Will Climate Change Affect Food and Water Security in Russia?

Summary Report of the International Project on Global Environmental Change and its Threat to Food and Water Security in Russia

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Executive Summary

1. This study takes a fresh view of the question of climate impacts on Russian agriculture and water resources by examining possible changes in the frequency of droughts and by studying climate impacts on the level of oblast/administrative region. The analysis also uses a new integrated model "GLASS" which provides a consistent method for examining changes in agricultural production and water supply.

2. The climate scenarios used in this study (produced by two state-of-the art global models) support the finding of earlier modeling studies that global climate change will lead to a wetter and warmer climate over much of Russia. We have computed that this will mean larger crop yields in many areas that now have marginal crop yields, as well as an expansion of potential crop growing area.

3. Although climate will become more favorable over much of Russia, the potential for food production in most regions is limited by other factors such as poor soils, lack of infrastructure, or remoteness from agricultural markets. Furthermore, better conditions for crops could also mean better conditions for pests, diseases and weeds that could hinder crop growth. Therefore better climate conditions will not necessarily translate into significantly greater food production.

4. It is noteworthy that only 15 important food-export regions out of the 89 administrative regions of Russia provide the rest of the country with much of its basic food requirements, and therefore play a central role in Russian food security (we refer to them here as the "main crop export regions"). About 50 percent of Russian agricultural production today comes from these regions. While the climate scenarios show that it is becoming warmer here as in other parts of Russia, they also show a drying tendency – Some climate scenarios show a decrease in average summer precipitation in these regions of up to 50% between the climate normal (1961-90) period and the 2020s.

5. The warmer and drier climate in the main crop growing regions will threaten the potential productivity of important crops such as wheat, rye, potatoes, maize, and barley. We compute that average potential productivity of grain (wheat and rye) in these regions will drop by 8 to 29 percent in the 2020s, and by about 14 to 41 percent in the 2070s (relative to current averages). A decrease as large as 40 percent in the 2020s and 65 percent in the 2070s is possible for individual administrative regions. In Russia as a whole, the losses in the South are balanced out by gains elsewhere so that the computed total grain production ranges from a 9 percent loss to a 12 percent gain by the 2020s (relative to current averages, with the range due to different estimates of climate change). By the 2070s country-wide production drops by 5 to 12 percent

6. Under current climate conditions, "bad harvests" occur in the main crop growing regions roughly one to three years out of every decade (depending on the region). Under climate change some regions may experience a doubling of the frequency of bad years after the 2020s and even a tripling after the 2070s. This also means that there is a higher chance that several parts of the main crop growing regions will experience poor harvests in the same year. Of importance, because much of Russia is dependent on the crops produced in these few regions, the effects of drought will be felt throughout the

country. We estimate that there are now about 58 million people living in regions that experience one or more bad harvests each decade (either in their own region, or in the region from which they import food). This number may increase up to 77 million in the 2020s and 141 million in the 2070s under the A2 scenario. The possibility of more frequent bad harvests is a threat to Russia's food security that should be taken seriously.

7. Threats due to poor harvests are avoidable. There are many strategies available for adapting to climate change, such as expanding the crop-growing area, changing the types of crops, increasing technological inputs to agriculture (more fertilizer and management), importing more food, changing food consumption habits, and/or building-up a larger strategic food reserve. Each strategy has its own economic, social, and political costs.

8. The expected increase in precipitation over most of Russia (except in the Southwest) will tend to increase river runoff and groundwater recharge, and therefore make more water available to water users. This will in general reduce the pressure on water resources.

9. However, the situation is different in the crop-growing areas in the Southwest. Here, the combination of severe pressure on water resources because of large water withdrawals, together with more frequent low river flows, may cause a significant threat to the water security of the population living in these regions. It will also hinder the development of new irrigation projects.

10. Because of climate change, many river basins outside of the Southwest are likely to experience more frequent extremely *high* runoff events. The possibility of more frequent flooding could pose an additional threat to the security of the Russian population.

11. As with food security, there is a wide palette of strategies available for coping with threats to water security, ranging from increasing the storage of water to reducing the dependence of society on limited water supplies through various water conservation measures.

12. Also, it should not be overlooked that food and water security can be enhanced by not only coping and adapting to climate change, but also by reducing greenhouse gas emissions and thereby avoiding or at least reducing the intensity of expected climate change. For this reason Russia should ratify the Framework Convention on Climate Change and take a leadership role in international climate policy.

13. Taken together, our findings challenge the belief that climate change will mostly benefit Russian agriculture and water resources. Instead our results point out how extreme events such as droughts may become more frequent in key areas of Russia and threaten the food and water security of its people.

Introduction

Although societies adapt and evolve along with their climate, this has been an especially difficult task for Russia because of its severe and capricious climate – Sometimes the rains fall too heavily, sometimes they fail completely, sometimes it is too warm, most often too cold. Indeed, extremes are the norm, and this has always taxed the ability of Russian agriculture to produce enough food for its people. While the soils can be rich, the rains can be fickle, and large parts of the main agricultural areas have been affected by severe drought at least once or twice a decade during the 20th century. Given the severity of its current climate, it is not surprising that some consider climate change a positive development for Russia – Climate models compute that the country is likely to become generally warmer and more moist, and it follows that warmer temperatures will bring longer growing seasons, while higher levels of precipitation might be better for crops and for the water supply situation overall. Indeed, some believe that climate change will bring net benefits to Russian agriculture in the form of expanded growing areas and better crop yields (see, for example, Anon, 1997). While there is some truth to this belief, we would also argue that it leans too heavily on *average* changes and not enough on the importance of *infrequent but consequential* droughts that can pose a threat to the security of food supplies. Hence, this study takes a fresh view of the question of climate impacts on Russian agriculture and water resources by giving special attention to possible changes in the frequency of extreme events such as droughts. Second, we analyze climate impacts on the level of oblasts/administrative regions and can therefore account for the decisive fact that only a handful of crop-growing oblasts in the south produce most of the food for the entire country. Third, for the impact analysis we use a new integrated model "GLASS" which provides a consistent method for examining changes in agricultural production and water supply (See Appendix). As pointed out below, *taking this fresh view provides new results that question the belief that Russia will generally benefit from climate change.*

The Study Approach

Although climate change can have many impacts on agriculture and water resources, we focus here on the impacts of droughts because they have always played an important role in the food and water security of Russia. Nevertheless we recognize that overabundant precipitation can also lead to problems of increased flooding and crop loss. Therefore, future studies should examine not only the impact of extreme dry periods, but also extreme wet periods.

The approach we use has two main parts: First, we review and evaluate Russia's "geography of food", that is, we examine the important factors influencing food production and distribution in different parts of Russia in the 20th century (Golubev and Dronin, 2003). This involves, in particular, the compilation and analysis of crop production and consumption data on the oblast/administrative region level. Some of these archived data, in particular from the early part of the 20th century, were only recently made available (Berelovich and Danilov, 2000a,b, Danilov et al. 2000a,b,c), and therefore provide new insights into the nature of food security in Russia. From this evaluation we can better understand how droughts have affected Russian food security up to now, and which factors may be important in the future. Nevertheless, large data gaps still exist in the story of food problems in the former Soviet Union.

Table 1. Assumptions of IPCC Scenarios for Russia, Year 2025

Year & Scenario	Description	Population (millions)	GDP per capita pro annum (US $/cap-a)
1995	---	148	4 046
2025 A2	Regionalized, economically-oriented	156	7 735
2025 B2	Regionalized, environmentally-oriented	139	10 463

The second major part of our approach is a scenario analysis of future impacts of climate on agriculture and water resources using the GLASS computer model (See Appendix). This model allows us to evaluate the consequences of climate scenarios computed by state-of-the-art climate models.

Box 1. About the Project

The study was financed by funds provided by the Max Planck Society and Humboldt Foundation of Germany and was a joint project of the University of Kassel, Germany, the Moscow State University, and the Russian Academy of Sciences.

Project leaders were:

- Prof. Dr. Joseph Alcamo, Director of the Center for Environmental Systems Research, University of Kassel
- Prof. Dr. Genady Golubev, formerly Deputy Director of the United Nations Environment Programme, and currently Professor in the Geography Department of Moscow State University

Other key participants were:

- Dr. Nikolai Dronin, Senior Scientist, Geography Department of Moscow State University
- Dipl. Inf. Marcel Endejan, Research Scientist, Center for Environmental Systems Research, University of Kassel
- Dr. Andrei Kirilenko, Senior Scientist, Center for Ecology and Forest Production, Russian Academy of Sciences (currently at Purdue University, USA)
- Dr. Karl-Heinz Simon, Senior Scientist, Center for Environmental Systems Research, University of Kassel

Combining our understanding of present food geography with results of the modeling studies gives us insight into how food security could be effected in the future. In our study we focus on changes between now and the 2020s and 2070s, periods for which we have credible climate scenarios.

The future climate will depend, of course, on many factors, and one of the most important is the trend of global greenhouse gas emissions. To take into account the uncertainty of future trends of emissions, we analyze the consequences of two distinctly different emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC, 2000):

(1) The “A2” emissions scenario assumes economic and population trends consistent with a regionalized and economically-oriented world. The future level of global greenhouse gas emissions are among the highest of the IPCC scenarios. Population growth is low, and economic growth is low to moderate. (Table 1).

(2) The “B2” emissions scenario assumes trends of the economy and population consistent with a regionalized world but with a strong environmental focus. Population decreases and economic growth is stronger than in the A2 scenario (Table 1). Global greenhouse gas emissions are less than half of the A2 scenario because the B2 scenario focuses on non-fossil fuel energy production. Yet neither the B2 nor A2 scenarios assume that action is taken to

Table 2 Data on main crop export regions of Russia

Administrative region	**Cereal production as percentage of 1995 total Russian cereal production**	**Number of years per decade with bad harvests [a]**				
		1961-90	2020s A2 Scenario	2070s A2 Scenario	2020s B2 Scenario	2070s B2 Scenario
Altaisky Kray	5.3	2	1	4-6	2	4-5
Belgorodskaya Oblast	1.5	1	1-3	3-5	1	3-4
Kalmykia	0.5	3	4	6-7	5-6	6
Krasnodarsky Kray	9.2	0	1	4	1	2-3
Kurganskaya Oblast	1.9	1	1-2	3	3-6	5-6
Kurskaya Oblast	2.3	1	1-2	1-2	0-1	1-2
Lipetskaya Oblast	1.4	2	3	4-6	2-3	4
Novosibirskaya Oblast	4.1	2	0-1	2-3	1-2	2-3
Orlovskaya Oblast	1.9	1	1-2	1-2	1-2	2-3
Rostovskaya Oblast	5.7	1	1-2	3-4	2-3	3-4
Saratovskaya Oblast	2	2	2-4	2-4	3-4	3-4
Stavropolsky Kray	6.2	0	1	4-7	1-4	3-5
Tambovskaya Oblast	1.4	2	2-3	3	2-3	3
Volgogradskaya Oblast	2.1	2	3	2-6	2-3	3-5
Voronezhskaya Oblast	2.4	1	2-3	2-3	2	3

[a] “Bad harvest years” are years in which the potential productivity of the most important crop in the region is below 50% of its 1961-90 average. The range in values for the 2020s and 2070s reflects the range of climate scenarios produced by the HADCM3 and ECHAM4 climate models.

explicitly reduce greenhouse gas emissions.

The A2, B2 and other emission scenarios have been used by global climate models to produce different climate scenarios. Because of the uncertainty of calculations, we have used and compared results from two different state-of-the-art models – the HadCM3 model of the Hadley Center in Great Britain (Pope et al., 2000) and the ECHAM4 model of the Max Planck Institute of Climatology in Germany (Roeckner et al., 1996). To sum up, in our study we analyze the impacts of two different climate scenarios (A2 and B2) generated by two different climate models. Using a range of climate scenarios allows us to take into account some of the obvious uncertainty of estimating future climate change.

Climate and Food Security

Throughout history many different factors have determined the security of food supplies in Russia. It is well known that some food crises have been provoked by the disruption of agriculture through political changes such as the civil war of the 1920s, or by autocratic national policies as in the forced collectivization of agriculture in the 1930s. Yet even during the politically turbulent times of the 1920s and 1930s, climate played a major factor in determining food security. – Newly available data (Berelovich and Danilov, 2000a,b, Danilov

Table 3 . Future climate-related potential crop production for various economic regions. Given as percentage of current mean potential crop production (production 1961-90 = 100). Grain production includes wheat and rye. Results based on climate scenarios from *HADCM3* climate model.

Economic Region		**A2 Scenario**				**B2 Scenario**			
		2020s		2070s		2020s		2070s	
		grain	potato	grain	potato	grain	potato	grain	potato
Central	Centralnii	92	95	93	86	104	117	90	89
Central Chernozem	Centralno-Chernozemnii	73	64	75	55	93	91	67	48
Far East	Dalnevostochnii	108	121	101	175	119	138	100	155
Kaliningradskaya	Kaliningradskaya Obl.	106	107	92	87	96	107	91	80
North	Severnii	127	136	148	125	140	152	159	146
North Caucasus	Severo-Kavkazskii	82	72	60	38	73	62	65	49
North West	Severo-Zapadnii	120	116	111	103	122	132	107	101
Ural	Uralskii	92	111	89	101	70	82	83	94
Volga-Vjatka	Volgo-Viatskii	97	91	94	80	94	92	102	92
East Siberia	Vostochno-Sibirskii	218	207	340	316	210	207	306	288
West Siberia	Zapadno-Sibirskii	110	140	86	194	97	129	83	160
Povolsky	Povolzhie	76	-	77	-	71	-	76	-
Russia		***94***	***106***	***90***	***104***	***91***	***122***	***88***	***104***

Table 4. Future climate-related potential crop production for various economic regions. Given as percentage of current potential crop production (production 1961-90 = 100). Grain production includes wheat and rye. Results based on climate scenarios from *ECHAM4* climate model.

Economic Region		**A2 Scenario**				**B2 Scenario**			
		2020s		2070s		2020s		2070s	
		grain	potato	grain	potato	grain	potato	grain	potato
Central	Centralnii	93	79	86	67	95	95	89	72
Central Chernozem	Centralno-Chernozemnii	85	67	59	34	84	70	71	49
Far East	Dalnevostochnii	125	145	143	205	124	149	128	191
Kaliningradskaya	Kaliningradskaya Obl.	85	82	77	55	94	95	74	56
North	Severnii	112	104	147	136	122	111	135	120
North Caucasus	Severo-Kavkazskii	88	85	62	47	80	68	67	53
North West	Severo-Zapadnii	105	92	97	83	109	105	100	83
Ural	Uralskii	129	119	95	88	92	80	89	88
Volga-Vjatka	Volgo-Viatskii	99	85	93	55	97	75	96	63
East Siberia	Vostochno-Sibirskii	271	264	493	382	332	317	442	373
West Siberia	Zapadno-Sibirskii	154	164	109	212	121	156	107	220
Povolsky	Povolzhie	92	-	64	-	80	-	68	-
Russia		***112***	***96***	***95***	***96***	***101***	***105***	***95***	***97***

et al. 2000a,b,c) indicate that drought was the major factor in about one-half of the crop failures during this period. But not only the absence of rain posed a problem; these data also showed that the next most important factor in food crises was the occurrence of too heavy rainfall. In general droughts cause crop failures in the steppe regions of Russia, while overabundant rainfall is responsible in forested regions.

For centuries Russia's agriculture was concentrated near the population areas in European Russia. Despite the best efforts of the peasants, crop yields were always limited by short growing seasons. The situation changed at the end of the 18th century when the food requirements of a growing population finally led to the expansion of cropland into the southern steppe region. Here, better soils boosted yields, and a warmer climate provided a longer growing season. On the other hand, the amount of precipitation in the steppe region varies very greatly from year-to-year and poses a constant challenge to agriculture. The main problem is drought, typically brought on by the formation of a stable anticyclone circulation in Southeast European Russia which sends very dry air to the south of Russia. When combined with stable anticyclone circulation over the Azores, drought can spread over a vast territory of southern European Russia. Major droughts occurred in Southern Russia in 27 years out of the 20th century, while four occurred during the period 1972 to 1981 alone.[1]

Today, the push to exploit minerals, lumber and other resources has spread population and agriculture to almost all parts of Russia. But crop productivity on most of Russia's territory – through most of northwestern Russia, central and northern Siberia and the Far East – is limited by poor soils and severe climate. The best that can be achieved are modest yields from hardy crops such as potatoes. Local production provides only a small part of total food consumption in these regions while the rest must be imported from Russia's main crop export regions in the South. Indeed, only 15 out of the 89 administrative regions of Russia[2] provide the rest of the country with much of its basic food requirements (Figure 1, Table 2**).** Together they account for 50 percent of Russia's total current agricultural production. These regions**,** therefore, play a central role in Russian food security.

How Will Climate Change Affect Agriculture?

The climate scenarios used in this study support the findings of earlier studies (e.g. IPCC, 2001) that climate change is likely to lead to a wetter and warmer climate over most of Russia. By the 2020s an increase in annual average temperature (relative to "climate normal") of roughly 1 to 3 ^{0}C is expected, and by the 2070s, 3 to 6 ^{0}C, depending on the scenario and oblast/administrative region (Figures 2a and b). Precipitation during the summer period (decisive, of course, for agriculture) increases over most of Russia by about 10 to 100 mm by the 2020s, and in some regions by more than 100 mm by the 2070s (relative to climate normal), again depending on location and scenario (Figures 2c and d). We emphasize that an increase in precipitation is expected over *most but not all of Russia*. Indeed, the territory experiencing a decrease in precipitation may be small relative to the total area of Russia, but it has important consequences discussed below.
We have computed that the increase in temperature and precipitation over most of Russia will mean a better climate for agricultural production in many areas now having low or modest crop yields (Tables 3 and 4). For example, under the A2 scenario we compute a 21 to 45% increase by the 2020s in the potential production of potatoes in the Far East (*Dalnevostochnii*), and 75 to 105% by the 2070s[3] (Tables 3 and 4). These results are consistent with earlier studies (see, for example, Sirotenko and Abashina, 1994; Sirotenko et al., 1991.)

The situation is different, however in the major crop export regions in the South – Here the climate scenarios also show a warming trend as in other parts of Russia (Figures 2a and b). But in contrast to the wetter climate expected over most of the country, the scenarios here show a drying tendency – Some climate scenarios show a decrease in average summer precipitation in these regions of up to 50% in the 2020s as compared to the "climate normal" period (1961-90) (Figures 2c and d).

The warmer and drier climate in the South will threaten the potential production of important crops such as wheat, rye, potatoes, maize, and barley. We compute that average potential production of grain (wheat and rye) in the highly populated and productive economic regions (Povozhskey, Central Chernozem, North Caucasus) will drop by 8 to 29 percent in the 2020s, and by about 14 to 41 percent in the 2070s (relative to current averages).[4] A decrease as large as 40 percent in the 2020s and 65 percent in the 2070s is possible for individual administrative regions. These results are also consistent with earlier findings of Sirotenko and Abashina (1994) and others.[5]

In Russia as a whole, the gains balance out the losses somewhat: Depending on the scenario, we compute either a 9 percent loss or a 12 percent gain in total potential grain production by the 2020s (relative to current averages).[6] By the 2070s, only losses are estimated, ranging from 5 to 12 percent for net country-wide production. (Tables 3 and 4).

But the preceding small changes averaged over many years may be not be as important from the standpoint of food security as changes in the frequency of poor harvests. Small average losses do not imply a serious food security problem since they can probably be compensated by food imports or by small changes in the types of crops grown. More serious are the occasional but severe droughts that can lead to temporary but serious shortfalls in food production. In our study we have estimated the change in frequency of droughts and related these to the future occurrence of bad harvests.[7] Under current climate conditions, bad harvests typically occur in the main crop export regions during roughly one to three years out of every decade (depending on the region) (Table 2). Under climate change some regions may experience a doubling of the frequency of bad years after the 2020s and even a tripling after the 2070s (Table 2). This also means that there is a higher chance that several parts of the main crop export regions will experience poor harvests in the same year. In 1984, for example, drought affected several administrative regions in the South at the same time

Because much of Russia is dependent on the crops produced in these few regions, the effects of drought will be felt throughout the country. Figure 3 shows the change in frequency of bad harvest years taking into account this dependence. With few exceptions, most regions in Siberia and the Far East will have more frequent "bad harvest" years, meaning that there will be more frequent bad harvests in the South from where they import their food.[8]

How many people will be affected by bad harvests if no special countermeasures are taken? We estimate that there are now about 58 million people living in regions that experience one or more bad harvests each decade (either in their own region, or in the region from which they import food). This number may increase up to 77 million in the 2020s and 141 million in the 2070s under the A2 scenario.[9] The possibility of more frequent disruptions of food exports is a threat to Russia's food security that should be taken seriously.

How Can Agriculture Best Adapt to Climate Change?

Since agriculture has always adapted to climate and changing societal conditions, the question arises, what strategies would work best to avoid an increasing incidence of bad harvests due to climate change? Here we comment on a range of different strategies to enhance the adaptive capacity of Russian agriculture.

The Option of Substituting Crops.

Under changing climate conditions it is reasonable to expect that farmers will gradually experiment with crops better adapted to the new conditions. To simulate this slow adaptation we have recalculated the potential total production in each administrative region under the assumption that current crops will be substituted by more productive crops. We calculate that crop losses in some regions can be somewhat minimized by substituting, for example, maize for wheat, wheat for rye, or rye for potatoes (Kirilenko et al., 2003). However, the difference in production in the 2020s and 2070s between the old and new crops is usually less than 5 percent.

The Option of Expanding Rainfed Agricultural Areas.

Since climate scenarios tend to show that most of Russia's territory is getting wetter and warmer, why not just open up new rainfed agricultural areas? To an extent this will be possible. For example, areas of the Far East and Southeastern Siberia which now have very low potential productivity will be able to grow maize, pearl millet and sorghum under the climate conditions of the 2070s.

But a variety of reasons will make it difficult to significantly expand crop growing area. First, soils outside of current agricultural areas tend to be of poor quality (Kruchkov and Rakovetskaya, 1990). Second, costs of increasing production (machinery, fertilizers) are substantial compared to the return on investment. (Kruchkov, 1990). Third, the cost of transporting crops to distant markets is very high outside the current growing areas. Fourth, although climate conditions may be getting better for crop production, they are also getting better for the pests, diseases and weeds that threaten crop production (see, e.g. IPCC, 1995 and 2001). In reality, total crop area in Russia has actually been declining since the 1980s because of a combination of factors including soil degradation and decreasing meat demand (Golubev and Dronin, 2003).

The Option of Expanding Irrigated Agricultural Areas

If the main crop export regions are getting too dry for rainfed agriculture, why not expand the area of irrigated agriculture? This may be technically feasible where agricultural land is close to large volumes of water such as the Don or Volga rivers. However, surface waters over most of the main food export regions are already under severe pressure from existing irrigation, industry or municipal users. Furthermore, decreasing precipitation is likely to further reduce river discharge and the volume of water available for new irrigation projects. (See section on "How Will Climate Change Affect Water Resources?").

Other Options for Agriculture

To an extent, substituting crops, or expanding agricultural areas may be options for adapting to climate change, but these strategies may be limited as noted above. Hence a variety of other strategies, national and international, should also be considered for increasing food security.

Diversification of Crops. Most major crops have a wide range of varieties with different climate requirements. It may be possible to identify an existing variety that is better suited to future climate. There are also, of course, major efforts underway to develop new genetically-modified varieties that fulfill various physiological and other requirements. But the advantages of these genetically-modified plants must be weighed against their long term risks to the genetic make-up of natural ecosystems.

Strategic Food Reserves. Not only bad harvest years are common in the main food export regions, but of course, so are very good production years. In principle it is possible to use surpluses from good years to build up a year-to-year strategic food reserve. This reserve would be tapped when a particular region faces a food shortage. Although there are costs associated with taking the grain from the market and placing it in reserve, these costs must be compared to the social and economic costs incurred by a region that faces a bad harvest year.

Improving Agricultural Management. Substantial and unnecessary losses of food occur when crops are harvested, processed and distributed to consumers. Better management could lessen these losses (RFMoA, 2003). Crop losses from pests could also be reduced if "integrated pest management" is used. Not only do unnecessary losses occur, but crop yields could be brought closer to their potential yield if fertilizer use would be better managed (to minimize the amount needed, and to prevent groundwater contamination and other problems). In principle improved agricultural management could make more food available to consumers and reduce the need for other strategies to enhance food security.

Monitoring and Early Warning Systems. While looking for long term solutions to security threats, it may be helpful in the meantime to collect observational data and set up early warning systems to help anticipate crises before they occur. Such systems are currently used, for example, by river basin authorities in Europe to predict river flooding, and by international organizations to predict the occurrence of food shortages in developing countries. An early warning system can be a useful tool to combine medium-term climate predictions with expert knowledge in helping to anticipate where food and water shortages are likely to occur.

Genuinely Free World Food Trade. Although food self-sufficiency is a popular goal of nations, the reality is that throughout history some parts of the world are food exporters and others food importers. Today grain surpluses from the southern regions of Russia provide food for the rest of the country, while the Midwest of the United States provides for the rest of the States, and exports from North America and Europe (among other regions) provide food for Japan and other countries. Producing food where it can best be produced makes economic sense because it enables some regions to focus on non-agricultural economic activities. The problem arises when food trade is used as a tool of national or international policy, either to reward friends or punish enemies. Since climate change is ushering in a new era of uncertainty in the food supplies of all nations (see, e.g. IPCC, 1995 and 2001) perhaps it is a good time to de-politicize world food trade. This may be the right time to do it because it is likely that sooner or later even the richest nations will have to import food. Indeed, a new ethic is needed that says that international food surpluses should be available for purchase and trade to all nations at all times, independent of their current relations. This ethic would take world food trade off the political agenda and enhance the food security of all nations.

How Will Climate Change Affect Water Resources?

Most river basins in the territory of Russia have relatively low levels of pressure on their water resources (Figure 4a). This can be explained by the low population density over much of its territory and the modest

Table 5. Water withdrawals in 2025 in Russia (km^3/a)

Sector	1990	Scenario 2025	
		A2	B2
Domestic	14	29	10
Industry	47	31	16
Irrigation	21	22-24	24
Livestock	1	1	1
Total	**82**	**83-86**	**52**

degree of water withdrawals compared to the volume of surface and groundwater available. Of course a low level of pressure does not necessarily mean that there are adequate canals, pumping stations, or other infrastructure to deliver the available water to all users. Another problem is that many river basins with “low levels of pressure” may in reality have contaminated surface waters due to wastewater discharges from municipalities, industries and cropland.[10] Despite these qualifications, Figure 4a gives a relatively good overview of particular problem areas. For example, through much of Southwest Russia, water requirements for households, industry and agriculture are high relative to the water available. Consequently much of this part of Russia is in the “severe pressure” category (Figure 4a). In these river basins strong competition is expected between different water users, and periodic water shortages are likely to occur.

How will the water situation change in the future? First of all, the expected increase in precipitation over most of Russia will tend to increase river runoff and groundwater recharge, and therefore make more water available to water users. This will on the whole reduce the pressure on water resources. However, in the Southwest where precipitation declines according to the climate scenarios, less water will be available to users.

But to make a good estimate of the future water situation in Russia, it is also necessary to take into account the likelihood of changing water withdrawals. We have computed that the A2 and B2 scenarios show different trends in future water withdrawals (Table 5). Under the A2 scenario, domestic withdrawals increase because of population and economic growth, while industrial withdrawals decrease because of efficiency improvements. Irrigation water requirements only slightly rise because of compensating trends – they tend to grow because of warmer temperatures but shrink because of efficiency improvements and additional precipitation in some irrigated areas. For the B2 scenario, much stronger improvements are assumed in water use efficiency because of the environmental-orientation of the scenario. Consequently, withdrawals sink considerably in the domestic and industrial sectors.

How will the combined trends of water withdrawals and river runoff affect the future water situation in Russia? Under the B2 scenario, the combination of sinking water withdrawals and increasing river runoff reduces pressure on water resources almost everywhere (Figure 4c). By contrast, under the A2 scenario, withdrawals either increase or remain the same (Figure 4b). There is a notable change in pressure in Siberia and the Far East because domestic water uses are proportionately higher here than in the West. The situation does not change significantly in the northern part of European Russia because sinking industrial withdrawals compensate for rising domestic withdrawals. Water resources in the food-growing regions of the Southwest are, as already noted, in the severe pressure category. According to both scenarios, the pressure in this region does not substantially decline, and therefore it is questionable whether new sources of water for irrigation can be found here. This is an important finding when considering the feasibility of expanding irrigated cropland to enhance food security, as discussed above.

In the preceding section we noted that the occurrence of infrequent droughts plays an important role in food security. In the same way, infrequent events (droughts and floods) also have a significant connection to water security. We have calculated that climate change will cause a major change in the variability of river runoff in some parts of Russia (Figure 5a). One important result is that extremely low runoff events may occur much more frequently in the crop-growing regions in the Southwest (Figure 5b). The combination of severe pressure on water resources because of large water withdrawals, and more frequent occurrences of low runoff, may signal a significant threat to the water security of the population living in these regions.

In many other areas of Russia, the frequency of extremely *high* runoff events may increase because of climate change (Figure 5). Here the increased occurrence of flooding could be another threat to the security of the population.

What Can be Done to Enhance Water Security?

A large number of options are available for dealing with threats to water security (see, e.g. Cosgrove and Rijsberman, 2002). These can be broadly divided into "supply-side" and "demand-side" strategies. Supply-side strategies include, for example, increasing water storage in reservoirs as a hedge against drought, although this has become unpopular because of its social and environmental impacts. Another supply-side option is to use lower grade water where possible, as in the withdrawal of water for power plant cooling. "Supply-side" options for flood protection include building river levees to contain flood waters, or constructing floodways to store peak discharges.

Demand-side options to deal with water shortages aim to reduce the needs of water users so that they are less reliant on water when shortages occur. These options include the package of approaches used to stimulate water conservation, from pricing policies to distributing water conservation devices. Another demand-side option is to plug up substantial leakages in municipal water distribution systems. An example of a demand-side option for flood protection is to build an early warning system for predicting floods, as mentioned above. Another would be to limit the use of floodplains for residential or business development.

It is not advisable to rank these options for Russia in general, because their effectiveness and cost depend very much on the characteristics of a particular river basin and the population living there. Consequently, options for enhancing water security can be best reviewed and evaluated on the river basin scale.

Enhancing Security Through International Climate Policy Action

It should not be overlooked that adapting and coping to climate change are not the only strategies for enhancing food and water security. Another effective approach is to reduce greenhouse gas emissions and thereby avoiding or at least reducing the intensity of expected climate change. For this reason Russia should cooperate in emission reductions under the Framework Convention for Climate Change. As of the writing of this report, the Russian government has expressed its support for ratifying the Kyoto Protocol to the Framework Convention (which would establish binding emission reduction targets for Russia and other signatories), but the Duma has not yet ratified it. It is worth noting that even if the Protocol is ratified, modeling analyses have shown that emission reductions under the Protocol will not significantly slow down climate change. (Although the Protocol will be a significant step in international climate policy). To seriously reduce the intensity of climate change, much stronger reductions are necessary. With this in mind, Russia should join with other industrialized nations in planning for the necessary emission reductions in the richer countries of the world, while also encouraging developing nations to slow down and eventually reverse the growth of emissions in their countries.

Concluding Remarks

This report has addressed the question, “will climate change threaten food and water security in Russia?”, and provided new information about security threats. Now the nature of these threats must be studied in more detail. These outstanding questions include: Is the assessment of climate impacts robust in the face of uncertainty of climate change? What regions are particularly vulnerable? How will the increase of bad harvests and extreme runoff events interact with the economic and political transitions going on in Russia?

Furthermore, not only must we dig deeper into the nature of the threat, but research is also needed to identify strategies for coping with this threat. Above we only began to sketch out some of the options available for enhancing food and water security. These and other options must be systematically examined and evaluated for different regions or river basins of Russia. An evaluation of options should also take into account institutional, political and social factors.

To sum up, our findings challenge the belief that climate change will generally benefit Russian agriculture and water resources. Instead they point out how extreme events such as droughts may become more frequent in key areas of Russia and may pose a threat to the food and water security of its people. Such threats deserve the serious attention of researchers, policy makers and the general public.

Appendix. The GLASS Model: A New Method to Estimate Threats to Food And Water Security

The basic tool used in this study for relating climate change to food and water security is the newly developed GLASS model (***Gl**obal **As**sessment of **S**ecurity*). GLASS was developed at the Center for Environmental Systems Research at the University of Kassel in Germany (Alcamo et al., 1999 and 2000). GLASS integrates information about global climate, environment, agriculture and water resources in a single framework. It also focuses on the impacts of extreme events such as droughts, and the relative susceptibility of the population based on socio-economic indicators. Hence it provides a good tool for analyzing the impact of climate change on food and water security in Russia. At the core of the GLASS model are two key submodels – the GAEZ model of potential crop production and the WaterGAP model of water availability and use. These models are used within GLASS to investigate changes, respectively, in crop productivity and water availability for various scenarios of climate change.

Computing Crop Production – the GAEZ Model. The GAEZ model (**G**lobal **A**gricultural **E**cological **Z**one) is used to compute climate-related crop productivity. The GAEZ model was developed at the International Institute of Applied Systems Analysis (IIASA) in Austria (Fischer et al., 2000) for global analysis of potential production of 154 varieties of crops on a 0.5^0 by 0.5^0 latitude, longitude grid. The following are the main steps of model calculations: First, the model estimates if it is feasible to grow a particular crop variety at a particular location based on empirical agro-climatic relationships. Second, for feasible crops, the model computes the maximum annual yield under theoretical conditions. Third, the potential production is modified by taking into account agricultural technology and other limiting factors. In using this study we compute the potential production of the main crops currently grown in Russia, or may be grown under changed climate. These include: wheat (eight varieties), rye (four varieties), forage maize (six varieties) and potatoes (four varieties), as well as rice, grain maize, barley, sorghum, millet, and cassava. Although the GAEZ model has been validated at sites throughout the world by its IIASA developers (Fischer et al., 2000), we have tested it further against Russian data. We compared model calculations of crop production with data from 1901 to 1995 from the Central Chernozem/Black Soil region (Centralno-Chernozemnii) and found an acceptable agreement, after taking into account the uncertainty of the historical record (Kirilenko et al. 2003). The model performed better for dry than wet periods which is significant since we are mainly concerned with the impacts of droughts in our study.

Computing Water Resources – the WaterGAP Model. The WaterGAP 2 model (**Water**-**G**lobal **A**ssessment and **P**rognosis) is used to compute water availability and use. The WaterGAP 2 model was developed at the Center for Environmental Systems Research at the University of Kassel in Germany and is a flexible tool that can compute many different indicators of the status of water resources (see, e.g., Alcamo et al. 2003, Döll et al., 2003). In this study the model is used to compute the "water withdrawals to availability ratio" as a measure of the degree of pressure put on water resources (including its quantity and ecosystems) by the users of these resources. Users include municipalities, industries, power plants and agricultural enterprises. WaterGAP computes water withdrawals by relating changes in national income to changes in the amount of water used per person and per unit electricity generated. These calculations also take into account the saturation of water demands at high incomes, as well as continuing improvements in water use efficiency due to technological change. Water requirements for irrigated crops are computed by taking into account the location of irrigated areas, local climate, and crop and management variables. Water availability (equivalent to the natural discharge in each watershed) is computed from daily water balances of the vegetation canopy and soil. These water balance computations are driven by precipitation, temperature, and other climate data. A water balance is also performed for open waters, and river flow is routed through a global flow routing scheme. WaterGAP 2 calculations of withdrawals have been calibrated against historical data provided by Shiklomanov (2000). Runoff calculations have been calibrated to annual runoff data from a network of stations covering most of the territory of Russia. The calibration of runoff is reported in Döll et al. (2003).

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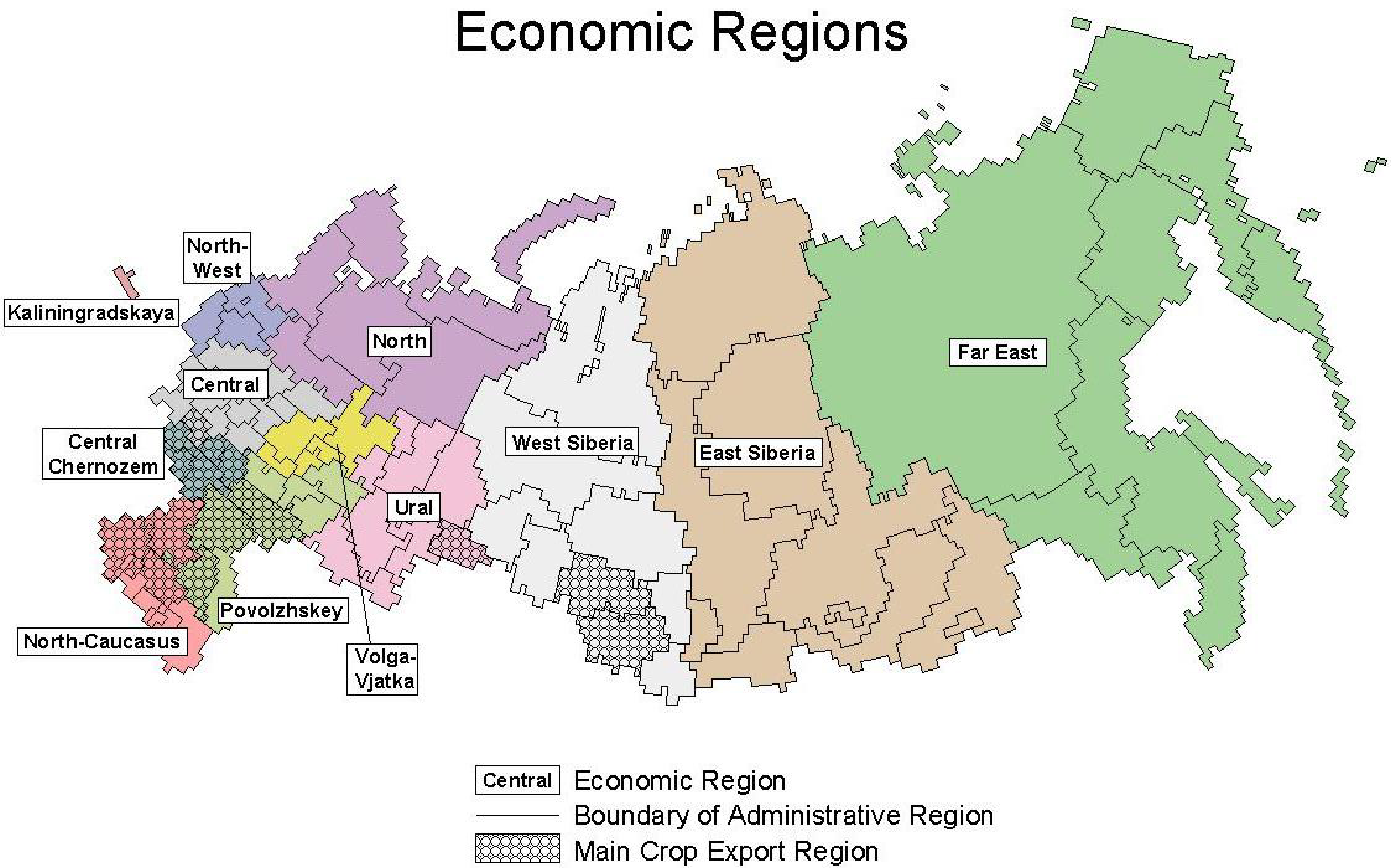
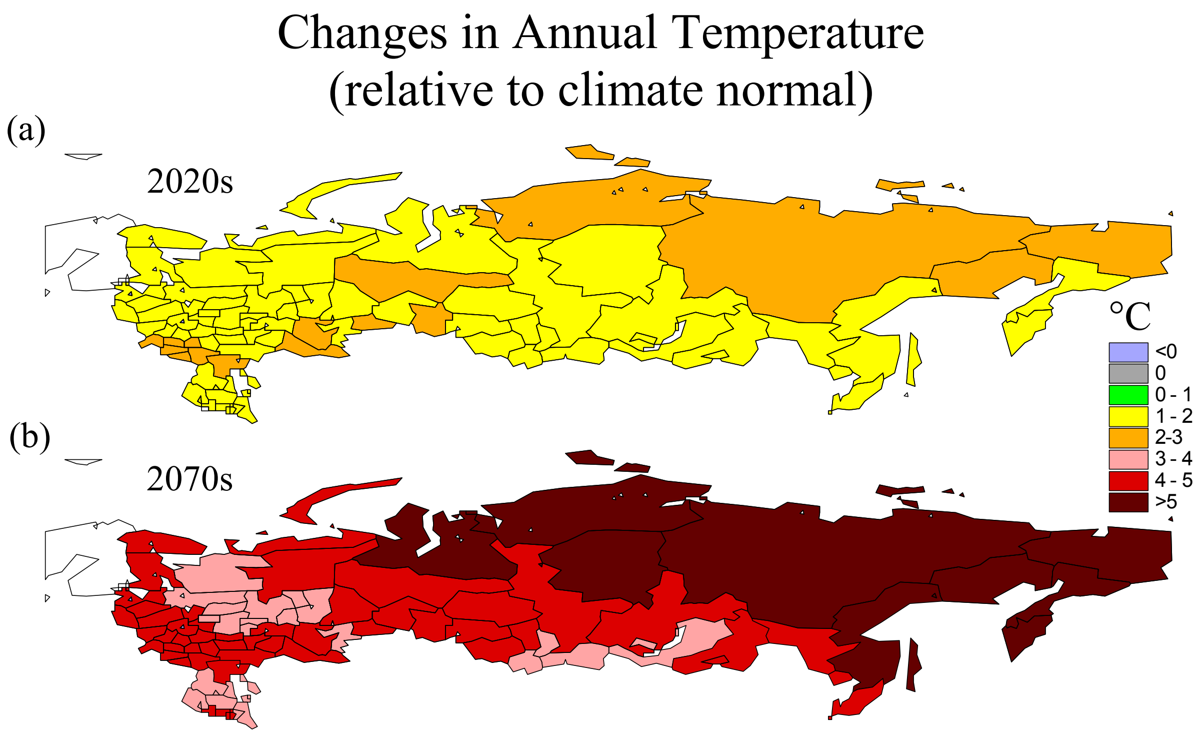


Figure 1: Economic and administrative regions of Russia.



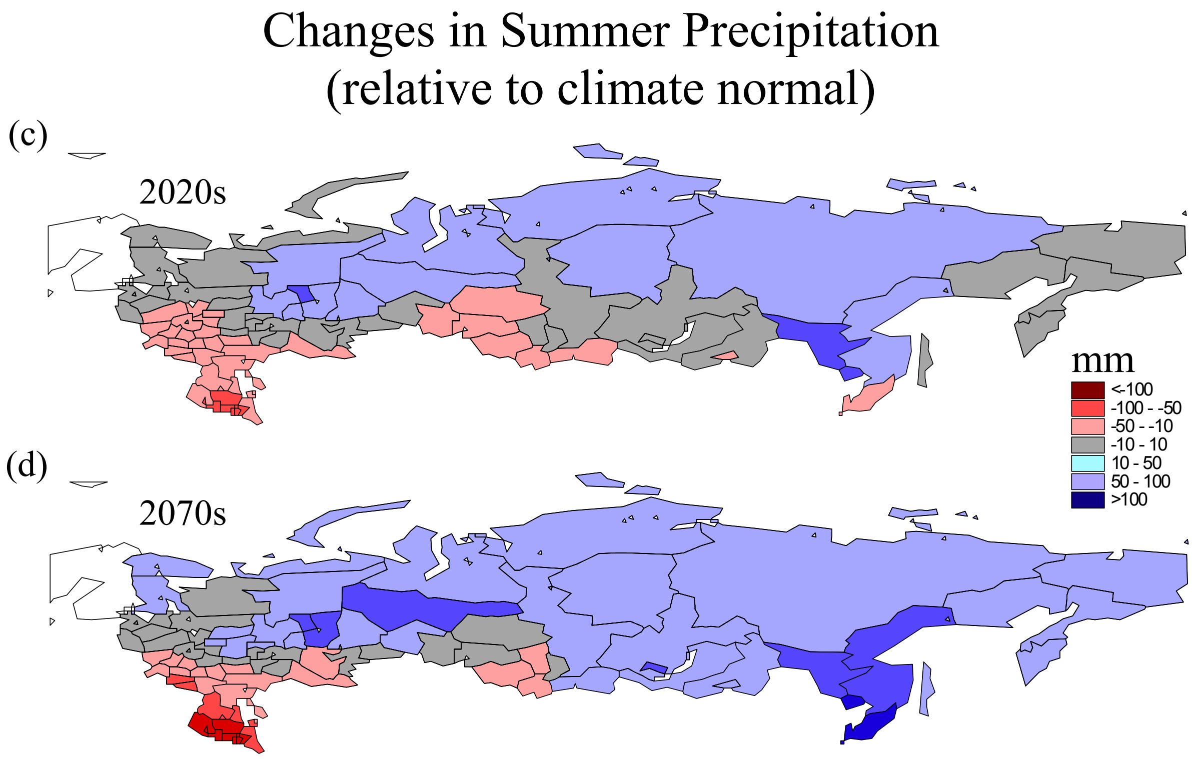


Figure 2: Changes in climate (relative to climate normal) for the A2 scenario computed by the HADC3 model: (a) annual surface temperature for 2020s, (b) for 2070s, (c) summer precipitation (July, August, September) for 2020s, (d) for 2070s. Note that precipitation changes are for the *summer* period.

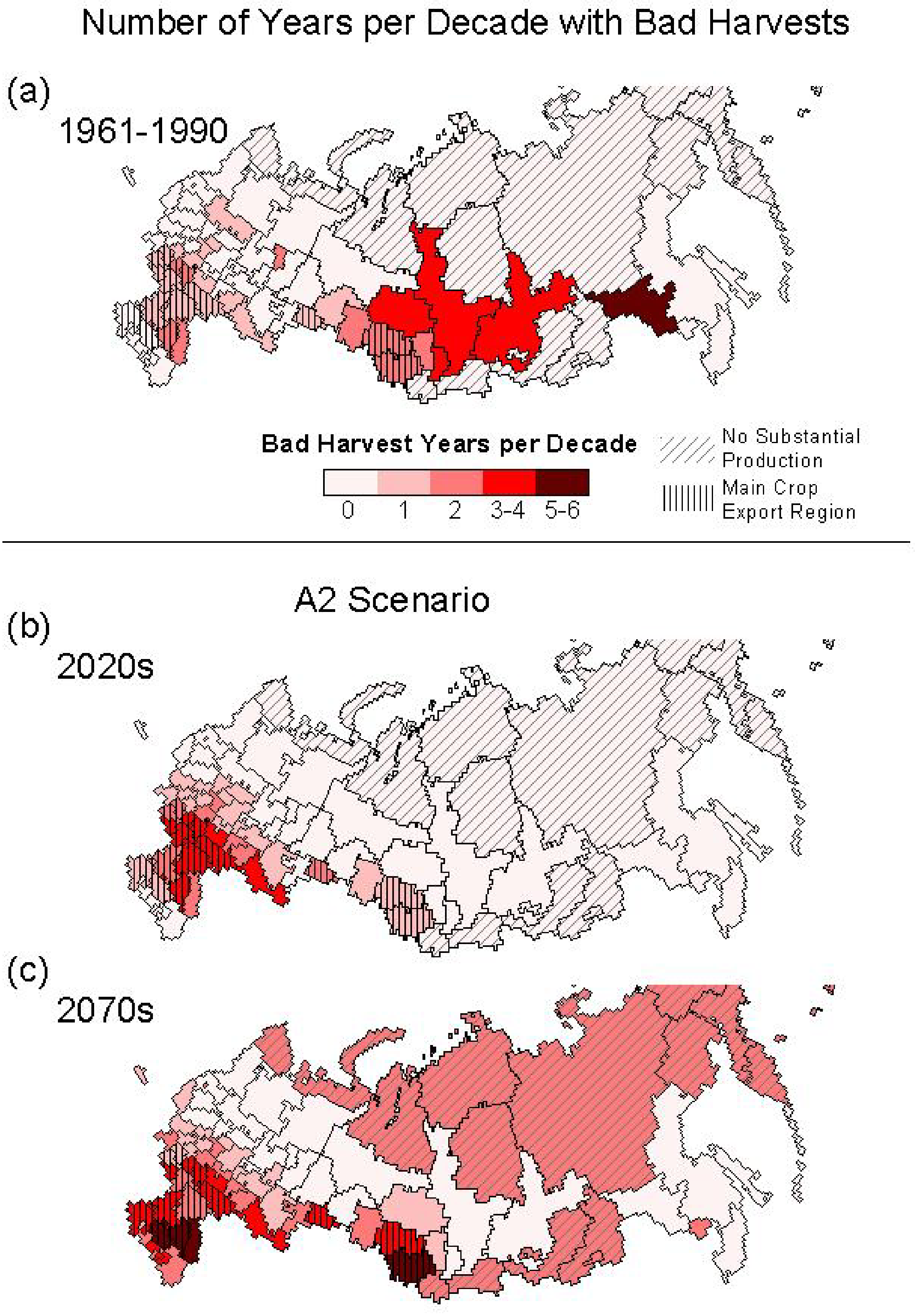


Figure 3: Frequency of bad harvest years computed by the GLASS model for the A2 scenario, with climate scenarios from the HADCM3 model. (a) Frequency under climate normal, (b) 2020s, (c) 2070s.

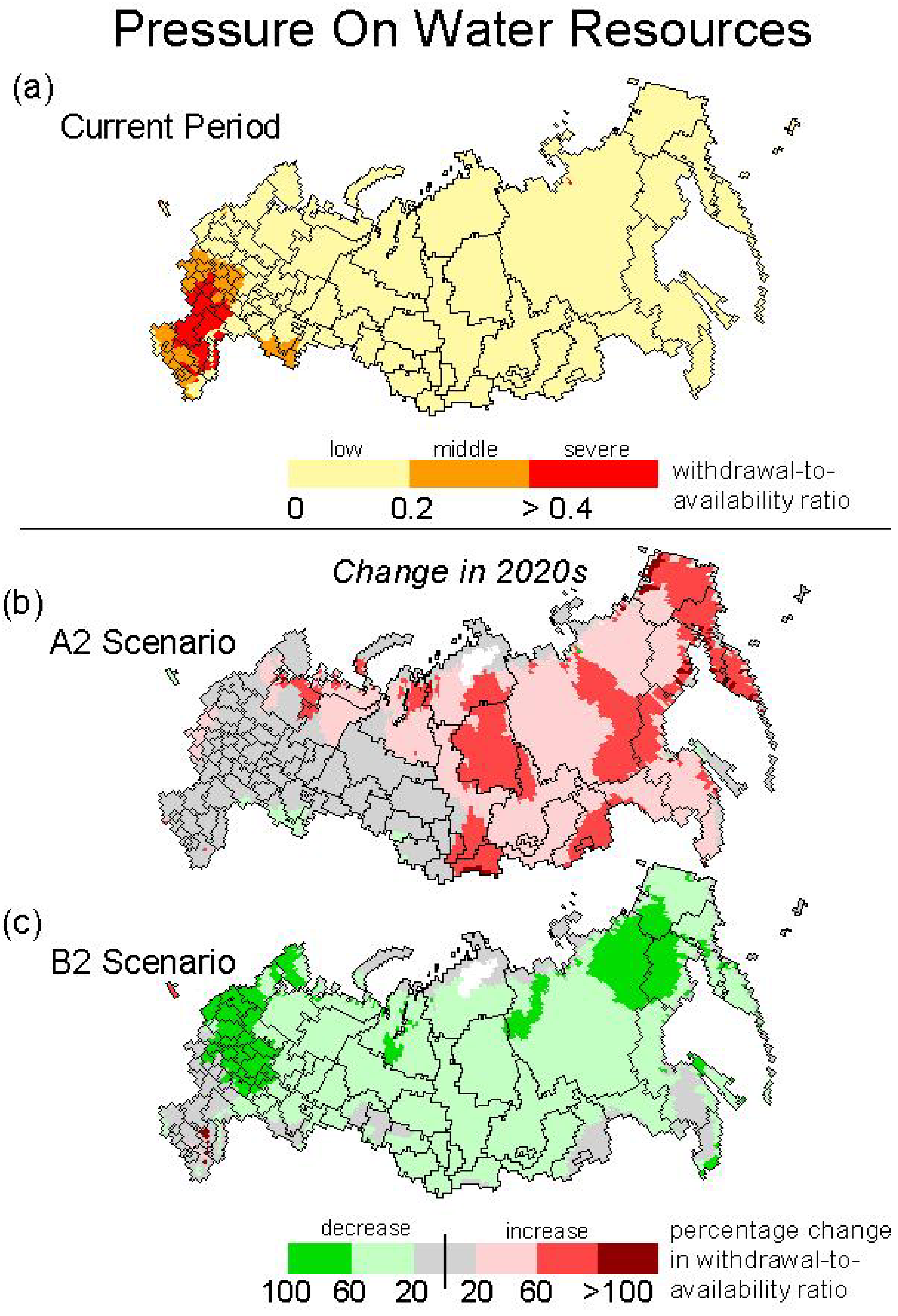
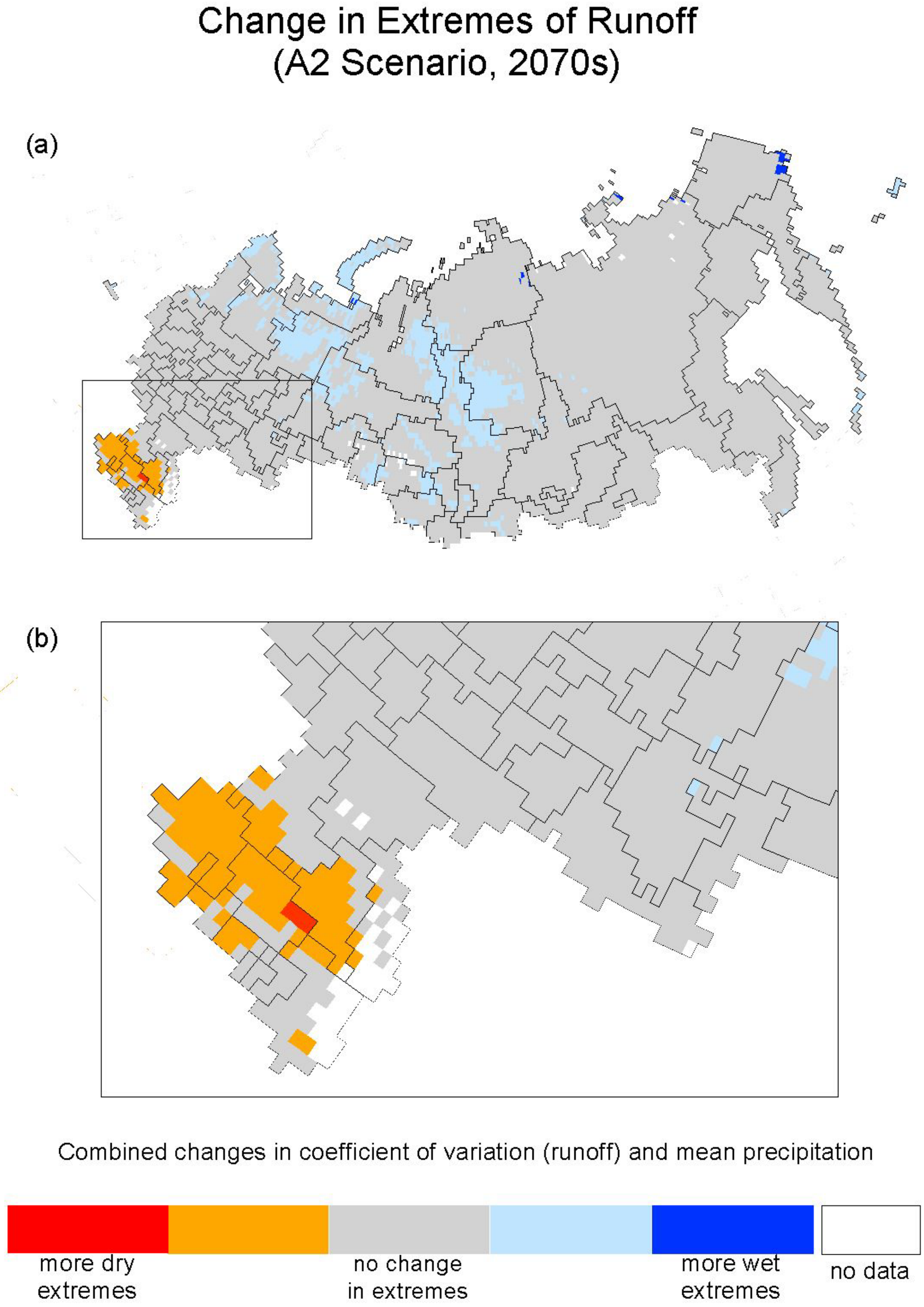


Figure 4: Pressure on water resources as indicated by the withdrawals-to-availability ratio (wta) computed by the WaterGAP model with climate scenarios from HADCM3: (a) current wta, (b) change in wta in 2020s under the A2 scenario, (c) change in wta under the B2 scenario.



(c) Center for Environmental Systems Research, University of Kassel, February 2003 - Water GAP 2.1D

Figure 5: Changes in extremes of runoff between the current climate and 2070s, computed by the WaterGAP model for the A2 scenario with climate scenarios from HADCM3. Orange indicates a decline of between 5 and 25% of the coefficient of variation of runoff and annual precipitation, and red a decline of more than 25%. Light blue indicates an increase of between 5 and 25% of the coefficient of variation of runoff and annual precipitation, and dark blue an increase of more than 25%. (a) for all of Russia, (b) inset for Southwest Russia.

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Endnotes

[1] A major drought is assumed to occur when the summer hydrothermal coefficient (HTC) is below 0.7. The HTC and the threshold for major droughts were proposed by Seljaninov (1966). We computed the HTC for all Russia using the climate data from New et al. (1999). From these computations we determined that major droughts occurred 27 times between 1901and 1995 in the South of Russia.

[2] These 15 regions are shown in Table 1 and are referred to collectively in this report as Russia's "main crop export regions".

[3] Ranges are due to different climate scenarios produced by the HADCM3 and ECHAM4 climate models.

[4] The range is due to differences between economic regions, different levels of climate change computed by the different climate models, and differences between the A2 and B2 scenarios. Recall that these are calculations of climate-related potential productivity. The actual productivity will depend on many other factors such as fertilizer input and the type of agriculture used.

[5] One difference between our analysis and the work of Sirotenko and Abashina and others is that we have not included the so-called "CO_2" fertilization effect – This is the effect observed under experimental conditions in which crop growth is stimulated by levels of atmospheric CO_2 that are comparable to the levels predicted by climate models. The implication of these experiments is that future levels of CO_2 will tend to boost crop production. We have not included this effect in our calculations because recent studies raise the question of whether these experimental results will be fully realized by actual crops in the field (see, for example, the literature review in IPCC, 2001). Nevertheless, the impact of the CO_2 effect on crop production in Russia should be further studied.

[6] The range is due to different levels of climate change computed by the different climate models, and differences between the A2 and B2 scenarios.

[7] The future frequency of droughts is estimated by the GLASS model (see Appendix) by combining month-to-month variability of climate patterns from 1961 to 1990 with average changes in monthly climate for the 2020s and 2070s, respectively, computed by the HADCM3 and ECHAM4 climate models. A "bad harvest year" is defined as a year in which the potential (climate-related) yield of the major crop in an administrative region is 50% or less than its climate-normal (1961-90) average. The resulting model calculations are very consistent with the large year-to-year variations of grain production historically observed in these regions.

[8] These calculations factor in the dependence of most Russian regions on food exports from the main crop export regions, as listed in Table 1. Therefore, the effects of future droughts in the major crop export regions propagate to the regions importing food. These calculations also take into account that a good harvest in one food-exporting region can partly compensate for a bad harvest in another. It also takes into account that some droughts will cause bad harvests in several administrative regions at the same time.

[9] For these estimates we use the computed number of bad harvest years shown in Figure 3. To estimate the current number of people affected, we use population census data from 1995. To estimate the number affected in the 2020s and 2070s we use the A2 population scenario from IPCC (2000) and Lutz and Goujon (2002).

[10] See, for example, the European Environment Agency. 1995. Europe's Environment: The Dobris Assessment. EEA Copenhagen. 676 pp.