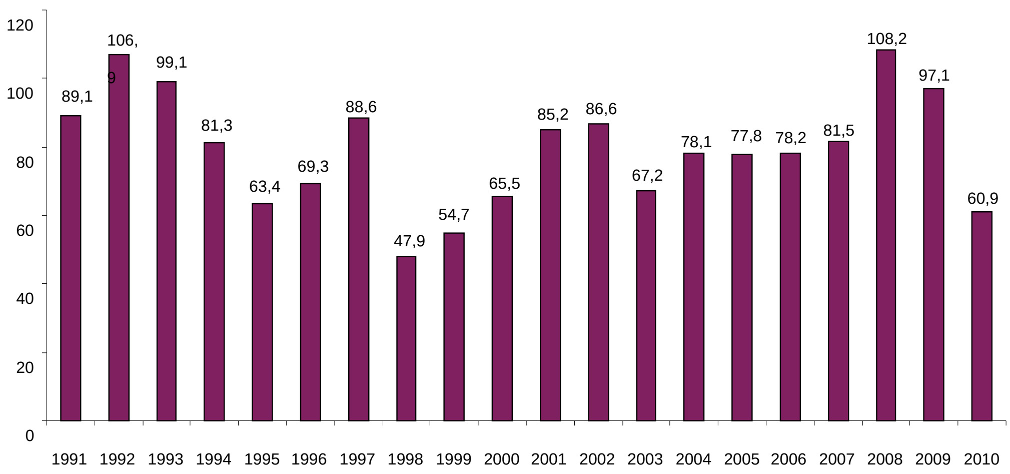
- grains – not less than 95%,
- sugar – at least 80%,
- vegetable oil – at least 80%,
- potatoes – not less than 95%.

*Grains*. Grain is an important product for the provision of food security, self-sufficiency and agricultural export supply. Grain production is about 16% of gross agricultural output. Grain crops occupy about 60% of the cultivated area.

Since the early 90s and until the financial crisis of 1998, there was a reduction in sown area, grain yields and gross output. Subsequent economic growth contributed to the increase of gross output of grains. Since the beginning of 2000, Russia transformed from a net importer to a net exporter of grains. In 2008, Russia had the highest harvest since 1991 (see Figure 19).

Along with the reduction of grain production in 1990s, there was an increase in the coefficient of variation (CV)[5] of gross grain production (Figure 20). This causes serious problems for the coherent development of the livestock industry, processing and export orientation of the grain sector. The maximum value of the CV was in 1990–2000 (27.5%). Since 2000, the variability of crop yields has declined. However, the CV is still relatively high compared to its lowest values observed in the 1980s. The main reasons for this are the lack of modern agricultural machinery and significant reduction in application of mineral fertilizers.

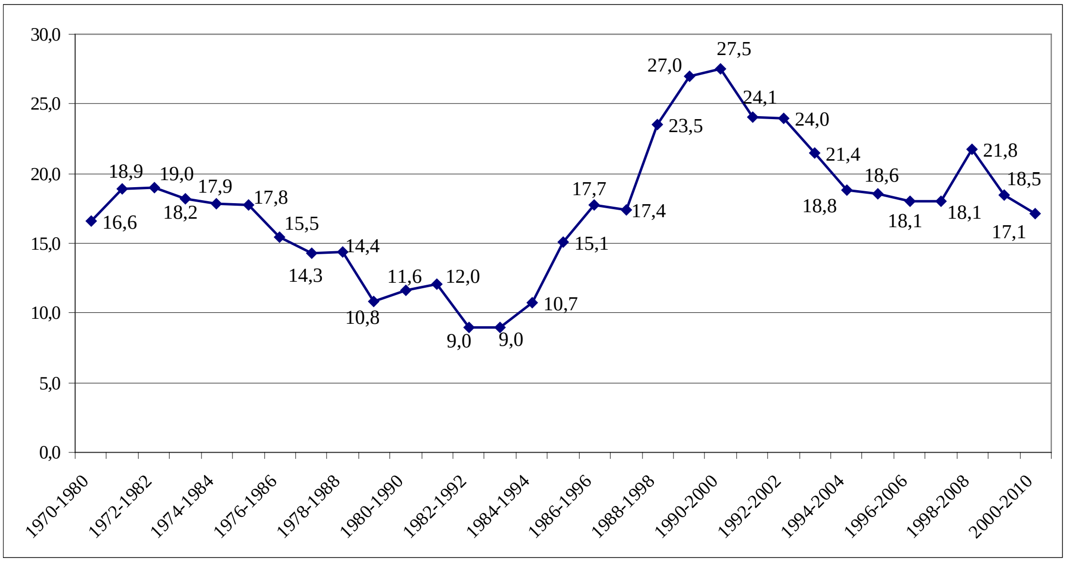
*Figure 19.* Gross grain harvests in Russia, million tons




Source: Russian Federation Federal State Statistics Service.

[5] The coefficient of variation is obtained by dividing the standard deviation into of the mean value of grain production.

*Figure 20.* Coefficients of variation of grain production In Russia in 1970–2010, %

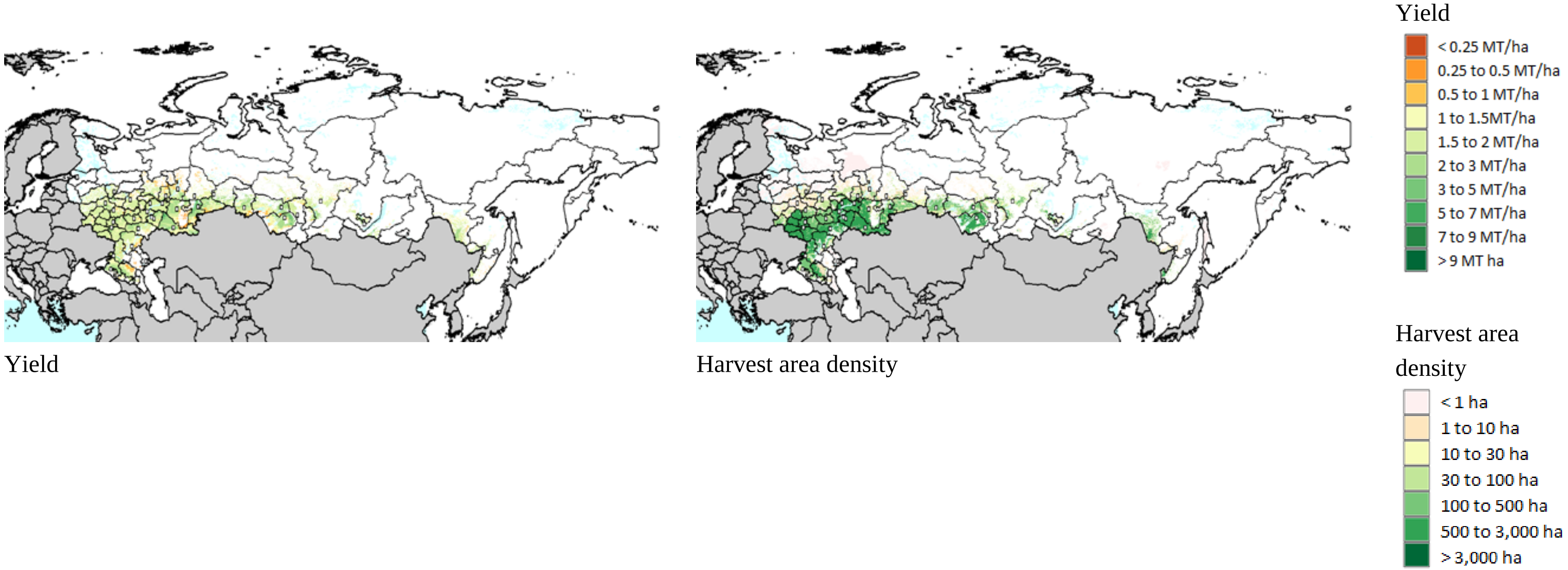



Source: Calculated using the data of Russian Federation Federal State Statistics Service.

Wheat is the main type of grain produced in Russia. It accounts for more than 60% of grain output. Figure 21 and Figure 22 show the estimated yield and growing areas for rainfed and irrigated wheat in 2000. These figures are based on the SPAM (Spatial Production Allocation Mode) data set (Liangzhi You, Wood, and Wood-Sichra 2009), a plausible allocation of national and subnational data on crop area and yields. As a general observation, Russian wheat production is concentrated in the south of the country. Currently, the largest wheat producers are Krasnodar region, Stavropol region, Rostov region, Altai Territory, Republic of Tatarstan, Republic of Bashkortostan, Volgograd region, and Saratov region. Traditionally, high yields of wheat are collected in Omsk and Novosibirsk regions (the south of Siberia).

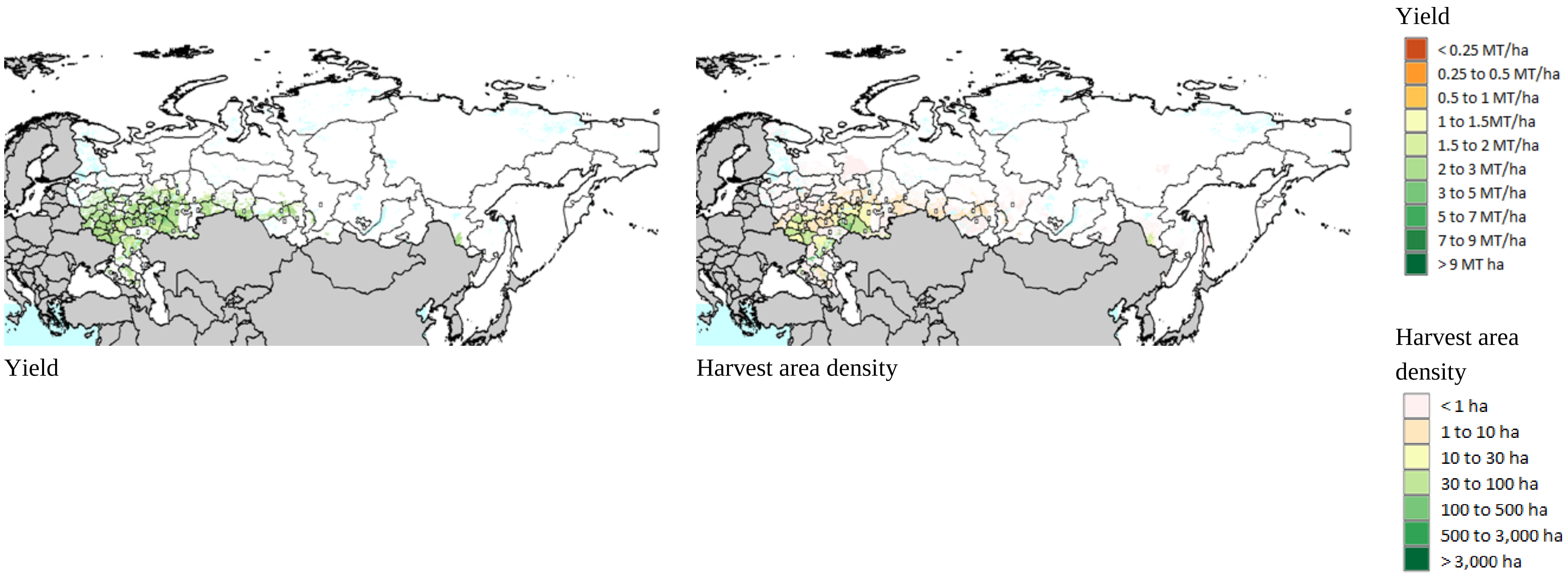
The use of grain for fodder is the main expenditure item in the grain balance sheet. By 2000, consumption of grain used for fodder declined by nearly 40 million tons or about 50% compared to 1990. This is due both to the reduction of livestock and poultry, as well as increases in efficiency of feed utilization.

*Figure 21.* 2000 Yield and harvest area density for rainfed wheat




Source: Based on the SPAM (Spatial Production Allocation Mode) data set (Liangzhi You, Wood, and Wood-Sichra 2009).

*Figure 22*. 2000 Yield and harvest area density for irrigated wheat




Source: Based on the SPAM (Spatial Production Allocation Mode) data set (Liangzhi You, Wood, and Wood-Sichra 2009).

However, since 2007 there has been an increase in grain consumption as a result of growth in poultry and pig production. In the long run, development of the livestock industry will require further increases of grain production.

Since 2000, Russia has become a net exporter of grain with record export volumes (21.8 million tons) in 2009.

Grain generally has the largest share in the value of the agro-food exports from Russia. However, in 2008 and 2010, exports of grain were significantly below its potential volumes due to the use of export restrictions. Thus, grain export regulation is directly dependent on the availability of grain in the domestic market. In the case of an excess grain production, export support is carried out in the form of providing the preferential terms for rail transportation of grain.

The following factors hamper the development of export:

- instability of grain production,
- the lack of transportation infrastructure development,
- the lack of port and terminal infrastructure development,
- low technological level of grain elevators.

Another distinctive feature of the grain market is the use of state purchase and commodity interventions to limit price volatility. The most significant volumes of state grain purchases took place in 2008–2009. At that time the state purchased 9.6 million tons of grain. Conducting procurement interventions aims at removing the excess volume of grain from domestic market and thereby at supporting the producers of grains. State commodity interventions, carried out in lean years, aimed at supporting the livestock producers and grain processors.

*Sugar*. The sugar market also has a certain specific. Despite the overall decline in sugar production, the share of sugar produced from sugar beet is growing, reaching a record level of 65.5% in 2008. The dynamic growth of sugar production from domestic raw is due to the following factor:

- active use of state instruments of foreign trade protectionism in order to replace imported raw materials with domestic ones;
- increasing the productivity of the sugar industry (in 2009, output of sugar from sugar beets reached a record level of 15.02%);

- increase in acreage of sugar beets.

Russia is among the top three world producers of sugar beets. A good harvest in 2008 contributed to the fact that Russia took the 2nd position in the world after the EU. Sugar beet areas are concentrated in Krasnodar, Kursk, Voronezh, Belgorod and Tambov regions. The share of these regions in total sugar beet production accounts for more than 60 percent. Also significant volumes of sugar beet are produced in the Republics of Bashkortostan and Tatarstan.

The existing capacity of the sugar processing industry could meet domestic consumption needs for sugar. However, imports of raw sugar form a significant part of sugar resources in the Russian market. Raw sugar is imported due to the lack of domestic raw materials for sugar processing.

Russia is a net importer of raw sugar (see Table 7). The Government of Russia uses a floating duty on imports of raw sugar that is tied to the world price (defined as the price at the New York Commodity Exchange).

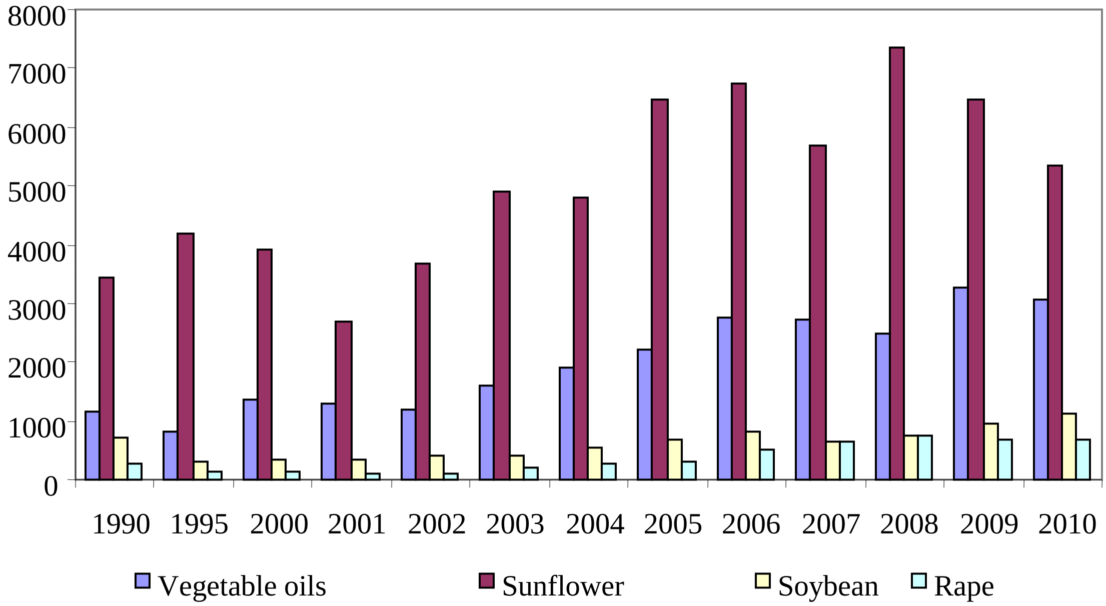
The Republic of Belarus remains the main supplier of white sugar to Russia. In 2007–2008, imports of white sugar was regulated by the agreement between the Government of Russia and the Republic of Belarus. Under this agreement the volume of sugar exported from Belarus to Russia in 2008 amounted to 100 thousand tons. In 2009–2010, the agreed volumes of sugar exported to Russia was increased to 150 thousand tons per year. For 2011 and the following years, the supply of sugar from Belarus was increased to 200 thousand tons.

*Table 7.* Russia's import and export of sugar in 2008–2009

| | Import | | | | Export | | | |
|---|---|---|---|---|---|---|---|---|
| | 2008 | | 2009 | | 2008 | | 2009 | |
| | Volume | Value | Volume | Value | Volume | Value | Volume | Value |
| | 1000 t | mln USD | 1000 t | mln USD | 1000 t | mln USD | 1000 t | mln USD |
| Raw sugar | 2419.9 | 944.2 | 1253.3 | 507.3 | 53.5 | 25.3 | 133.7 | 56.7 |
| White sugar | 165.1 | 87.4 | 258.9 | 147.3 | | | | |

Source: Russian Federation Federal State Statistics Service.

*Figure 23*. Production of oil seeds and vegetable oils in Russia in 1990–2010, thousand tons




Source: Russian Federation Federal State Statistics Service.

*Oilseeds and vegetable oil.* Russia is the world leader in the production of sunflower seeds and sunflower oil. However, strengthening of Russia's position in the world market of vegetable oils began only in 2007. The share of sunflower seeds in total production of oil-yielding crops is about 75–80%. Production of rape and soybean has been increasing gradually (see Figure 23).

Production of vegetable oils in Russia reached 3.07 million tons in 2010. From 2002 to 2010, production of vegetable oils had increased by more than 2.5 times due to the policy to encourage domestic producers by raising import duties on vegetable oils in 2002. Rostov region and Krasnodar territory are the leading producers of vegetable oils in Russia.

Export values of vegetable oils significantly exceed values of oilseeds exports (see Table 8). Development of oilseeds export is limited by the application of 20% export duty. Since 2009, rape seed export has exceeded export of sunflower seeds.

Soybeans account for most of the oilseeds imports. Traditionally Russia exports mainly sunflower oil and imports tropical oils.

The main trends in the market of vegetable oils are the following:

- increasing consumption of sunflower oil,
- increasing prices for vegetable oils,
- increasing consumption of vegetable oils (palm, coconut, olive oils) that have not traditionally been consumed in Russia.

*Potatoes*. Russia is the second largest producer of potatoes after China. Currently, more than 80% of potatoes are produced by household plots. The share of imported potatoes in its total supply is less than 2%. Imports of potatoes are seasonal. Potatoes are produced in all regions. Republics of Bashkortostan and Tatarstan are the leading potato producers in Russia.

Thus the main markets for crops in Russia have certain peculiarities. Based on the availability of land and human resources, Russia is able to meet the domestic demand for the main crops by domestic production. Part of crop output can be exported. However, sustainable development of exports requires the development of market infrastructure to ensure the competitiveness of domestic production in the world market.

The most successful regions form a rather compact area of agricultural production from the Belgorod region and Krasnodar territory through the Volga

*Table 8.* Russia's import and export of oil seeds and vegetable oils in 2008–2009

| | Import | | | | Export | | | |
|---|---|---|---|---|---|---|---|---|
| | 2008 | | 2009 | | 2008 | | 2009 | |
| | Volume | Value | Volume | Value | Volume | Value | Volume | Value |
| | 1000 t | mln USD | 1000 t | mln USD | 1000 t | mln USD | 1000 t | mln USD |
| Oil seeds | 693,9 | 574,4 | 1070,8 | 674,1 | 198,1 | 88,1 | 334,5 | 110,9 |
| Sunflower | 11,8 | 80,7 | 13,0 | 81,0 | 85,0 | 29,7 | 103,1 | 28,2 |
| Soybean | 561,6 | 326,6 | 959,3 | 442,9 | 4,5 | 1,2 | 1,8 | 0,5 |
| Rape | 7,2 | 12,2 | 0,5 | 4,6 | 48,1 | 24,4 | 128,4 | 43,0 |
| Vegetable oils | 1131,2 | 1404,5 | 751,9 | 747,4 | 603,3 | 803,5 | 985,1 | 775,1 |

Source: Russian Federation Federal State Statistics Service.

region and Southern Urals to the Altai region. Outside of this area relatively successful centers of agricultural production are concentrated in Moscow, Leningrad, Nizhny Novgorod and Sverdlovsk regions, as well as in the Republics of Tatarstan and Bashkortostan. Half of the total increase in agricultural output in recent years produced only 15 regions. With all this going on in the southern regions from 50 to 75% of agricultural enterprises operate successfully, while at the periphery of the black soil zone of Russia only 25% or less of enterprises are relatively successful. In the areas with unfavorable climate conditions only agricultural enterprises located in the suburbs have relatively high level of development.

In many regions, including the north-west and central regions the depression of agriculture outside of suburban areas is a result of the reduction of working age people and underdeveloped social and engineering infrastructure in rural areas.

Long-term risk for the development of agrarian sector is the increase in the number of older people and reduction of the population. With the general reduction of the proportion of rural population, its absolute reduction will occur more rapidly.

## 3 Scenarios for Adaptation

In this section, the current status of the country with respect to vulnerability is reviewed. This includes a brief overview of current population trends, per capita income growth and its distribution, and the state of agriculture.

To better understand the possible vulnerability to climate change, it is necessary to develop plausible scenarios. The Millennium Ecosystem Assessment's Ecosystems and Human Well-being: Scenarios, Volume 2, Chapter 2 provides a useful definition: “Scenarios are plausible, challenging, and relevant stories about how the future might unfold, which can be told in both words and numbers. Scenarios are not forecasts, projections, predictions, or recommendations. They are about envisioning future pathways and accounting for critical uncertainties” (Raskin et al. 2005).

For this report, combinations of economic and demographic drivers have been selected that collectively result in three global pathways – a baseline scenario that is “middle of the road”, a pessimistic scenario that chooses driver combinations that, while plausible, are likely to result in more negative outcomes for human well-being, and an optimistic scenario that is likely to result in improved outcomes relative to the baseline. These three overall scenarios are further qualified by four climate scenarios: plausible changes in climate conditions based on scenarios of greenhouse gas emissions.

## 3.1 Biophysical Scenarios

This section presents the climate scenarios used in the analysis and the crop physiological response to the changes in climate between 2000 and 2050.

***Climate Scenarios***

As mentioned in the introduction, we used downscaled results from 4 GCMs with 2 SRES scenarios for each GCM. Figure 24 shows precipitation changes for Russia under 4 downscaled climate models with the A1B scenario.[6]

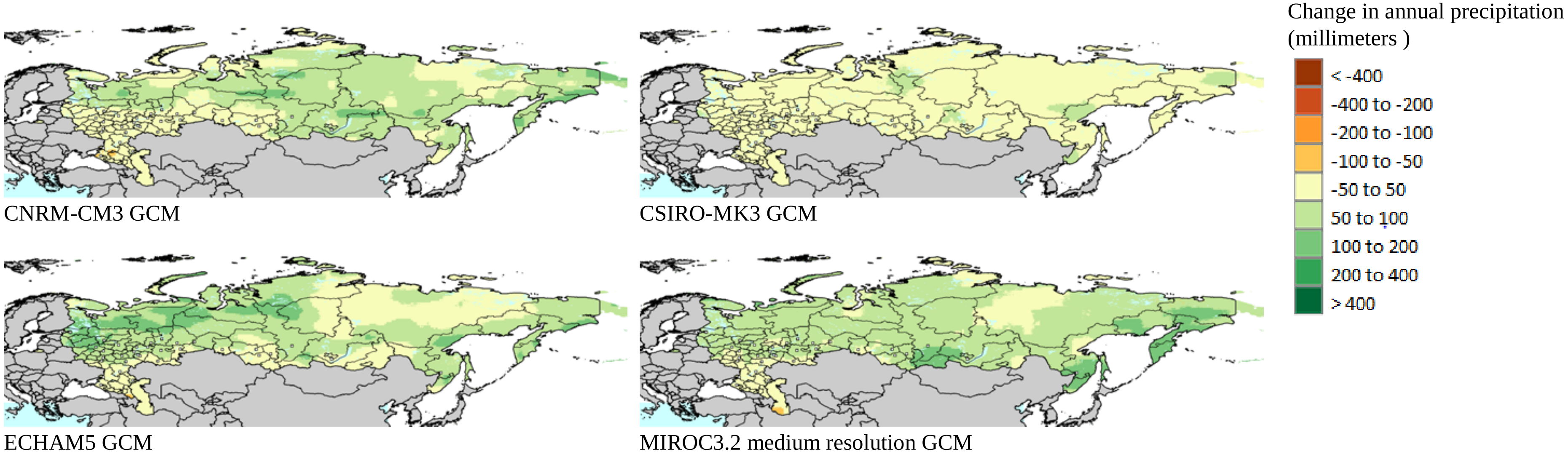
In general all models demonstrate the increase in precipitation for most parts of Russia. Minimal changes in precipitation are predicted by the CSIRO GCM. In this case, there is even a chance of precipitation decrease. The wettest national climate is from the CNRM, ECHAM, MIROC models. However, the simulations differ regionally in their precipitation patterns. In the southern regions of Russia, all models predict rather small changes in precipitation. Southern areas may face either decrease or increase in precipitation. The same situation is predicted by CNRM and CSIRO GSM for the black soil zone of Russia, the Volga regions and Southern Ural regions. The ECHAM and MIROC models' simulations resulted in wetter climate for these parts of Russia.

Thus, for Russia as a whole changes in precipitation will have no adverse effects. However, there is a probability of slight precipitation decrease in the South of Russia.

Figure 25 shows changes in maximum temperature for the month with the highest mean daily maximum temperature. All GCMs have temperature increases

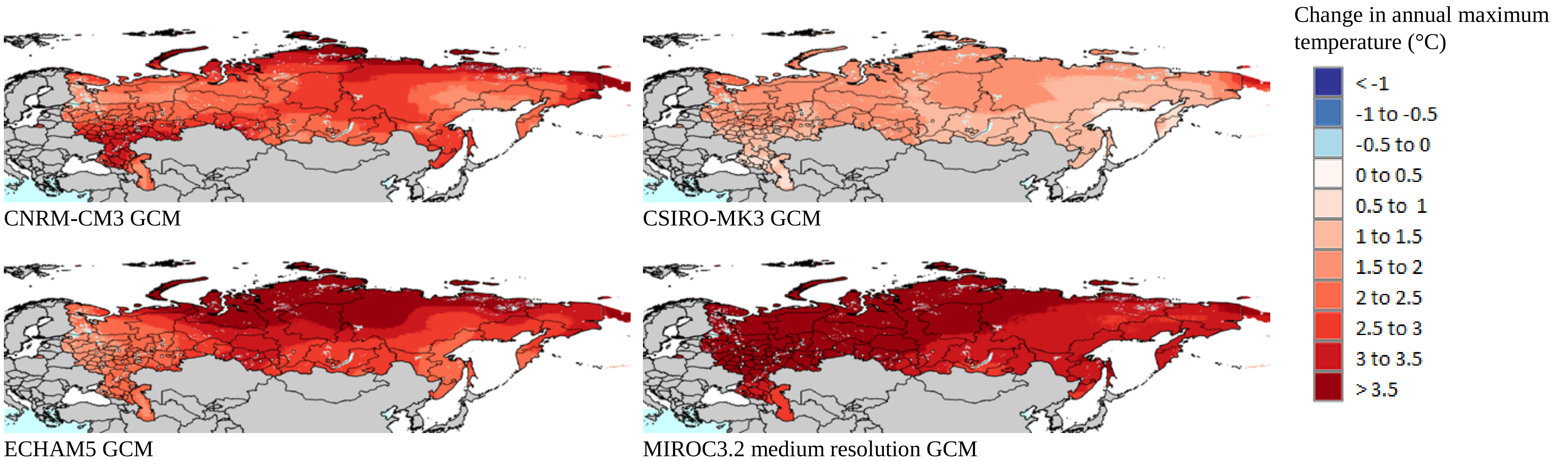
[6] The A1B scenario is described as having a balanced use of all energy sources (fossil fuels and non-fossil fuels). This scenario is characterized by rapid economic growth, increase of world population to 9 billon people by 2050 with subsequent gradual decrease, fast dissemination of new and efficient technologies, equalization of income and style of life in different regions, broad social and cultural interaction in the world.

*Figure 24*. Changes in mean annual precipitation for Russia between 2000 and 2050 using the A1B scenario (millimeters)




Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

*Figure 25*. Changes in normal annual maximum temperature for Russia between 2000 and 2050 using the A1B scenario (°C)




Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

for all parts of Russia. Minimal temperature increases are predicted by the CSIRO GCM. According to this GCM the highest maximum temperature rise occurs in the Chukotka Autonomous Okrug - the eastern region of the country. In this region the maximum temperature increases by 3–3.5°C. For most parts of the country (regions of the central zone of the European part of Russia, northern territories, and south of Western Siberia), the maximum temperature rise will be from 2 to 2.5°C. In the south of the country, Volga regions, Southern Urals regions, south of Eastern Siberia, and most territories of the Far East the temperature will increase by 1–1.5°C.

The other GCMs predict greater temperature increases. The MIROC GCM shows the highest temperature rise. In this case the temperature increase by more than 3.5°C in the western part of the country and in the northern regions. To a lesser extent (from 3 to 3.5°C) maximum temperature rises in the south of the country, Far Eastern regions and in the South of Siberia. The ECHAM GCM forecasts temperature increase as approaching to the northern latitudes of Russia. Maximum temperature growth is observed in the northern territories. In regions where agricultural production is concentrated now, the temperature rise is moderate. The CNRM GCM predicts the highest temperature growth in the extreme northern territories of Russia. Moving south, the temperature increases to a lesser extent. Nevertheless, a relatively large temperature rise is observed in the southern regions, the Black Soil regions, Southern Ural regions, the Volga regions of the country.

Hence the climate on the major part of Russia on the base of forecasts up to 2050 will be warmer and more humid. However the increase of maximum temperature may be accompanied by a reduction or small increase of rainfall on the country's south, in the Volga and Black Soil regions, and in the Southern Urals and South of Siberia. The frequency of droughts in major grain-producing regions of Russia may increase by 1.5–2 times. In these circumstances, to adapt to drier conditions, it is necessary to change the specialization of the traditional agricultural regions in the direction of expansion of drought-resistant crops, to carry out major irrigation works, and to implement technology aimed at the rationalizing use of water and land.

***Crop Physiological Response to Climate Change***

The DSSAT crop modeling system (Jones et al. 2003) is used to simulate responses of five important crops (rice, wheat, maize, soybeans and groundnuts) to climate, soil, and nutrient availability, at current locations based on the SPAM dataset of crop location and management techniques (Liang You and Wood 2006). In addition to temperature and precipitation, we also input soil data, assumptions about fertilizer use and planting month, and additional climate data such as days of sunlight each month.

The exercise is then repeated for each of the future scenarios for the year 2050. For all locations, variety, soil and management practices were held constant. We then compared the future yield results from DSSAT to the current or baseline yield results from DSSAT. The results for several rainfed key crops (wheat, maize, potato) are mapped in Figure 26 to Figure 28. The comparison is between the crop yields for 2050 with climate change compared to the yields with 2000 climate.

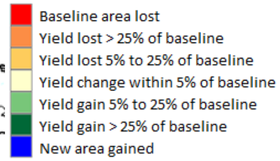
According to the simulations conducted, all GCMs demonstrate quite similar results for the rainfed crops considered. For wheat, an increase in yields (from 5 to 25%) is observed only in the regions bordering the northern part of Kazakhstan. In other regions producing wheat, there is a reduction of its yield. The largest wheat yield decline (more than 25% of the baseline) is in the Krasnodar region – currently the largest wheat producer and exporter.

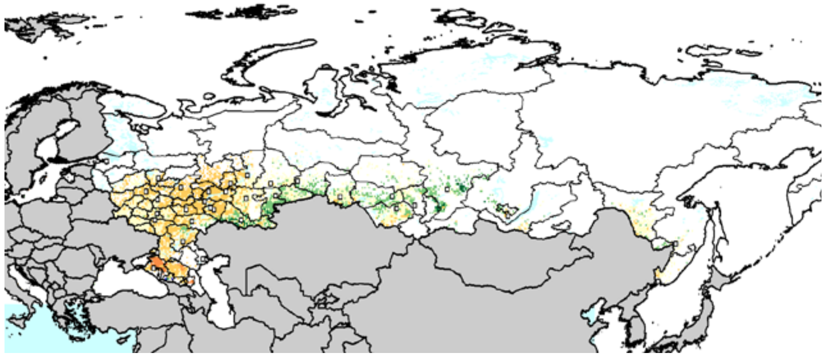
In contrast, climate change will contribute to an increase of maize yields in traditional maize growing regions. In addition, new areas of maize cultivation will appear in the south of Western Siberia. However, the CNRM GCM forecasts a significant reduction in maize acreage in the regions of the Black Soil Zone and the Southern Urals.

Potato acreage could increase north of its traditional areas of cultivation, as well as in Southern Siberia. At the same time potato yields will be less in the Black Soil Zone. In the Volga and Southern Ural regions, the GCMs give conflicting predictions. The CNRM model predicts the reduction of areas for potato growing in these regions. The CSIRO model forecasts a decline in potato yields, while ECHAM and MIROC GCMs predict a rise in potato yield in the Volga and Southern Ural regions.

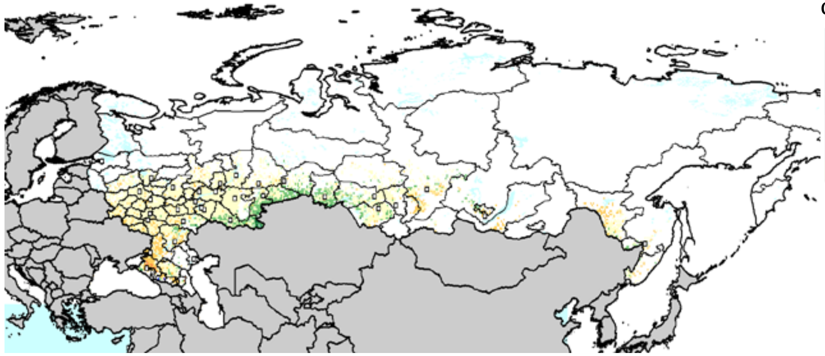
*Figure 26*. Yield change map under climate change scenarios: rainfed wheat

Legend for yield change figures

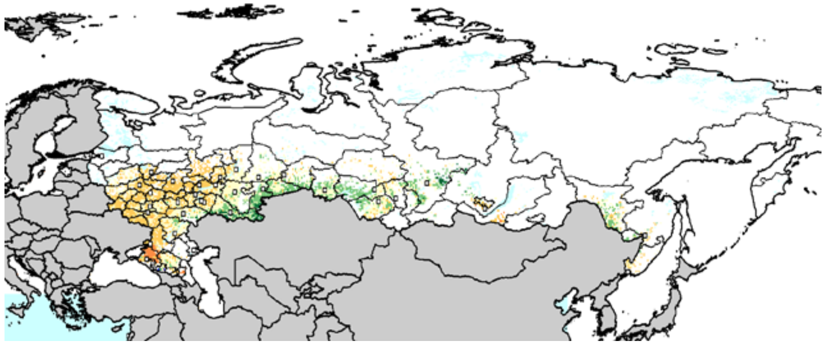


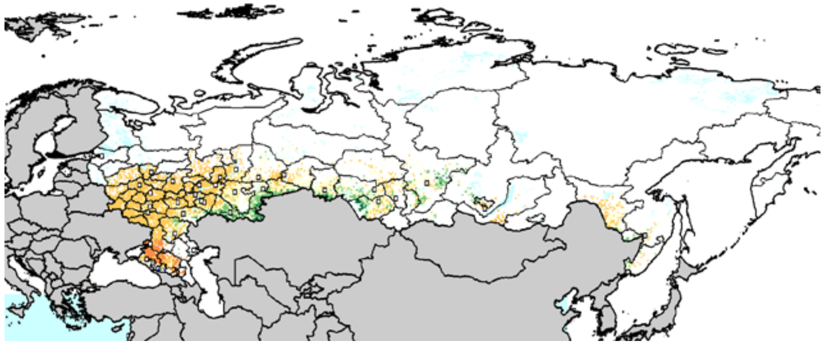
CNRM-CM3 GCM



CSIRO-MK3 GCM



ECHAM5 GCM

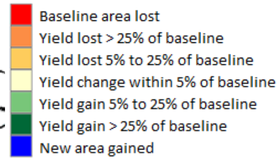


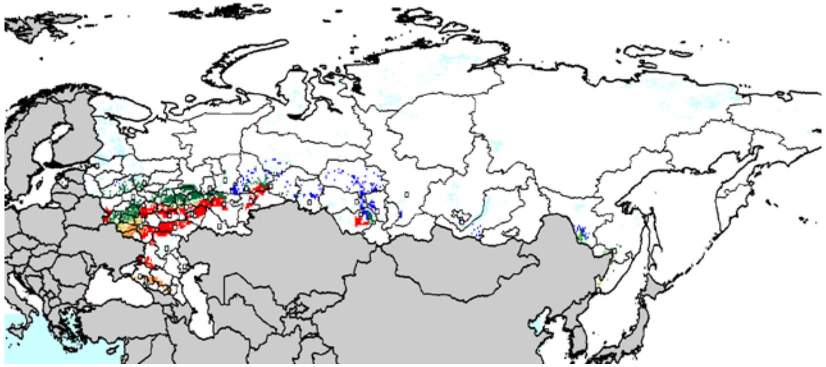
MIROC3.2 medium resolution GCM

Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

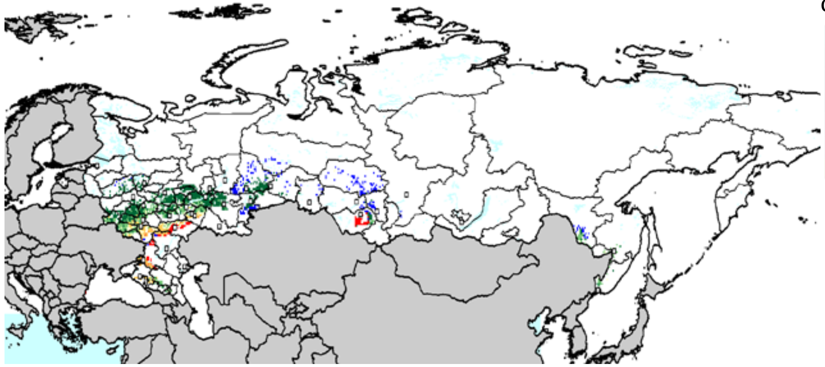
*Figure 27*. Yield change map under climate change scenarios: rainfed maize

Legend for yield change figures

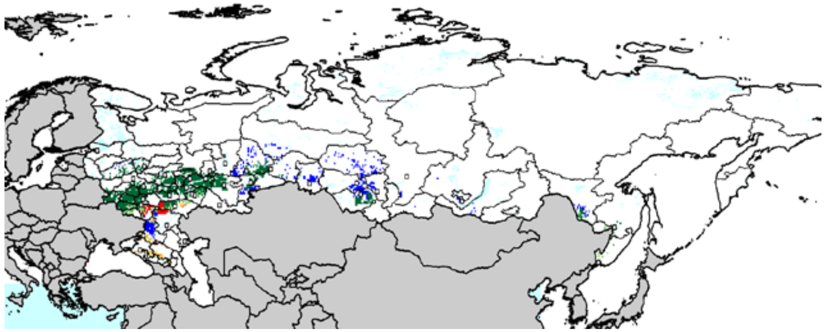


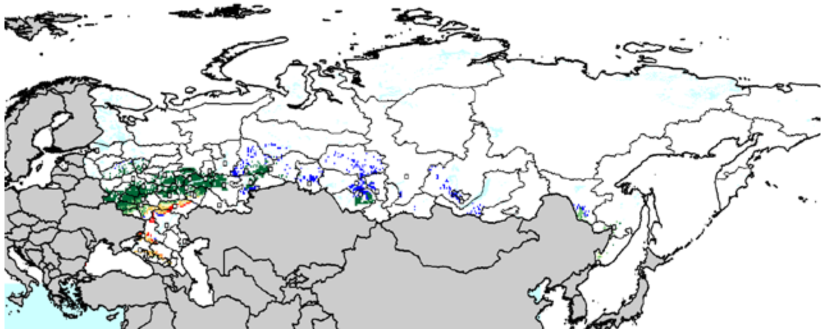
CNRM-CM3 GCM



CSIRO-MK3 GCM



ECHAM5 GCM

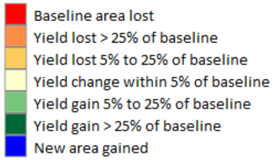


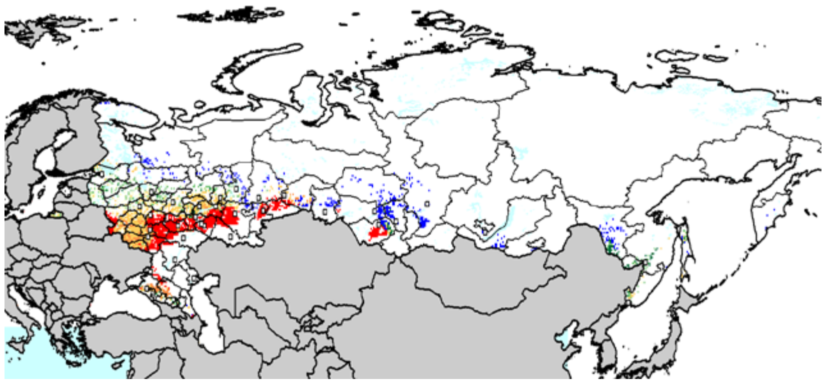
MIROC3.2 medium resolution GCM

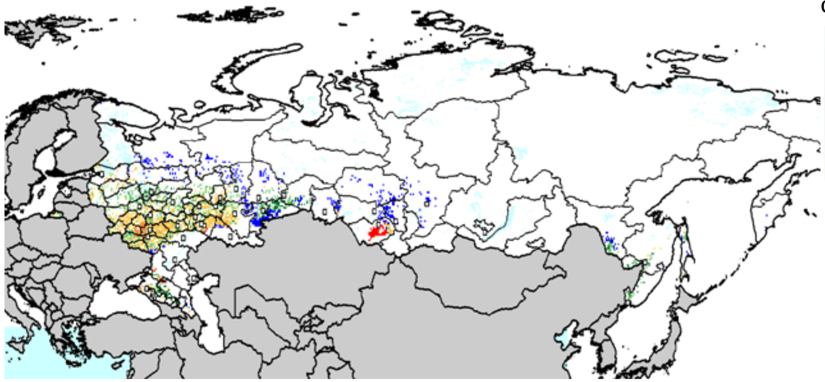
Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

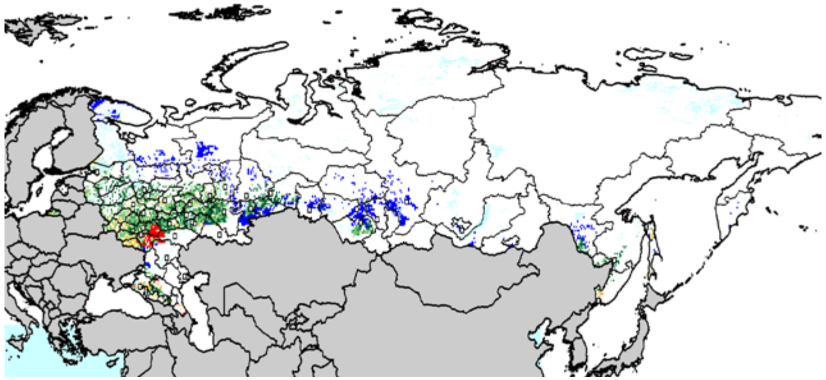
*Figure 28*. Yield change map under climate change scenarios: rainfed potatoes

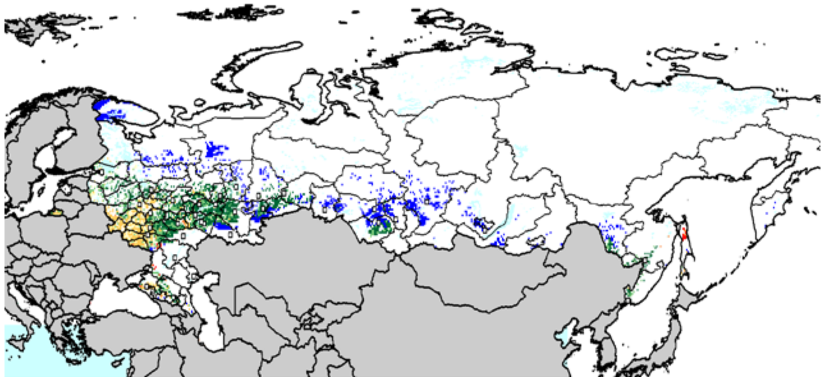
Legend for yield change figures





CNRM-CM3 GCM


CSIRO-MK3 GCM


ECHAM5 GCM

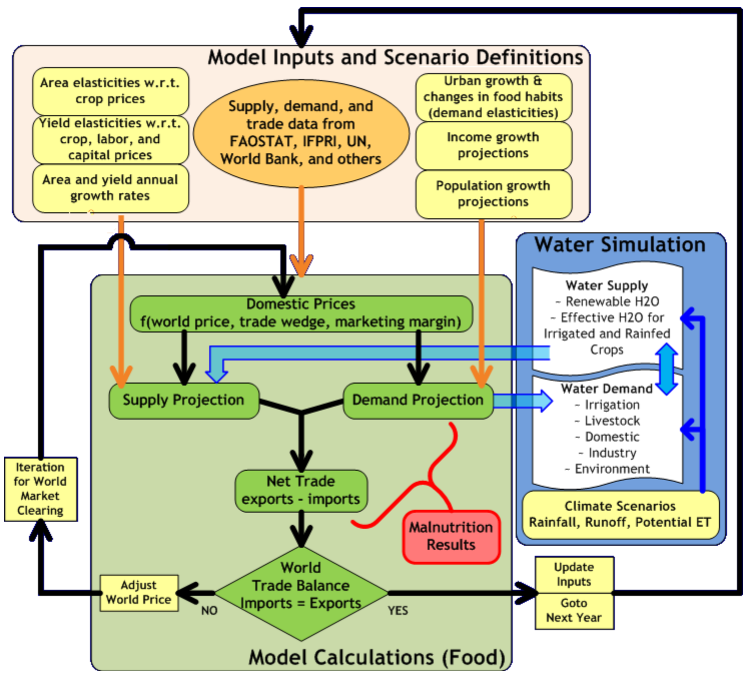

MIROC3.2 medium resolution GCM

Source: IFPRI calculations based on downscaled climate data available at http://ccafs-climate.org/.

## 3.2 From Biophysical Scenarios to Socioeconomic Consequences: The IMPACT Model

Figure 29 provides a diagram of the links among the three models used in this analysis: IFPRI's IMPACT model,[7] a partial equilibrium agriculture model that emphasizes policy simulations; a hydrology model and an associated water-supply and demand model incorporated into IMPACT; and the DSSAT crop modeling suite (Jones et al. 2003) that estimates yields of selected crops under varying management systems and climate change scenarios. The modeling methodology reconciles the limited spatial resolution of macro-level economic models that

*Figure 29.* The IMPACT modeling framework




Source: Nelson, et al. (2010).

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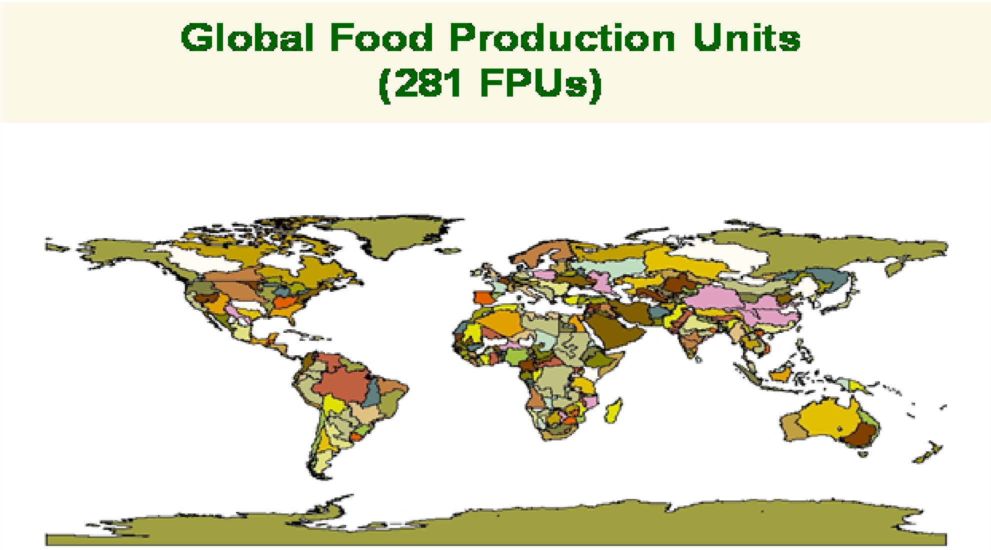
[7] Rosegrant, Mark W, and IMPACT Development Team. 2012. "International Model for Policy Analysis of Agricultural Commodities and Trade ( IMPACT ) Model Description". IFPRI, Washington D.C.

operate through equilibrium-driven relationships at a national level with detailed models of biophysical processes at high spatial resolution. The DSSAT system is used to simulate responses of five important crops (rice, wheat, maize, soybeans, and groundnuts) to climate, soil, and nutrient availability, at current locations based on the SPAM dataset of crop location and management techniques. This analysis is done at a spatial resolution of 15 arc minutes, or about 30 km at the equator. These results are aggregated up to the IMPACT model's 281 spatial units, called food production units (FPUs) (see Figure 30). The FPUs are defined by political boundaries and major river basins. Eleven FPUs are located in Russia: 4 FPUs in the European part (Baltic, Black Sea, Dnieper, Oder) and 7 FPUs in the Asian part (Amur, North Euro, Ob, Upper Mongolia, Ural, Volga, Yenisey).

*Figure 30*. The 281 FPUs in the IMPACT model




Source: Nelson et al. (2010).

## 3.3 Income and Demographic Scenarios

IFPRI's IMPACT model has a wide variety of options for exploring plausible scenarios. The drivers used for simulations include: population, GDP, climate scenarios, rainfed and irrigated exogenous productivity and area growth rates (by crop), and irrigation efficiency. In all cases except climate, the country-specific (or more disaggregated) values can be adjusted individually. Differences in GDP and population growth define the overall scenarios analyzed here, with all other driver values remaining the same across the three scenarios.

Table 9 documents the GDP and population growth choices for the three overall scenarios for this analysis.

The IMPACT modeling suite was run with four climate model and two SRES scenarios (the A1B and the B1 scenarios) combinations. Those eight outputs were used with each of the three GDP per capita scenarios. Table 10 shows the annual growth rates for different regional groupings as well as for Russia. In all scenarios, Russia’s income growth exceeds those of the developed group of countries and most developing countries, although it is expected to slow from the current rapid pace.

Figure 31 graphs the three GDP per capita scenario pathways, the result of combining the three GDP projections with the three population projections of Figure 4 from the United Nations Population office. The “optimistic scenario” combines high GDP with low population. The "baseline scenario" combines the medium GDP projection with the medium population projection. Finally, the "pessimistic scenario" combines the low GDP projection with the high population projection.

The GDP per capita scenario results for Russia and the U.S. can be seen in Table 11. In the pessimistic scenario, U.S. per capita income increases less than 2

*Table 9.* GDP and population choices for the three overall scenarios

| Category | Pessimistic | Baseline | Optimistic |
|---|---|---|---|
| GDP, constant 2000 US$ | Lowest of the four GDP growth rate scenarios from the Millennium Ecosystem Assessment GDP scenarios (Carpenter et al. 2005) and the rate used in the baseline (next column) | Based on rates from World Bank EACC study (Margulis 2010), updated for Sub-Saharan Africa and South Asian countries | Highest of the four GDP growth rates from the Millennium Ecosystem Assessment GDP scenarios and the rate used in the baseline (previous column) |
| Population | UN High variant, 2008 revision | UN medium variant, 2008 revision | UN low variant, 2008 revision |

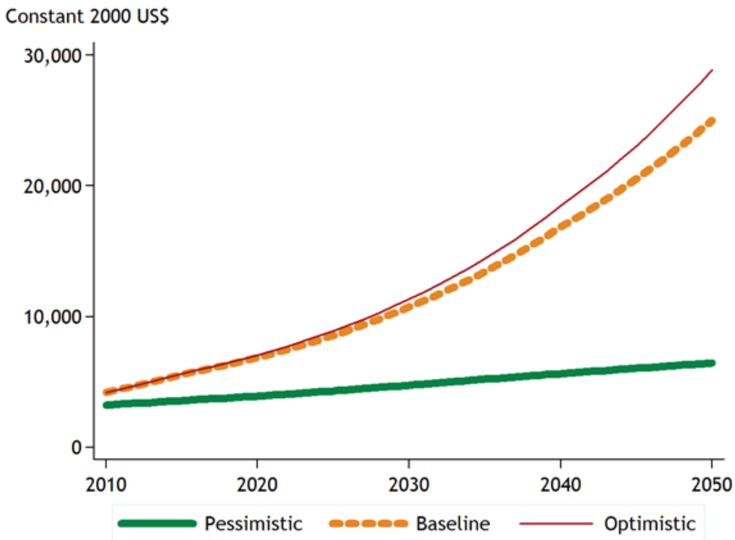
Source: Based on analysis conducted for Nelson et al. (2010).

*Table 10*. Average scenario per capita GDP growth rates (percent per year)

| Category | 1990–2000 | 2010–2050 | | |
|---|---|---|---|---|
| | | Pessimistic | Baseline | Optimistic |
| Russia | –3.60 | 2.24 | 4.19 | 4.54 |
| Developed | 2.7 | 0.74 | 2.17 | 2.56 |
| Developing | 3.9 | 2.09 | 3.86 | 5.00 |
| Low-income developing | 4.7 | 2.60 | 3.60 | 4.94 |
| Middle-income developing | 3.8 | 2.21 | 4.01 | 5.11 |
| World | 2.9 | 0.86 | 2.49 | 3.22 |

Source: World Development Indicators for 1990–2000 and authors' calculations for 2010–2050.

*Figure 31*. GDP Per Capita Scenarios




Source: Based on IMPACT results of July 2011, computed from World Bank and United Nations population estimates (2008 revision).
Note that the scenarios used apply to all countries; that is, in the optimistic scenario, every country in the world is assumed to experience high GDP growth and low population growth.

times while in the optimistic scenario, it almost triples between 2010 and 2050. The Russian per capita income triples in the pessimistic scenario and increases almost 12 times in the optimistic scenario. However, despite Russia's much more rapid growth than in the U.S. its per capita income in 2050 is still only one-fifth of that in the U.S.

*Table 11.* Russia and U.S. Per Capita Income Scenario Outcomes (2000US$ per person)

| | 2010 | 2030 | 2050 |
|---|---|---|---|
| Pessimistic | | | |
| Russia | 3,170 | 4,484 | 7,948 |
| U.S. | 37,504 | 51,132 | 58,291 |
| Baseline | | | |
| Russia | 4,135 | 10,137 | 23,000 |
| U.S. | 37,723 | 56,517 | 88,841 |
| Optimistic | | | |
| Russia | 4,135 | 10,696 | 26,570 |
| U.S. | 39,218 | 67,531 | 101,853 |

Source: IMPACT model simulation results.

## 3.4 Agricultural Vulnerability Scenarios (Crop-specific)

Figures 32 to 36 show simulation results from the IMPACT model for wheat, maize, other grains, sugar beet and potato. Each crop has five graphs: one each showing production, yield, area, net exports, and world price.

Several of the figures below use box and whisker plots to present the effects of the climate change scenarios in the context of each of the economic and demographic scenarios. Each box has 3 lines. The top line represents the 75th percentile, the middle line is the median, and the bottom line is the 25th percentile.[8] All scenarios result in a gradual increase in real world prices for all crops considered. The relatively high price increases observed for wheat, maize and sugar beet. Against the backdrop of rising prices there is an increase in production of major crops except potatoes. Potato production falls due to reduced acreage.

The substantial increase in grain production will be caused mainly by the improvement in its yield (taking into account rainfed and irrigated crops exogenous productivity improvement) and implementation of measures aimed at mitigating negative impacts of climate change (especially increase in irrigated

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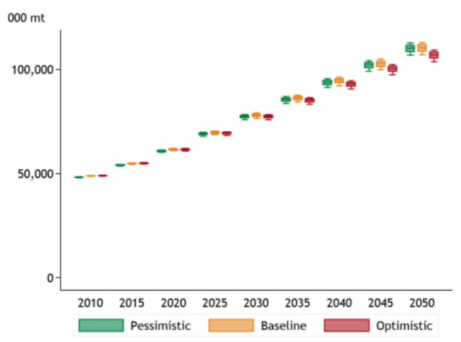
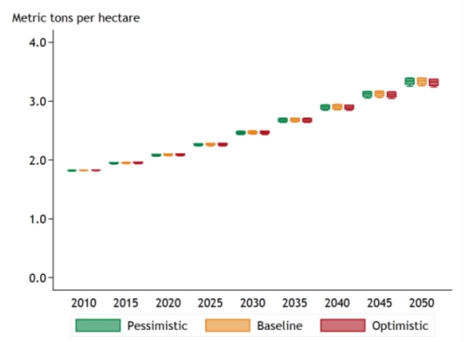
[8] These graphs were generated using Stata with Tukey's (Tukey 1977) formula for setting the whisker values. If the interquartile range (IQR) is defined as the difference between the 75th and 25th percentiles, the top whisker is equal to the 75th percentile plus 1.5 times the IQR. The bottom whisker is equal to the 25th percentile minus 1.5 times the IQR (StataCorp 2009).

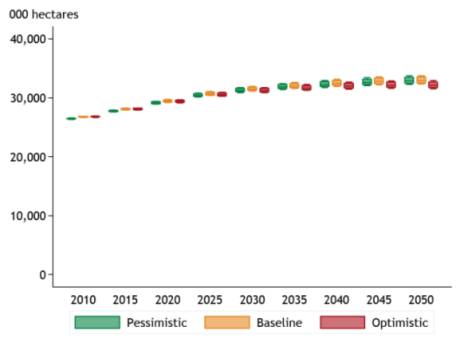
*Figure 32.* Scenario outcomes for wheat area, yield, production, net exports, and prices



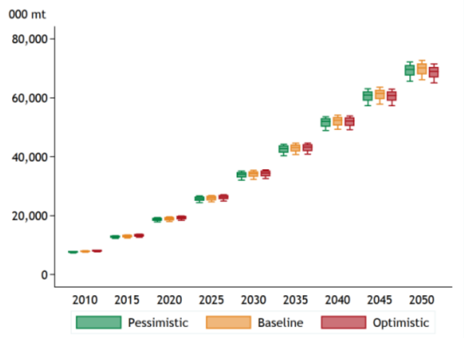

Production



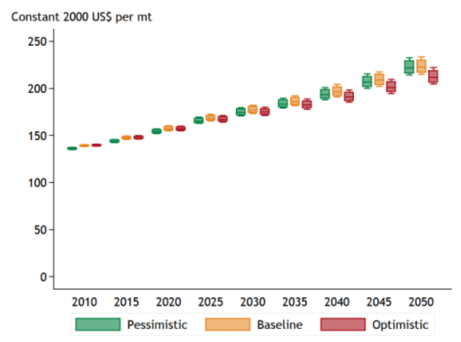

Yield




Area




Net Exports

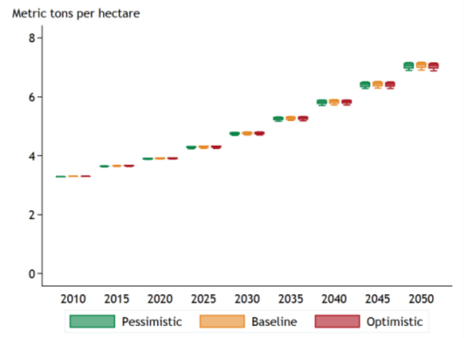



Prices

Source: Based on IMPACT results of July 2011.

*Figure 33.* Scenario outcomes for maize area, yield, production, net exports, and prices

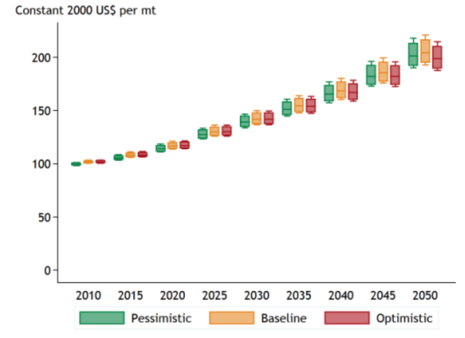

Production




Yield


Area


Net Exports

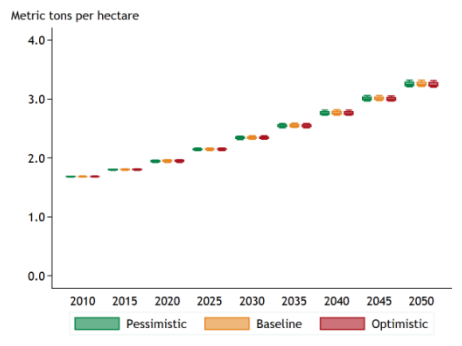



Prices

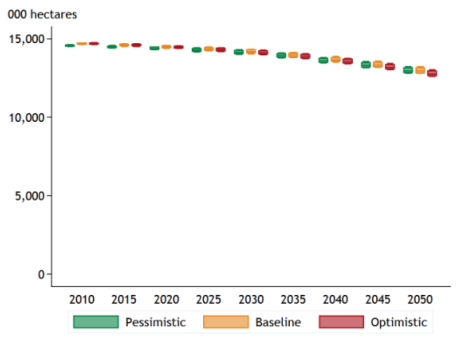
Source: Based on IMPACT results of July 2011.

*Figure 34.* Scenario outcomes for other grains area, yield, production, net exports, and prices

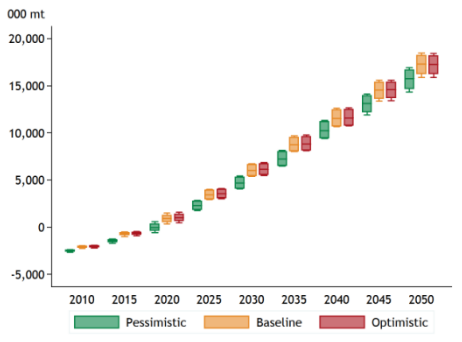

Production



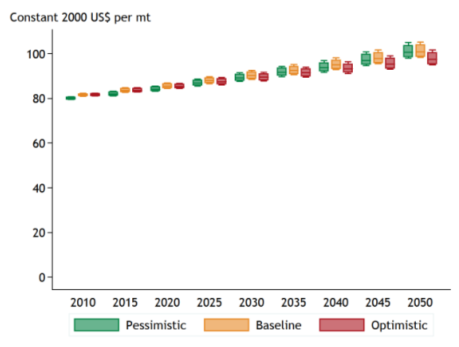

Yield




Area



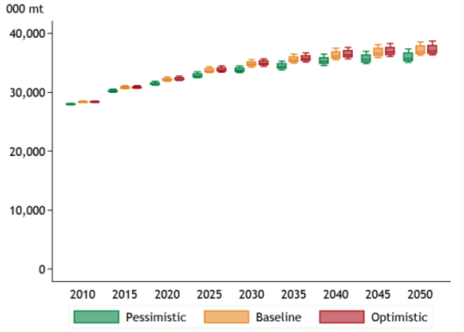

Net Exports



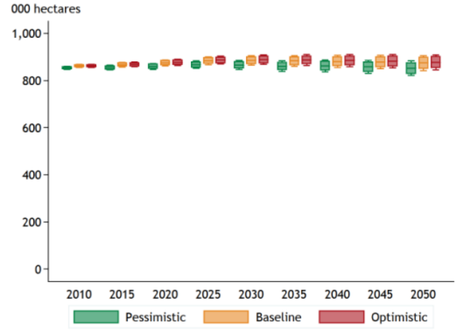

Prices

Source: Based on IMPACT results of July 2011.

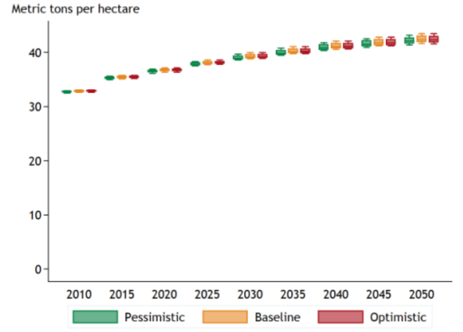
*Figure 35*. Scenario outcomes for sugar beets area, yield, production, net exports, and prices



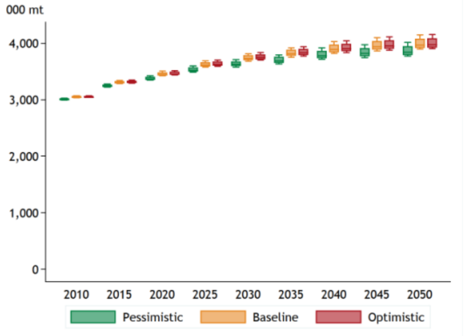

Sugar Beet Production



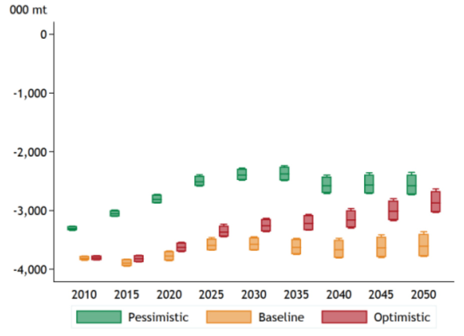

Sugar Beet Area



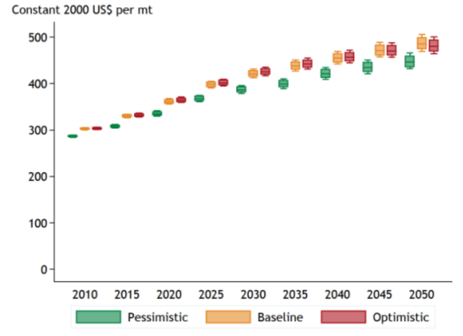

Sugar Beet Yield




Sugar Production




Net Sugar Exports

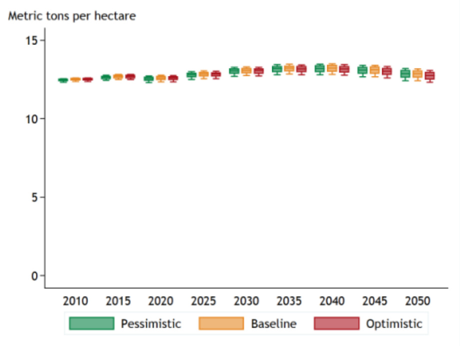



Sugar Prices

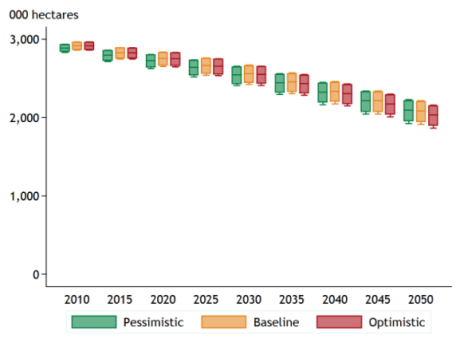
Source: Based on IMPACT results of July 2011.

*Figure 36.* Scenario outcomes for potato area, yield, production, net exports, and prices

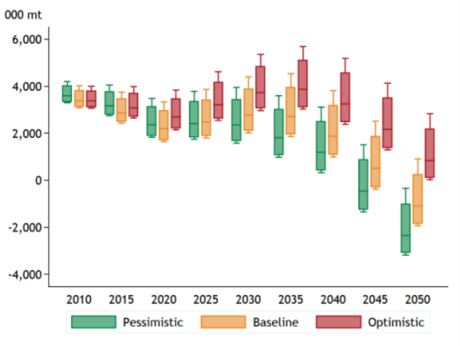

Production



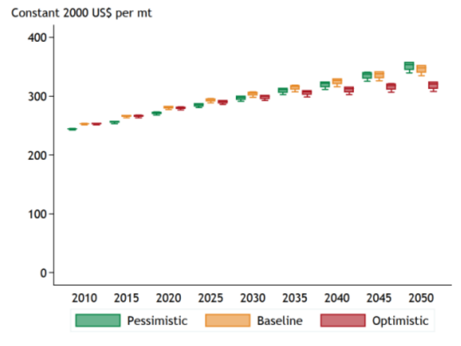

Yield




Area




Net Exports




Prices

Source: Based on IMPACT results of July 2011.

area). Yields of corn and wheat will increase, though Russian yields will be less than the yields in European countries. In addition, the area under these crops will be extended. In contrast, the increase in other grains production will be accompanied by an acreage reduction.

By 2050, production of wheat will reach 100 million tons, maize – about 10 million tons, other grains – about 40 million tons. Against the backdrop of rising incomes and declining population, an almost twofold increase in grain production will result in growth of exports. Net exports of wheat will increase by more than 5 times compared to 2010.

Despite the growth of sugar beet production, Russia will remain a net importer of sugar.

This applied analysis makes it possible to estimate the potential influence of climatic, demographic and economic factors on crop production. Taking into account climate change and increase in demand for agricultural products in the world, the major challenges for Russia are carrying out adaptation policy in the main agricultural regions and increasing the efficiency of agricultural production to strengthen the competitiveness of a domestic production in the world market. This is especially important to do for production of wheat in Russia’s southern regions where a negative impact of climate change is expected.

## 3.5 Human Vulnerability Scenarios

Figure 37 shows scenario outcomes for average daily kilocalories per capita. The baseline and optimistic scenarios show increases in calorie availability; the pessimistic scenario has a small decline, from about 3,000 kilocalories per day in 2010 to 2,900 kilocalories per day in 2050.

As the box and whiskers plots indicate, within a particular overall scenarios climate change has relatively little impact on the average daily kilocalories per capita. The reason is the ability of Russia to import and/or export depending on how climate change affects production domestically and abroad.

*Figure 37.* Average daily kilocalories availability under multiple income and climate scenarios (kilocalories per person per day)


Source: Based on IMPACT results of July 2011.

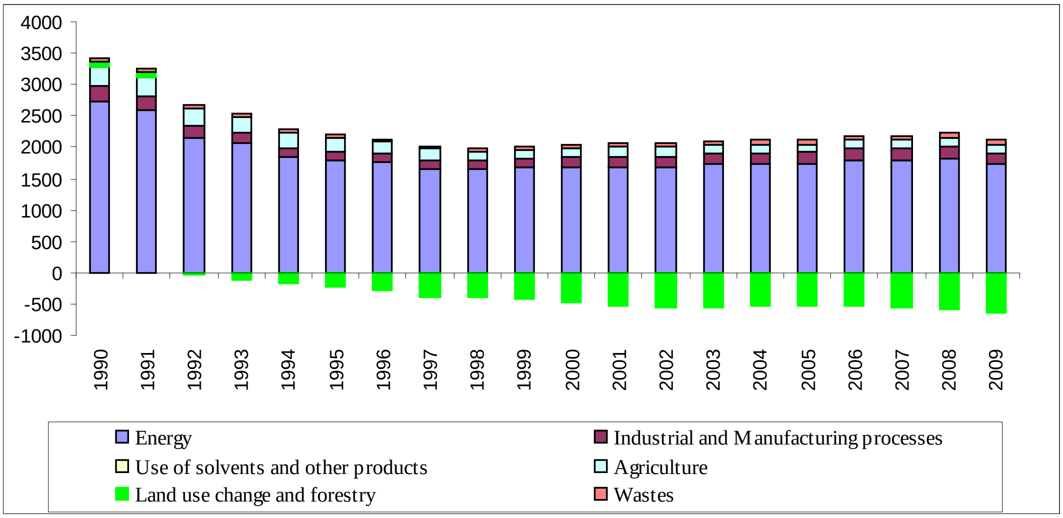
# 4 Agriculture and Greenhouse Gas Mitigation

## 4.1 Agricultural Emissions History

Figure 38 shows data on the total anthropogenic greenhouse gas emissions in Russia for the period from 1990 to 2009. Since 1990 the total emission decreased significantly (57.4%). Total volume of greenhouse gas emissions includes $CO_2$ and other greenhouse gases from land use change and forestry. This sector is characterized by a distinct tendency to reduce emissions and absorption increase during the period considered.

From 1990 to 1998, the reduction of greenhouse gas emissions in Russia was caused by the negative dynamics of domestic economy. In subsequent years there was a steady increase in greenhouse gas emissions due to an economic growth. By 2008, greenhouse gas emissions rose by 2.4% (taking into account the contribution of Land use change and Forestry sector) as compared to 1998 – a year with the

*Figure 38.* GHG Emissions (CO2, CH4, N2O, PFCs, HFCs, SF6) in Russia by Sector (mln. tons CO2-eq)




Source: The Russian Federation national report for 1990–2009 on anthropogenic emissions by sources and absorption of greenhouse gases not controlled by the Montreal Protocol, 2011.

lowest total greenhouse gas emissions. In 2009 the emissions in the leading sectors of the economy declined (in the Energy sector by 5.2%, Industrial and Manufacturing processes – by 12.4%, Agriculture – by 0.3 %) as a result of the influence global economic crisis on the Russian Federation.

Total greenhouse gas emissions in 2009 amounted to 2,111 million tons $CO_2$-eq., significantly (37.0%) lower than in 1990. The pace of growth in emissions observed in recent years was relatively low due to both a general increase in the efficiency of the economy and structural changes.

The distribution of emissions by sector for 1990–2009 has had rather small changes. Emissions from the energy sector dominate (in 1990 and 2009 they accounted for 81.1% and 82.3% respectively). The share of agricultural sector in total greenhouse gas emissions declined from 9.5% in 1990 to 6.7% in 2009). This is a rather low level, given the global average level of 15%. In absolute terms, greenhouse gas emissions of agricultural sector amounted to 142.4 million tons $CO_2$-eq. in 2009. The contribution of nitrous oxide (N2O) in the overall agricultural greenhouse gas emissions was more than twice high (68.1%) compared with the contribution of methane ($CH_4$) – 31.9%.

In 2009, total greenhouse gas emissions from the agricultural sector of the Russian Federation amounted to 44.9% of 1990 level. During this period direct emissions of nitrous oxide from agricultural land decreased by 46.6% and methane emissions from animal enteric fermentation processes were reduced by 59.5%. Reduction of greenhouse gas emissions is a result of a decline in livestock and poultry numbers, as well as acreage and mineral fertilizer application. Compared to 1990, livestock numbers decreased by 63.8%, pigs – by 55%, sheep and goats – by 62.2%, poultry – 34.3%. Cultivated area was reduced by 33.9% or 39.9 million hectares. The application of mineral nitrogen fertilizers declined by 70.6%, which corresponds to a reduction of nitrogen input to agricultural soils of 3.0 million tons.

Greenhouse gas emissions due to land-use change and the forestry sector include emissions from agricultural land, organic soil, forest fires, peat activity and deforestation, as well as carbon dioxide absorption in biomass and other pools of carbon-managed forests, grasslands and lands transferred from arable to hayfields and pastures.

The dynamics of agricultural land-use emissions is characterized by a clear trend of increasing absorption and emission reductions due to the following reasons:

- emission reduction of arable land (due to the reduction of arable land, increasing the average yield of most crops in recent years and lower levels of microbial respiration of arable soils as a result of low application of organic fertilizers)[9]
- accumulation of soil organic carbon on land converted from arable to hayfields and pastures.

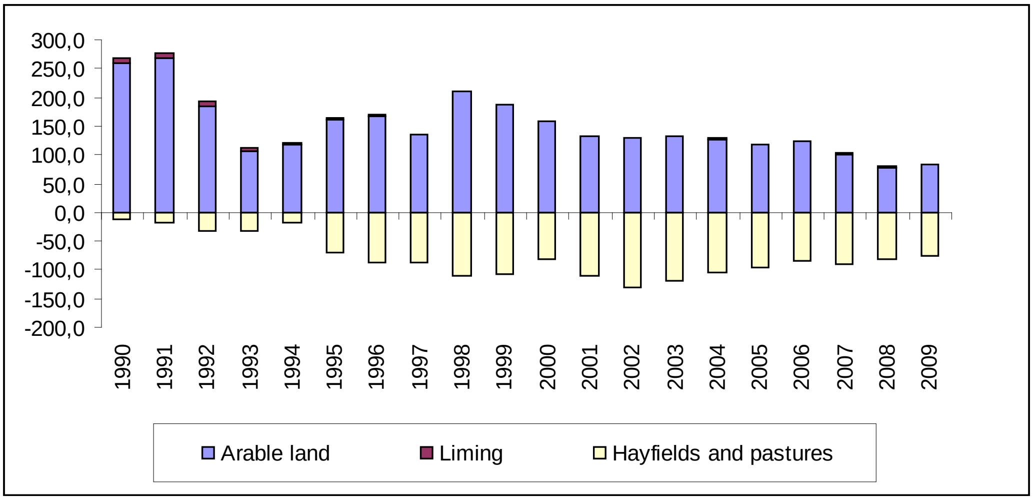
9 Reduction in the numbers of livestock and poultry resulted in decreasing application of organic fertilizers. The application of organic fertilizers was reduced by 86.2% from 389.5 million tons in 1990 to 53.7 million tons in 2009. As a result of the reduction in use of organic fertilizer, the carbon input to soil was reduced from 71.1 million tons in 1990 to 9.8 million tons in 2009.

In 2009, $CO_2$ emission from arable land amounted to 83.0 million tons (see Figure 39). At the same time hayfields and pastures absorbed 76.5 million tons of $CO_2$.

Greenhouse gas emissions in Land use change and Forestry sector were dominated by absorption in 1990–1992 during the active usage of agricultural land and forest resources. In 2009 Land use change and Forestry sector absorbed 649.6 million tons of $CO_2$-eq.

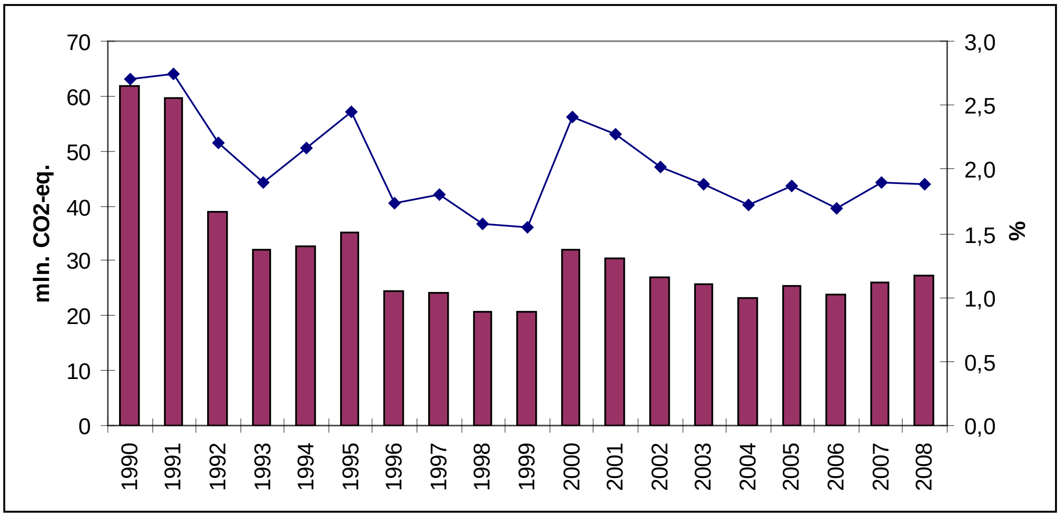
Besides greenhouse gas emissions from agricultural lands and animals, agricultural activity produces emissions from the combustion of motor fuels (gasoline, liquefied gas, diesel and other motor fuels). Figure 40 shows such emissions for agriculture/forestry/fisheries during the period of 1990–2009. The share of agriculture in total fuel combustion activities' emissions is not large. Throughout the period considered, it declined from 2.7% in 1990 to 1.9% in 2009.

*Figure 39.* CO2 emission and absorption in agricultural land use sector in Russia (mln. tons)




Source: The Russian Federation national report for 1990 – 2009 on anthropogenic emissions by sources and absorption of greenhouse gases not controlled by the Montreal Protocol, 2011.

*Figure 40*. GHG emission from the combustion of motor fuels in agriculture/ forestry/ fisheries (mln. tons CO2-eq) and its share in total fuel combustion activities (%)




Source: The Russian Federation national report for 1990–2009 on anthropogenic emissions by sources and absorption of greenhouse gases not controlled by the Montreal Protocol, 2011.

## 4.2 Technical and economic potential for mitigation of agricultural greenhouse gas emission

Currently, greenhouse gas emissions of agricultural sector are not substantial. However, since there are good reasons to predict the increase in agricultural production in the future, it is important to prevent the adverse effects of this process on climate change. To reduce greenhouse gas emissions the agricultural producers may use the following measures:

1. Optimizing the use of fertilizers on arable lands and grasslands on the basis of an exact calculation of crop needs for fertilizers, applying fertilizers with slow or controlled release of nutrients. The implementation of these measures could lead to more rational use of fertilizers and increase in crop yields.
2. Restoration of drained organic soils (peat). Such soils occupy 4.4 million hectares of arable lands. Restoration of organic soils by flooding will help

to reduce carbon emissions and contribute to carbon absorption. Also it is necessary to reject completely the practice of the drainage of such soils.

3. Restoring lands degraded as a result of their intensive use, erosion, loss of organic content, acidification, etc.
4. The use of advanced agronomic practices that increase productivity and promote a more intensive carbon absorption:
    a. The use of improved varieties.
    b. The use of crop rotation methods, which contribute to the accumulation of soil carbon and reduce the acreage of fallow lands.
    c. The application of advanced methods of tillage.
    d. The use of feed additives and vaccines for livestock in order to suppress methanogenesis and enteric fermentation processes.
5. The application of anaerobic systems for the collection and storage of manure, and increase in the use of manure as a biofuel.
6. Improving energy efficiency of the agricultural sector. Using modern technology and equipment.

In addition to the measures listed above, the rural population can take part in planting forests on land previously covered by forests, and planting shelter belts on agricultural lands. These measures should be implemented in areas characterized by significant degradation of soils and forests. Their implementation will help to restore the landscape.

Implementation of measures for the reduction of greenhouse gas emissions in agriculture is associated with significant costs. Currently, the majority of agricultural producers do not have sufficient incentives to reduce emissions of greenhouse gases. Also they do not have the necessary equipment and facilities for the introduction of new technologies and processes into production. In addition, in most regions there is the lack of information about new technologies and methods that could contribute to the increase in productivity and help to reduce greenhouse gas emissions in the agricultural sector.

In these circumstances the RF Government as part of the policy on Sustainable Development of the agricultural sector should include measures aimed at providing information for individual producers, provide technical assistance and financial aid in the implementation of the pilot projects on introduction of advanced technologies and methods of agricultural production. In addition, the provision of agricultural subsidies could be linked to the application of measures to reduce greenhouse gas emissions.

## 5 Policy for adaptation of agriculture to climate changes

The long-term risks of development of agriculture include climatic changes occurring around the globe. In general, global climate changes will positively affect Russian agriculture. In high and middle latitudes global warming will expand the growing season. Acreages of agricultural crops may expand toward the north, although yields will likely be lower due to less fertile soils.

However, in the southern regions there is a possibility of drier climate, which has a negative impact on crop yields and livestock productivity. In addition, global warming will increase the scarcity of water resources, and encourage weed and pest proliferation.

Climate change increases the short-term risks associated with an increase in extreme weather events and natural disasters. Every year some regions in different periods of time show the weather parameters beyond the average.

Because climate change is inevitable, but the precise effects remain uncertain, policies for adaptation of agriculture should be formulated that include measures at the federal and regional levels to develop specific programs based on scientific research. Topics include farming systems, changes in the share of production of various crops (growing more adapted or less risky but less profitable crops), the ratio of different varieties and crop planting dates.

The adaptation of crop production in regions with warmer and more humid climate should include expanded plantings of a late-ripening and higher yielding varieties of grains and legumes, sunflower, canola, soybean, late-ripening varieties of potatoes, and thermophilic species of fodder crops.

In the arid zones the adaptation policy should be aimed at expansion of irrigated agriculture, which is considered as a necessary condition for the fullest use of additional warming in plant production, rationalization of water use through the widespread introduction of moisture saving technologies (snow retention, reducing unproductive evaporation, drip irrigation), and the expansion of winter crops (wheat in the steppe regions of the Volga and the Urals, barley in the Northern Caucasus).

The adaptation policy should cover probable changes of agrarian specialization of the regions, their land-use and crops production patterns. This will require significant investment in infrastructure development both in areas of possible improvement and deterioration of agroecological conditions, carrying out activities such as mechanization, amelioration, and adoption of new technologies. An example is the necessity of developing transport and export infrastructure in Siberia where grain yields and area are likely to increase. In addition, programs to restore degraded lands due to their intensive use and to deal with nutrient depletion, erosion, and acidification will be needed to deal with growing food and feed demands.

Beyond a focus on adaptation in crop agriculture, investments in afforestation are also needed. The scale of afforestation works has decreased last years despite the need for the expansion of such work, including the reason of the obvious climate changes. It should be taken into account that afforestation not only exerts favorable influence on soil, moisture regime, and crop microclimate, but also fulfills a function of carbon sequestration in the soil and thus slows global warming.

The system of adaptation should take into account the strong likelihood of an increase in the number of dangerous meteorological events. Such events are hard to predict. It is necessary to improve accuracy and reduce delays in providing weather data through the modernization and extension of observation networks, as well as the introduction of modern methods of evaluation of the observed data. Adaption to dangerous meteorological events presupposes not only improvement of forecasting and monitoring of natural environment changes; development and application of a set of economic measures are important. Examples include development of a reliable system of risk management and insurance of crops and agricultural producer income. Insurance indices, indices of the weather, early warning system for possible losses are climate risk management tools, which should be considered in Russia.

A specific program should be developed to carry out activities that reduce the degree of risk from extreme weather conditions. Such a program could be federal or departmental. It should take into account a spectrum of problems. It should not be limited to the allocation of financial resources. Educational programs for farmers, managers and employees should also be carried out. It is important for agricultural producers to have technical and financial assistance and support to facilitate the implementation of technologies aimed at adapting to climate change.

The differences in the scenarios of climate change influence, both favorable and unfavorable, on the crops production in various regions of Russia should be taken into account. In other words, different sets of adaptation measures, which respond to specific characteristics of regional climate changes, should be made available to producers.

It is necessary to increase funding for research in order to carefully study the effects of climate change on agro-ecological conditions, and on this basis to form the adaptation policy aimed at sustainability of agricultural development in the new environment.

Studying the effect of climate change influence on the spread of agricultural pests and animal diseases is an important direction of research. In addition, more support for research in aimed at creating plant varieties with desired characteristics is badly needed.

Scientific research on refinement of climate change forecasts in the agricultural areas of different regions should be continued. In line with these forecasts, local rural development programs addressing the adaptation capabilities of individual groups of crop producers should be developed and implemented. The absence of such predictive estimates and programs may result in large social and economic losses, irrational distribution of investments and irrational specialization in agriculture.

It should be noted, that preparing high-quality long-term perspectives depends on Russia's participation in international projects to assess the impact of climate change on agriculture. In this connection it should intensify research in the field of data collection and analysis of spatial data with reference to specific regions and water basins. This will require the use of remote sensing equipment, carrying out research on deciphering and interpreting data, and their linkage to official statistics and the creation of database management systems, allowing easy access to the necessary data. These data should be available to users.

An essential component of adaptation is social support of vulnerable groups of the rural population. In Russia, 18.1 million people or 12.8% of the population have incomes below the poverty line and 42% of these people live in rural areas. Low income groups are most vulnerable to adverse impact of climate changes and rising prices for food. Mitigation of these problems is possible through operating a system of insurance income of agricultural producers; such a system is currently absent in Russia. The challenge of subsidizing the consumption of food for low-income groups remains large.

For the purpose of sustainable development of the agrarian sector and securing the presence of primary agricultural goods on the domestic market, it is essential to form food reserves (primarily, grain reserves), that is, to buy production of crop producers in yielding years for subsequent provision of crops supply stability in fail years. This measure provides support for producers and prevents abrupt and excess price fluctuations. Development and modernization of storage facilities to reduce the storage losses are also of a great importance for Russia.

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