Geography of Droughts and Food Problems in

Russia (1900-2000)

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

February 2004

Genady Golubev and Nikolai Dronin

Department of Geography, Moscow State University,
Moscow, Russia

Published by the
Center for Environmental Systems Research,
Kassel, Germany

Geography of Droughts and Food Problems in Russia (1900-2000)

Report A 0401, February 2004

Center for Environmental Systems Research,
University of Kassel, 34109 Kassel, Germany
Phone: +49- (0) 561 804 3266
Fax: +49- (0) 561 804 3176
Internet: http://www.usf.uni-kassel.de

Please cite as:
Golubev, G. and Dronin, N. (2004) Geography of Droughts and Food Problems in Russia (1900-2000), Report No. A 0401. Center for Environmental Systems Research, University of Kassel, Kurt-Wolters-Str. 3, 34109 Kassel, Germany. http://www.usf.uni-kassel.de.

Front and back cover:
Original photograph from Nikolai Dronin

Contents

Contents 2
Acknowledgements 3
Introduction 4
Chapter 1 6
Geography of Russian agriculture 6
1.1. Crop composition 6
1.2. Division into “Consumption” and “Production” regions 10
1.3. Weather variability and agricultural production 13
Chapter 2 19
Why has Russian agriculture been vulnerable to weather variability? 19
Chapter 3 23
Droughts and food crises in Russia 23
Chapter 4. Conclusions 25
To what extent should Russian agriculture be changed in order to cope with climate change? 25
References 27

Acknowledgements

We would like to express our thanks to the colleagues from the Center for Environmental Systems Research of the University of Kassel, headed by Prof. Dr. Joseph Alcamo, who invited us to participate in the project on "Modeling Climate Change and Its Impacts on Agriculture in Russia". Our research would not have been possible without this project. We are also grateful to the team of the Open Society Archives of the Central European University (Budapest, Hungary) for their permanent support in obtaining invaluable information and data. Thanks are due Barbara Lübkert-Alcamo for editing this report with financial support of the Institute for Integrated Systems Analysis (IISA).

Introduction

This study of the geography of droughts and food problems of Russia is part of the International Project on Global Environmental Change and Its Threat to Food and Water Security in Russia. It has been conducted by University of Kassel (Germany), the Center for Environmental Systems Research, in cooperation with Moscow State University (MSU), the Faculty of Geography and the Center for Ecology and Forest Production of the Russian Academy of Sciences. The main result of the international project is a new integrated model "GLASS" which provides a consistent method for examining changes in agricultural production and water supply in the Russian Federation as a result of global climate change. The retrospective analysis of the geography of agricultural and food problems in Russia is to reveal the most important factors influencing food production and distribution in different parts of Russia in the 20th century in order to better understand how Russia could react to climate change.

As a consequence of climate change, the GLASS model computes a considerable decrease of cereal yields in the most productive parts of Russia. Even though cereals will grow in the more humid central and northern regions, the average yield in Russia will decrease considerably due to a severe increase in droughts in the most productive regions. At its extreme, in Stavropolsky Krai, the key agricultural region of the Northern Caucasus, potential cereal production would decrease by 27% in the 2020s and by 56% in the 2070s. In contrast, the yield of cereals in the central region will not change much, whereas yields in the northern regions will increase significantly. However, this latter increase contributes little to the total grain production of the country.

Our analysis of the history of agricultural and food problems in Russia in the 20th century proves that Russia belongs to one of the countries most vulnerable to climate variability due to unfavorable natural conditions and a weak agricultural sector as well as poor mechanisms of social insurance. During the last hundred years, the country faced numerous severe droughts that affected the major agricultural zone of the country. In some years, the food shortage struck the whole country. Mass famine occurred in years of political instability. Later, in order to cope with grain shortages, the Soviet Union had to import large amounts of grain from the West. In the 1970s and 1980s, the Soviet Union was the largest grain importer in the world. After the break up of the USSR, the share of food imports still reaches 20-30 percent (for example 28% of grain was imported in 1995) because of the dramatic decline of its own agricultural production (Agriculture in Russia, 2000, p.130).

Now, we turn to the historical analysis. Why has Russia experienced permanent food problems through its history and how likely is it to face food shortages in the future? The country is characterized by a relatively high level of cropland available for cereal growth, i.e. 0,47 ha per

person, which is much higher than the world's average figure of 0,12 ha per person. Russian population growth was moderate in the second half of the 20th century, i.e. 0,7 percent a year. As most countries of the world, from 1950 to 1980, Russia considerably raised the productivity of its croplands due to the implementation of technological achievements of the Green Revolution. The country achieved a cereal yield comparable to that of the developed countries located in similar geographical conditions (e.g., Canada). In 1990, the Soviet Union occupied the third place in the world in terms of grain consumption per capita (842 kg). The Russian agricultural sector received considerable state subsidies for many decades comparable to that of any western European country or the United States.

In addition to the various scientific works on the economic history of the Soviet Union, there are two main sources of original information on this subject. In order to reconstruct the performance of the agricultural sector of key agricultural regions in Russia, we have relied on different official statistical reports on the agriculture of Russia, which are available for the last hundred years. The reliability of Soviet agricultural statistics has also been studied in the course of this research.

Valuable original information on agricultural policy and food problems in Russia was accessed at the Open Society Archive of the Central European University (Budapest, Hungary). The archive has a rich collection of materials (including articles from Soviet and foreign papers, analytical notes of the Institute of Radio Free Europe) on agricultural development and food problems and other historical aspects of the USSR in the postwar period (1950-1990). This has been an important source of information because the historical literature of the USSR covers this period even worse than earlier ones (for example, the 1920s) due to Soviet suppression of information on food supply difficulties in any parts of the USSR during the era of "developed socialism" (1970s and 1980s).

Chapter 1.
Geography of Russian agriculture

1.1. Crop composition

When analyzing the development of Soviet agriculture, it has to be kept in mind that, due to its northerly location, Russia is comparatively poorly off in terms of agricultural land and climatic conditions. This means that, under any system of farming, the agricultural labor and/or capital productivity would be appreciably lower than in the United States or Western Europe. The center of Russia lies at roughly the same latitude as the Hudson Bay, and St.Petersburg is at the same latitude as southern Alaska. Western European countries, although roughly at the same latitude as Russia, experience an unusually temperate climate due to the influence of the Gulf stream.

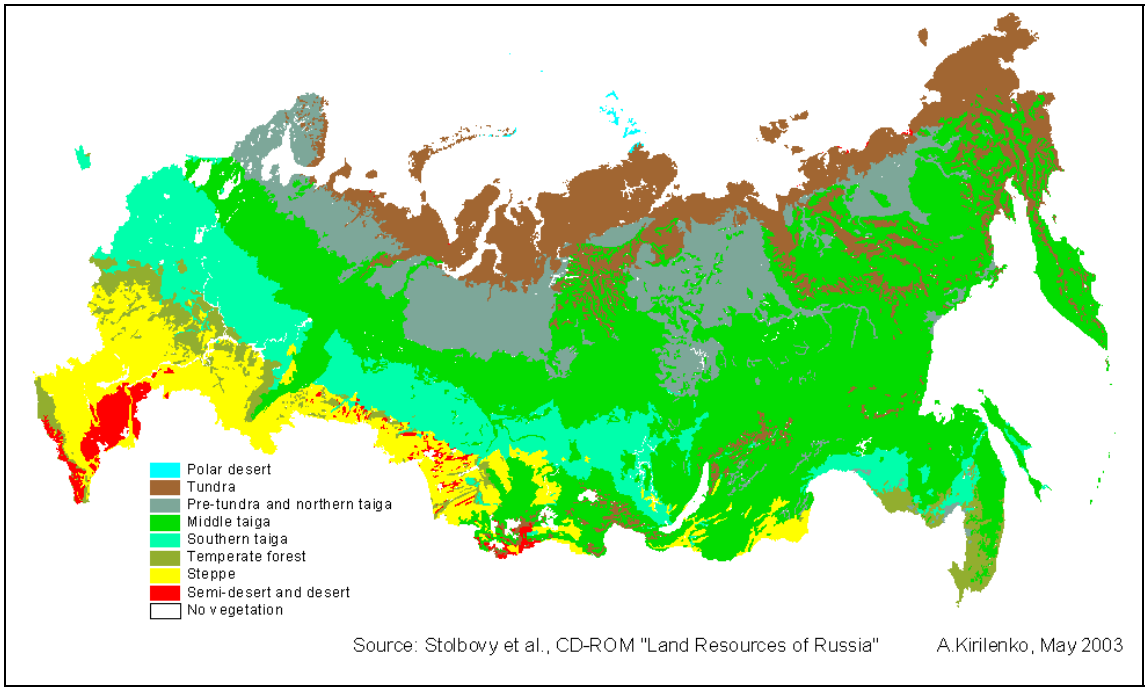
In 1972, W.H. Parker compared the USSR and the United Sates in terms of the Koppen's classification of climate. The predominant climate in the USA is "humid temperate", characterized by rain all year round with hot summers and mild winters. This type of climate is characteristic for 34 percent of the land area of the USA, but only found in 0,5 percent of the USSR in an area along the Black Sea. In the USSR, the predominant climate was the "humid continental", marked by at least some precipitation all year round but with cool summers and cold winters. This type of climate was characteristic for 31 percent of the USSR, but can be found only in small parts of Alaska in the USA.

N.C. Field (1968) assessed the climate of both countries from the point of view of its potential for agriculture. He found that whereas 80 percent of Soviet cropland fell within the "least productive thermal zone", only nineteen percent fell into this category in the United States. On the other hand, the United States has 32 percent of its cropland in the most favorable thermal zone, the Soviet Union only four percent. The USSR was also found unfavorably placed with regard to soil moisture. Its continental position means generally low rainfall and more restricted water supply; it has no extensive humid areas corresponding to the American East, South-East, and North-West regions into which moist oceanic air is drawn without impediment. As a result, the average annual precipitation over the United States (782 mm) is much higher than that for the Soviet Union (490 mm).

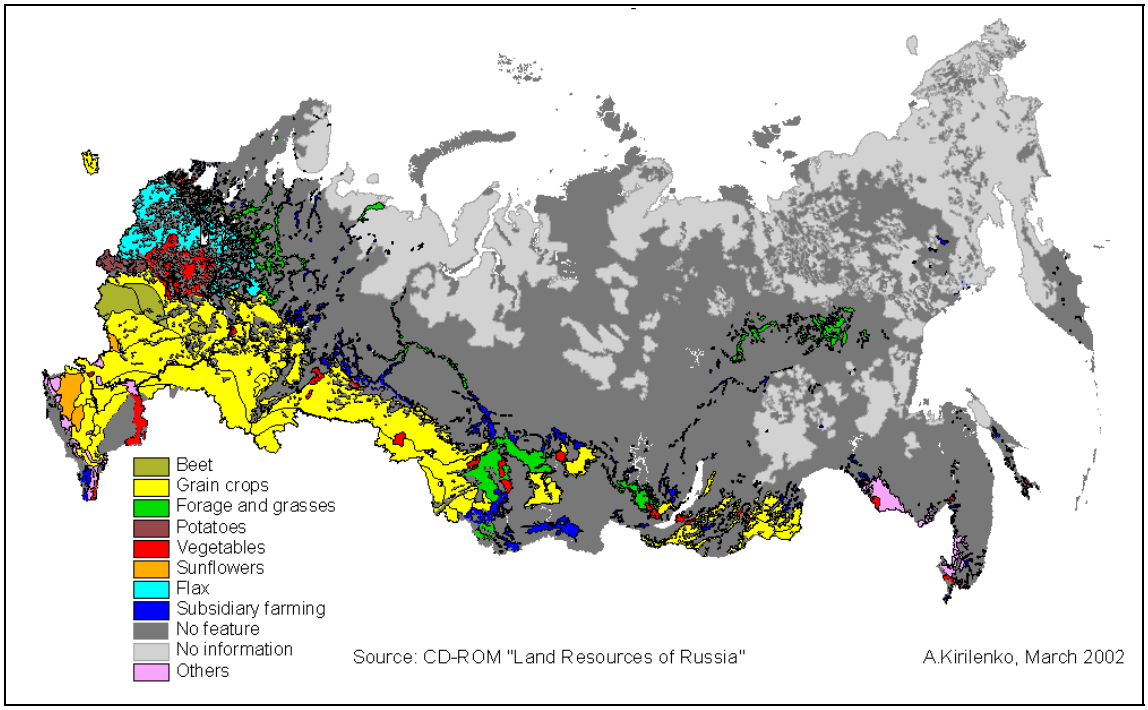
According to Peter Gatrell (2000), in the USSR only 1,4 percent of land suitable for cereal cultivation was located in areas of an optimum combination of temperature and moisture. In the United States, such optimum climate conditions were found for 56 percent of its cropland. In Russia, about four fifth of its cropland lies in a zone of risky agriculture while, in the United States, only one fifth of its cropland could be regarded as located in this risky zone.

Regarding crop composition, there is a big difference between the USSR and the United States since most territory of the USSR was so cold that only hardy, early-matured crops could be grown. The country was also characterized by a great variability in the first and last onsets of frost (White, 1987). Frost limits the length of the growing season, and the lack of degree days over 20 °C restricts the range of crops. The growing season, essentially the frost-free period, is only 130-160 days long in the central chernozem region, famous for its rich soils. In the central regions of European Russia, the growing season lasts for 110-130 days. Further to the north, the growing season is down to 120 days (Arkhangelsk oblast). In the south of European Russia, being the major agricultural region of the country – the North Caucasus and the Volga basin –the growing period ranges between 165 and 200 days. In the steppe regions of Western Siberia, the growing season decreases to 115-130 days (Khomyakov, Kuznetsov, et al., 2001). The growing season everywhere in the Russian Federation is considerably shorter than in Western Europe (260-300 days).

In the USSR, the most important food crop was wheat. It covered more than 50 percent of cereal crop area in the 1960 and 1970s (see Table 1.). In comparison with most cereals of the moderate zone, wheat is very vulnerable to cool weather and soil acidity. Both factors limit the geography of wheat production to the forest steppe and steppe zones in the former Soviet Union (see Map 1. & 2.). Winter wheat crop is cultivated mainly in the Ukraine, the Northern Caucasus and the chernozem belt where conditions for the crop wintering are most favorable. The climatic regime to the east - in the south of Western Siberia and Northern Kazakhstan – with late but hot summers, dry autumns, and frequently a light snow cover during a severe winter – rules out winter wheat. In these regions, spring wheat is planted although average yield of spring wheat is only 50 percent of winter wheat (Kruchkov, Rakovetskaya, 1990). Climate also favors the hard red grain over the soft wheat, the former being characterized by a shorter growing season and a lower yield (White, 1987).



Map 1. Natural vegetation cover of the former USSR



Map 2. Dominant crops

Rye is another principal food crop in Russia. In the 17th century, rye prevailed as a crop in Russia, reaching 50 percent of the total crop area (Milov, 2001). In the first half of the 20th century, rye crop still occupied up to 20 percent of the cereal crop area and only later, the rye crop area declined to less than 10 percent. In other countries, including the United States, rye has never played a significant role in agricultural production. In Russia, preference for rye shows again the limitations of Russia's physical environment. Winter rye can withstand colder temperatures than

wheat and requires less precipitation, particularly during the growing season. Rye also tends to do better in the podzolic soils of the forest zone. The hardier root system of rye penetrates the compacted soils more easily and therefore requires less deep plowing. Rye also does better with regards to weeds compared to wheat (White, 1987). Rye is cultivated mainly in the forest zone, i.e. in the central and northern part of the country.

Table. 1. Structure and area of cropland in the Russian Federation in 1913 – 1997 (million ha)

Year	1913	1928	1940	1945	1950	1960	1965	1970	1985	1997
Total crop area	69,8	74,2	92,1	67,1	88,9	120,7	123,9	121,9	119,1	96,5
Inc. Cereal	62,9	61,4	70,2	50,9	64,9	71,4	77,6	72,7	68,1	53,6
Wheat	18,2	17,3	25,5	14,1	24,2	35,7	40,5	38,9	24,2	26,1
Rye	20,2	19,2	16,5	14,2	14,0	12,4	11,8	7,7	7,2	5,0
Other cereal	24,5	24,9	28,2	22,6	26,7	23,3	25,3	31,2	36,7	22,5
Technical crops	2,8	5	6,2	3,8	5,7	5,9	5,8	5,6	5,7	5,4
Inc. Flax	0,97	1,22	1,52	0,77	1,4	1,02	0,7	0,5	0,5	0,11
Sunflower	0,88	2,55	2,45	1,71	2,3	2,29	2,3	2,2	2,3	3,6
Sugar beets	0,11	0,12	0,34	0,27	0,3	1,33	1,4	1,5	1,5	0,9
Potato and Vegetable	2,5	4,8	5,3	6,4	5,7	6,1	5,1	4,5	4,2	4,1
Forage	1,4	2,7	10,4	6,0	11,8	37,3	38,2	40,1	40,8	33,2

Source: The Russian Federation for Fifty Years, 1967; Agriculture in Russia, 2000.

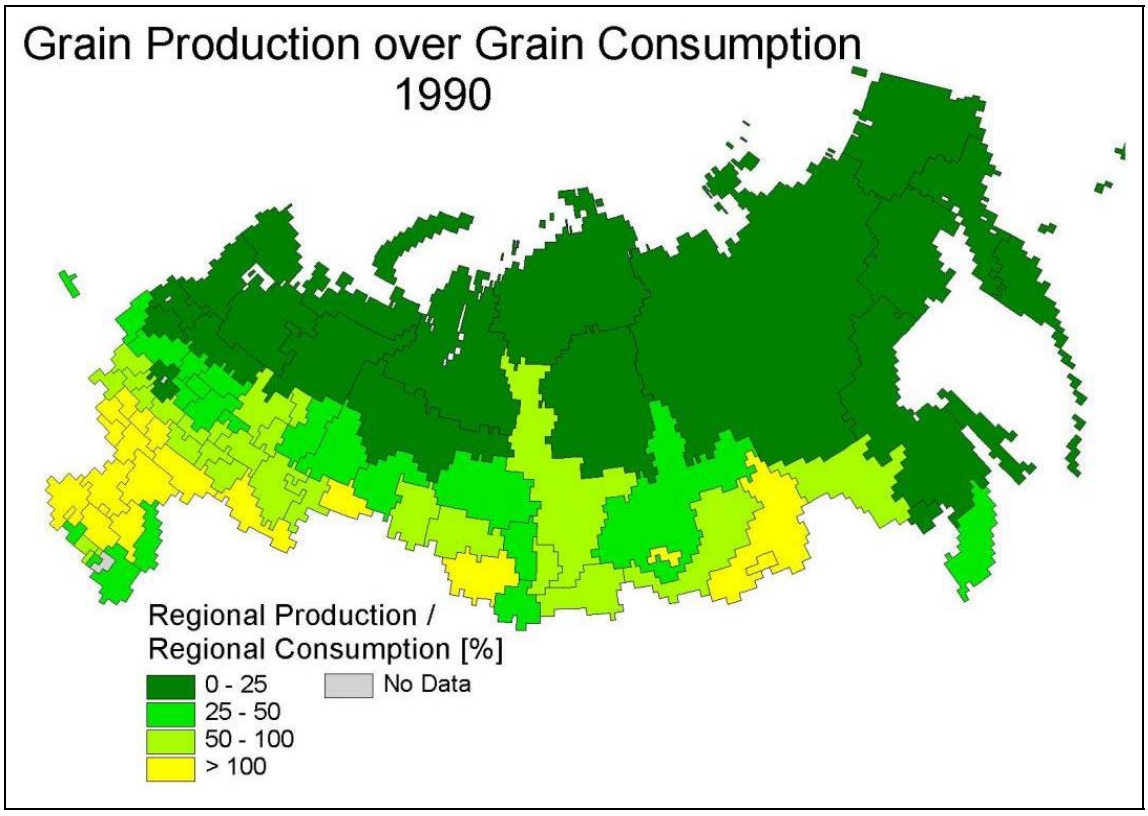
In the USSR, a major feed cereal was barley. The main advantage of barley is that the crop can withstand early frost and a deficit of moisture. Barley produces a good harvest when being planted on clay soils. This peculiarity of the crop determines its wide geographical distribution in Russia. It is cultivated both in northern regions, which are characterized by a deficit of heat, as well as in the arid regions of the country. From 1940 to 1980, the area of barley crop had increased threefold due to a growing domestic demand for feed grain. Oats - another feed grain - differ from barley by its higher vulnerability to heat and the moisture regime. Oats are more affected by drought. On the other hand, oats can withstand the acid regime of poor podzolic soils. That is why it is cultivated mainly in the forest zone (Kruchkov, Rakovetskaya, 1990).

The most important feed grain - maize -, which prevails in the United States, cannot be grown in Central Russia because of the short growing season and insufficient precipitation. Maize crop is very vulnerable to even slight frost. The optimum growing season for maize is 150-180 days. For full maturation, maize requires a thermal level of 200 degree-days and a moisture level of 80 percent, a combination found only in a small part of the USSR (Western Ukraine and Northern Caucasus) but in 35 percent of American cropland (White, 1987). The same problems are observed with the cultivation of beans, sorghum, soybeans, and peas. Their vulnerability to

heat, early frost in the autumn, and soil acidity made Russian farmers reluctant to cultivate these crops. Thus, one of the problems associated with the adverse climatic conditions in Russia is the limited cultivation of feed grain crops rich in protein.

1.2. Division into "Consumption" and "Production" regions

The most notable feature of the geography of Russian agriculture is the strong division of the country into "consumption" and "production" regions. The fact that the most valuable market crop wheat was initially found in steppe and forest-steppe zones of Russia determined the division of the country into potential production areas of "steppe" and "forest steppe" and potential consumption areas of all other land cover zones (e.g., "forest", etc.). "Consumption" and "production" regions were officially distinguished for administrative purposes in Russia starting in the late 19th century. They are based on the natural features of the country and, in the same way, still exist now. Northern and central "forest" regions traditionally have to import wheat and other agricultural products from the southern "steppe" zones. Map 3. shows that the ratio of grain production to consumption in the regions of Russia differs in different natural zones of the country. At present, 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 the country's food security. About 50 percent of Russian agricultural production today comes from these regions.



Map3. Ratio of grain production to consumption in the regions of Russia

Map 3. shows the geographical distribution of surplus grain production in the different regions of the country. The large difference in availability of actual crop area and potential productivity in the southern and northern parts of Russia is a very important factor in the functional division of the country. Cereal yield on podzolic type of soils prevailing in the forest zone is 1,5-2,0 time less than that on chernozem (black earth) soils of the steppe and forest-steppe zones. In addition to the difference in fertility of these soils there are some other factors involved. W.H. Parker (1972) made an interesting observation comparing yields in the USSR and the USA. He found that, on the drier lands, the yields are comparable, but as one moves into areas with a positive moisture balance, yields increased much faster in the United States than in the Soviet Union. Thus, in the coniferous forest belt, average yields of oats are four times higher in the US than in Russia. This is most likely explained by demographic reasons. Farmers in the cooler and moister parts of the United States have over the years left the rural regions and moved to the urban areas, leaving only the best and most productive lands in cultivation. In Russia, on the other hand, we have not observed this trend and although some land has gone out the cultivation in the taiga forest and northern mixed forest zones, a much larger portion of the cultivated land is poor and marginal reducing the average yields.

The difference in potential productivity in forest and steppe zones has been a significant factor in the economy of Russia during the last hundred years. In the late 19th century, an intensive expansion of the railway network connected the central regions with new agricultural lands in the South and East (and the Ukraine) and made it possible to transport large amounts of cereal and other agricultural products from the periphery to the center. This improved access to cheaper grain from the South led to much reduced prices for cereal in the center of the country. The price system of the local market, therefore, was determined by the regions where the cost of production was lowest. Almost all operations for producing cereals in the southern regions demanded less investments than in the central regions, the biggest difference in costs being the application of organic fertilizers (manure) (Central industrial region, 1925).

From 1928 on, in the course of the collectivization of Russian peasants, all elements of market mechanism were liquidated. Soviet authorities adopted central plans for grain production in every region regardless of the different natural conditions of the regions. However, the authorities could not help but take into account the fact that the cost of grain production in the forest and steppe regions differed very much. Two major strategies were applied to extract a form of differential rent: by varying the scale of payments in kind for the service of the Machine Tractor stations (MTSs) [1], and by varying the quota of compulsory deliveries of the produce at low prices.

After Stalin's death in 1953, the system of political and economic control of kolkhozes ("collective farms") through the MTSs was replaced a by more economically reasonable system of

[1] In Stalin's time, MTSs were set up to provide kolkhozes with technical assistance in ploughing and harvesting. In fact, the MTS provided rather fiscal and political control over Soviet collective farms. One MTS could control as many as a dozen of kolkhozes.

state purchases of grain at a fixed price. This system was introduced in 1958, and the authorities tried to "correct" the natural advantages by varying the state purchase price among the areas. The cost variations were quite substantial as shown in Table 2. In 1963, then Soviet leader, Mr. Khrushchev, proposed to free the north-western regions from production of marketable cereals and reoriented them mostly to livestock breeding. In these regions, cereals were replaced by forage crops (Khrushchev, 1963). Unfortunately, this plan of Khrushchev's (he was removed from the office in 1964) was not implemented. Instead, the next price reform of agricultural production was introduced in 1965. The price revision improved matters in one respect: the zonal differences in prices were increased considerably. Thus, in the Northern Caucasus wheat was increased in price by 13 percent, whereas the increase exceeded 50 percent in the non-chernozem belt (Nove, 1969).

Table. 2. Cost and profitability of grain production in Russia (1958), rubles per 1 ton (Nove, 1969)

Zones	Costs	Average purchase prices	Price required to cover costs	Surplus or deficit
Production regions (Northern Caucasus)	22,00	59,00	30,14	+ 28,86
Consumption Regions (Non-Chernozem Zone)	88,00	74,00	120,56	- 48,56

However, the cost variations for grain production remained considerable in the forest and steppe regions. The highest cost of grain production was observed in regions of the central and southern taiga where the cost was 1,5-2 times higher than the average figure in the USSR (Kruchkov, Rakovetskaya, 1990). As stated before, the greatest cost difference between regions depended on the cost of fertilizer application. In 1970, farmers applied from 4,0 to 6,8 tonnes of organic fertilizers per hectare of arable area in forest regions of Russia, 1,8 tonnes in the central chernozem region, 1,0 ton in the Volga region, and only 0,6 tonnes in the southern area of Western Siberia. In the forest zone (central and southern taiga), organic and mineral fertilizer application reached 16 percent of the total expenditure, but only 2-5 percent in the steppe zone of the Volga region. Labor and seed expenditure ranged from 15 to 25 percent of the total cost of grain production, the difference in these expenditures being strongly influenced by differences in natural conditions. Labor cost was determined by the average size of the field which is smaller in the forest zone than in the south. In dry regions, a smaller amount of seeds is required per area than in the forest zone. In the eastern regions of the steppe zone, for example, about 0,11-0,13 tonnes per hectare of seed of spring wheat was sown, while in the forest zone, 0,26-0,30 tonnes per hectare were required (Kruchkov, Rakovetskaya, 1990). In addition to dryness, the amount of seed-to-sow generally depends on the natural fertility of the soils (Milov, 2001).

Table 3. Cost of grain production in kolkhozes in the different natural zones and economic regions of Russia in 1970 and 1980 (ruble per ton)

Natural Zone	Regions	1970	1980
USSR (average)		50	76
Middle and southern taiga	North-West	122	225
Southern taiga	Central	73	145
Forest steppe and steppe	Central Chernozem	37	64
Steppe and semi-arid landscape	Northern Caucasus	34	58
Steppe and semi-arid landscapes	Volga	46	77
Forest steppe and steppe	Western Siberia	54	74
Forest steppe and steppe	Eastern Siberia	66	99

Source: Kruchkov, Rakovetskaya, 1990.

Table 4. shows that the current agricultural market in Russia reveals again significant differences in the cost of grain production between forest and steppe zones. At present, it is more profitable for regions located in the forest zone to purchase grain in steppe regions and to transport it. The example of Permskaya oblast (Urals region) is typical in this respect; here, it is still considerably cheaper to purchase and transport grain from the Northern Caucasus than to produce it in the oblast itself.

Table 4. Costs of grain production in Permskaya oblast in comparison with that of main producer regions of Russia, $ for 1 ton (1999)

Zone	Oblast	Production Cost	Transport cost	Total cost
Southern taiga	Permskaya (Urals)	46,6	0	46,6
Forest steppe	Bashkorstan (Urals)	32	6,7	38,7
Steppe	Orenburgskaya (Urals)	28	8,3	36,3
Forest steppe	Altai Krai (South of Western Siberia)	32	13,3	45,3
Steppe and semi-arid landscapes	Rostovskaya (Northern Caucasus)	26	16,7	42,7

Source: Internet: official site of the Permskaya oblast "The Problem of Securing Perm Oblast's Self-sufficiency in Agricultural Food Products".

1.3. Weather variability and agricultural production

Another notable feature of Russian agriculture are the rather large fluctuations in year-to-year yield, which are considerably higher than in any other major grain producing country in the world. Colin White (1987) pointed out that the average coefficient of variability of wheat yield, measured over a 50 to 70 year period, was in most of Russia almost double that of the USA. In the Ukraine, which includes forest prairies, the coefficient of variation is above 0,24 (i.e. 24 percent), whereas in the Central United States, it is closer to 0,1 (i.e. 10 percent).

V.G. Kruchkov and L.I. Rakovetskaya (1989) found that in the forest zone of the USSR, the variability of grain production (for the period 1966-1980) was 15 percent, and somewhat less than this in the Baltic Republics and Belarus. It was 15-20 percent in the central region of the

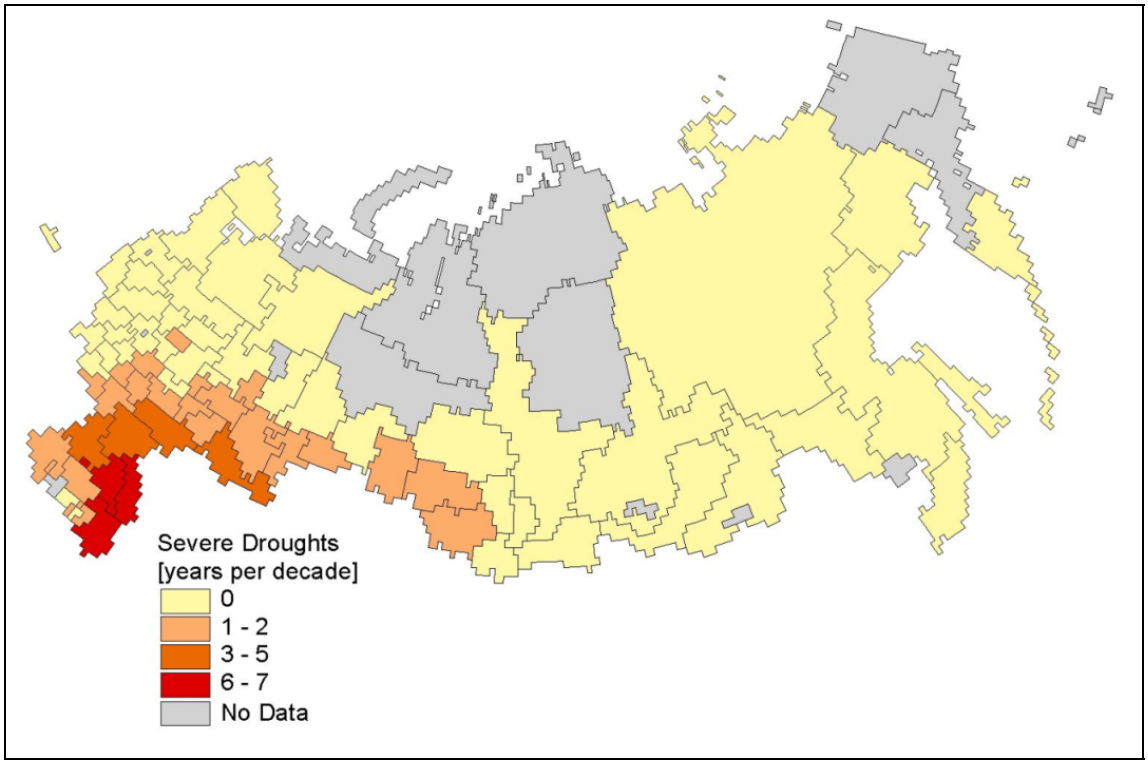
forest zone and forest-steppes (Black Earth region) as well as in the western part of the Northern Caucasus. Some regions of Western Siberia located in the southern taiga are characterized by a variability in grain production from 20 to 25 percent. The variability of grain production increases up to 25-35 percent in the forest steppe of the Urals and the Middle Volga. According to V.G. Kruchkov and L.I. Rakovetskaya (1989), the highest variability of cereal production from 35 to 50 percent was observed in the steppe zone of the Low Volga, the very southern parts of Western Siberia, and Northern Kazakhstan. This shows that the main grain production regions of the USSR are characterized by extremely unstable yields, reaching on average 25 percent.

These high fluctuations in total cereal production were undoubtedly the result of irregular precipitation. Figure 1. shows that drought is the major climatic phenomenon frequently hitting Russian farming.

Droughts are an inherent feature of the climatic conditions in the main agricultural zone of Russia. Droughts occur when a mass of dry arctic air sweeps down into European Russia and forms an anticyclone. The anticyclone, being quasi stationary somewhere in the Southeast of the country, causes the air mass to become drier. Along the southern and south-western periphery of the anticyclone, dry and hot air spreads. An especially strong drought takes place when an anticyclone is fed by an air mass from an Azores anticyclone moving in from the West. Moving across Europe, the air mass loses its humidity and reaches European Russia completely dry (Protserov, 1950). The droughts resulting from these large scale atmospheric processes usually cover vast territories of Russia, including the Northern Caucasus, the Middle and Low Volga basin, the Urals, and periodically spread over the central chernozem region and even the northern regions of European Russia. For example, the drought of 1946 covered 50 percent of total agricultural land of the USSR. As a result, the scale and consequences of droughts can be catastrophic for the country.

In European Russia, prospects of good harvests are associated, first of all, with the meteorological conditions of late spring and early summer. One of the approaches to statistical research of droughts was proposed by A.A. Meshcherskaya and B.G. Blazhevich (1990). They found for the economic regions of the Russian Federation that droughts affect agricultural production of a region negatively if 25 percent of the territory of that region receives only 80 percent or less of the normal precipitation and experiences an increased temperature of more than 1 degree in May-July. According to the authors, in 1891-1983 Russia went through at least 27 years, based on these parameters, of climatic droughts. There is a considerable difference in intensity of droughts in the different economic regions of the country (see Table 5.). A more detailed picture of the geography of large droughts (affected more than 50 per cent of sown area of

a region) can be constructed on the basis of the hydrothermal coefficient HTC [2] of Seljaninov (1966) as shown in Map 4.



Map 4. Number of years per decade with a large drought

Table 5. Numbers of years with droughts in the main economic regions of the Russian Federation in 1891-1983

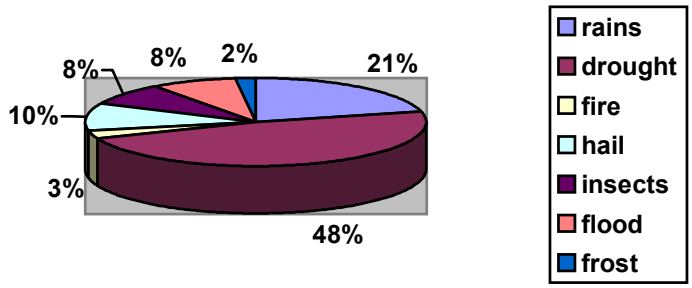
Regions:	Moderate Drought	Strong Drought	Total
North West	15	6	21
Central	20	9	29
Central Chernozem	17	15	32
Northern Caucasus	15	9	24
Volga-Vyatka	20	12	32
Volga	16	13	28
Urals	14	14	28
West Siberia	11	7	18

Drought is regarded as "moderate" if it affects 25-40 percent of total area of the region, and "strong" if it affects more than 40 percent of total area of the region.
Source: based on the catalogue of Mesherskaya and Blashevich (1990).

[2] The HTC is defined as follows: HTC = $10 * \sum_{T_i \geq 10} P_i / \sum_{T_i \geq 10} T_i$, where i- is the number of days, P_i, T_i – daily precipitation and temperature. HTC values usually stay within 0.4 and 2, where lower values correspond to dryer conditions. HTC values below 0.7 are considered to characterize droughts, and values from 0.7 to 1 moderately dry summers. The calculations of HTC for the economic regions for the period 1901-1995 were made by A. Kirilenko.

.

Figure 1. Main natural disasters affecting agriculture in Russia



The diagram is based on materials presented in a five volume book "Tragedy of the Russian village" (Danilov, Manning, Violy, 2000-2002) and a six volume report "The Soviet village through the eyes of the KGB" (Berelovich, Danilov, 2000a,b). These books are a collection of reports of the KGB (OGPU) on political, social and economical situations in the Russian village in the period from 1918 to 1939. Many of these reports contain information on weather conditions if they damaged crops. The diagram shows the frequency of reports on different types of such weather anomalies. Forty-eight percent of all reports named droughts as the main cause of crop loss in regions. The second main cause are heavy rains that damage crops mostly during the autumn in the central and northern parts of Russia. Hail is the third cause of crop loss. It may be surprising to find that frost is only responsible for 2 percent of all crop losses although spring and autumn frost are traditionally regarded as a major unfavorable factor in Russian agriculture (see White, 1987). This graph is based on data between 1918 and 1939; in spite of such a short period, these twenty years were not uncommon with respect to climate.

Analysis of droughts in Russia during the last hundred years shows that there are three main geographical areas most affected by droughts; they are Central, Southern and Eastern Russia (Experience of Preliminary Analysis, 1933). The central type of drought covers the vast territory of the Volga basin, the Northern Caucasus and the central chernozem region and some oblasts of the central region. This type of drought is most disastrous as it affects major agricultural regions of Russia. This drought also affects the forest zone of European Russia resulting in numerous forest fires in the central and northern regions. The southern type of drought is limited to the Volga basin (Volga and Volga-Vyatka) and Urals region. Although this type of drought covers less area, its intensity has generally been more severe and has often destroyed the entire crop production of the region. The eastern type of drought affects steppe and forest-steppe of Western and Eastern Siberia, usually when the south of European Russia is characterized by good weather. The central and southern types prevailed in the last hundred years reaching 36 and 40 percent, respectively (see Table 6.). The eastern type of drought occurred only in 24 percent of the situations; it has demonstrated the relatively important role of Siberia in the total grain production of Russia.

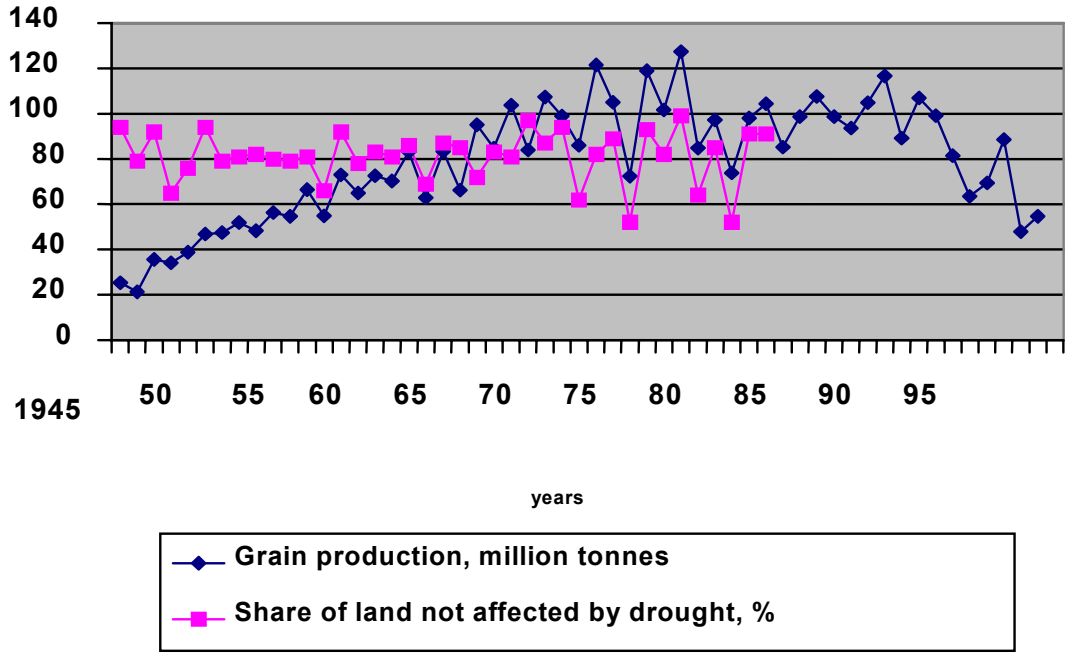
Table 6. Frequency of different types of major droughts during 1901-1995

Geographical location of drought	Years of drought
"Central"	1920, 1924, 1936, 1946, 1972, 1979, 1981,1984
"Southern"	1901, 1906, 1921, 1939, 1948, 1951, 1957, 1975, 1995
"Eastern"	1911, 1931, 1963, 1965, 1991

Figure 2. shows the fluctuations in grain production and its correlation with the share of areas not affected by droughts in the main agricultural zone of the Russian Federation in 1945-83 (based on the catalog of A.A. Meshcherskaya and B.G. Blazhevich). In the case of the most serious crop failures in grain production in the USSR (1946, 1948, 1957, 1959, 1963, 1972, 1975, 1979 ,1981), droughts were responsible. However, one should take into account the complicated character of links between weather variability and grain production. There might be some details of certain weather situations that cannot be reflected by statistical meteorological parameters (such as monthly temperature and precipitation). For example, even a single good rain after two months of continuous drought may radically improve the state of the crop or, on the contrary, the crop may be damaged seriously in spite of good weather during May and June by only a few days of excessively strong dry winds ("sukhovei") or a dust storm ("mgla"). Prospects of a good harvest also strongly depend on the amount of moisture in the top layer of the soil at the beginning of the growing period, however, statistical data on this parameters are rare. The severity of winters is a further essential factor in the surviving of winter crops in Russia.

While analyzing the long and complicated history of the Soviet Union, it should not be underestimated that, under dramatic political changes, different social and technical factors played a significant (mostly negative) role in the dynamics of agricultural production distorting the influence of climatic conditions. Such analysis, for example, was made for the Soviet Russia for the 1930s by S.G. Wheatcroft (1994).

Figure 2. Grain production and area not affected by drought in Russia between 1945 and 1999



The figure shows a good correlation between the most serious reductions in grain production and the share of area not affected by droughts in period from 1945 to 1983. These bad years for Soviet agriculture were 1946, 1948, 1951, 1957, 1959, 1963, 1972, 1975, 1979, and 1981. The intensity of droughts is calculated as an average area of the main agricultural regions not affected by drought (Meshcherskaya, Blazhevich, 1990). The data on droughts only cover the period until 1983. Agricultural statistics are taken from a statistical report (Agriculture in Russia, 2000). The report provides data on the gross grain production for 1945-99.

Chapter 2.
Why has Russian agriculture been vulnerable to weather variability?

The impact of droughts on the food situation in Russia depends on the balance between agricultural production and domestic demand. Figure 3. shows changes in grain production as well as grain requirements in the postwar period of the USSR. Since the late 1950s, a considerable progress in grain production has been observed. It had been achieved due to two different agricultural policy programs implemented in the Soviet Union. In the period 1955–65, a remarkable growth of crop area in the USSR took place during the so-called "virgin land" campaign inspired by then party leader Nikita Khruschev. In the course of this campaign, the total crop area of the USSR increased by 42 million hectares (or 23 percent) mostly at the expense of pasture and grasslands in Kazakhstan and the Western Siberian regions of the Russian Federation. In the Russian Federation alone, 14,5 million hectares "new" land for cultivation were created (see Table 1.). Such an enormous expansion of arable land during three years was unique in modern world history. As a result of this campaign, the gross cereal production increased although yields remained unsatisfactorily low.

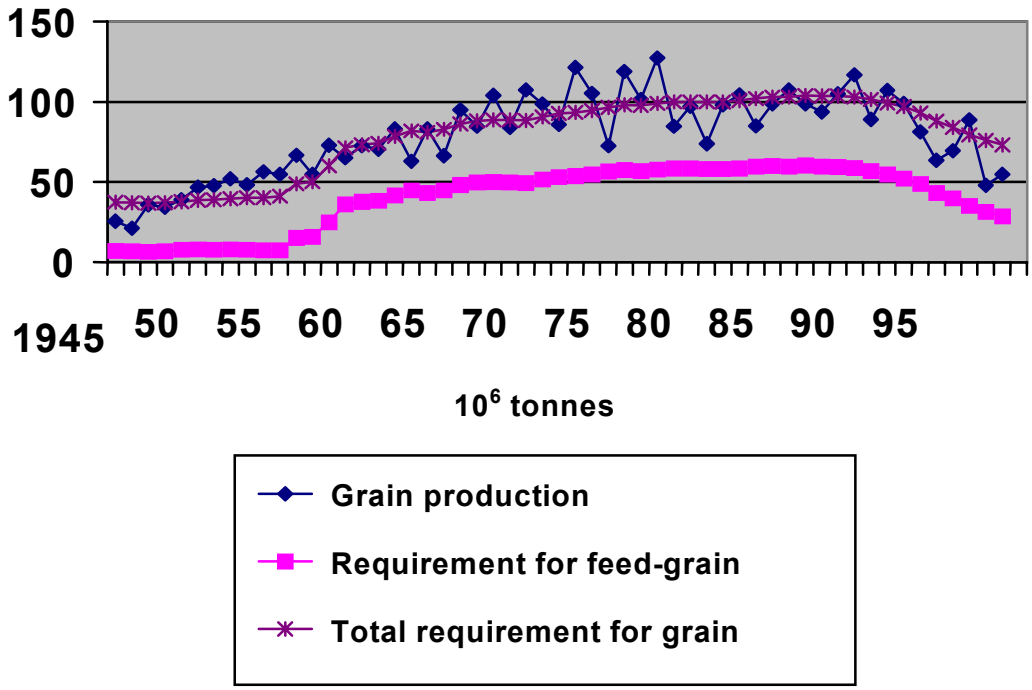
Since the mid 1960s, intensification of cereal production was emphasized. From 1900 to 1950, the average cereal yield only reached 0,6-0,8 tonnes per hectare. In the early 1960s, there was no progress either. Then, starting from 1965, a considerable growth of cereal productivity was observed. During that decade (1965-1975), the average yield in cereal increased from 1 to 1,5 tonnes per hectare or by 50 percent. This progress was mainly due to large-scale application of mineral fertilizer in the Soviet Union during this period. After 1980, however, there was a stagnation in cereal productivity in Russia although state investments in agriculture continued to grow.

Unlike the "virgin land" campaign, this period of development of the Russian agriculture was not something unique. All developed countries and many states of the third world intensified their farming during the same period due to the introduction of the same international pool of yield-raising technologies. Between 1950 and 1984, the world grain production expanded 2.6-fold, outstripping population growth and raising the grain harvested per person by 40 percent (Brown et al., 1998, p.177). In comparison, Russian gross cereal production had risen 1.9-fold and per capita production had increased by 65 percent at that time. In the 1980s, the USSR occupied the third place in the world for grain consumption per capita (843 kg) following only the United States (860 kg) and Canada (974 kg). W.H. Parker (1972, p.156) has reason to say that "in view of the adverse natural conditions of Russia, the productivity of the Soviet agriculture seems remarkable".

Figure 3, however, shows that despite considerable progress in gross cereal production, the Soviet agriculture reportedly failed to meet its domestic grain demand. The situation became

crucial in years of drought when the grain production was far behind the domestic demand in grain. In such years, the grain deficit reached 20-25 percent of the domestic requirements.

Figure 3. Grain production and grain requirements in the Russian Federation from 1945 to 1999



The figure shows that the grain production closely followed the demand throughout the history of Russia during the Soviet period. In the 1950s, grain production was slightly above grain requirement but only due to a very low level of meat and dairy consumption in the country (see Table 3.). From the late 1950s, much progress was observed in grain production, but at the same time, a policy to raise significantly the level of meat production had started. The figure shows that the requirement for feed grain was a major factor in the rapid growth of total grain demand. The demand for feed grain was higher than the actual production potential of the country. For 27 out of the 54 years, or each second year from 1945-99, grain demand exceeded grain production in Russia. In years of droughts, the gap between grain demand and grain production reached 15-25 million tonnes or more (20% of the average grain production). The total grain demand here is calculated as the sum of the feed grain demand and grain demand for food consumption and seed grain demand.

It seems that the livestock sector of the Soviet agriculture caused an increased pressure on the grain production sector of the country. Even in the 1950s, the country could produce enough grain to meet food demand, but the Soviet people still consumed less meat than in 1913 (Table 8). The numbers of Russian livestock did not increase during 1916-1957 whereas the population rose by 25 percent (Agriculture in Russia, 2000).

A weakness in the livestock sector has been characteristic of Russia and is linked to the adverse climatic conditions. First of all, Russian cattle is kept in stalls for a long period out of the

year, and therefore, large amounts of feed need to be stored from a relatively short harvest period. In the heartland of Russia, the stall period lasts from 180 to 200 days while in continental Europe, the stalls regime is half as long, i.e. from 90 to 105 days. In some parts of Europe, a milder climate allows the herd to graze outside all year long at the same latitude as the steppe regions of Russia where cattle has to be kept indoors for as long as six months.

Since the late 1950s, the Soviet Union was determined to raise its meat and dairy consumption up to the level of Western countries at any cost. It was planned to develop all types of feed resources including pasture land and hayfields. The pasture land and hayfields of the country were in poor condition and needed large-scale and expensive improvements. The duration of the growing period plays a very important role in the productivity of grassland. In the northern and central regions, where the main pasture lands and hayfields are located (in large river valleys), the growing period lasts from 110 to 130 days. This is too short in comparison to the growing season in Western Europe. In the "productive" regions of Russia, the prospects for raising the livestock were no better. The expansion of cereal crops during the 19th century resulted in a sharp decrease of pasture land and hayfields. Further, yields from natural grassland in the steppe zone are considerably lower than those in the humid forest zone.

In fact, since the 1950s, there had not been any progress in raising the productivity of natural grassland in Russia. In the 1980s, the average yield of grassland in the country remained 1,0-1,5 tonnes per hectare, the same as it was in the 1950s. The yield was too low in comparison to Western countries where average productivity of grassland reached 4-8 tonnes per hectare (Livestock production in Europe,1982).

However, between 1950 and 1990 the output of meat in the Russian Federation increased 3.9-fold from 2.6 to 10.1 million tonnes, which was higher than the average global growth of meat production (2.6-fold). The remarkable growth in the Soviet herd was achieved mainly due to the rapid increase in feed grain consumption, although an increase of the amount of succulent feed took place simultaneously (Figure 5.). In the 1960s alone, the share of feed grain supplied to livestock had increased three fold from 0,25-0,28 to 0,9-1,0 tonnes per conventional head per year while hay and pasture grass in terms of head consumption had fallen by 48 and 47 percent, respectively.

Figure 4. Change in feed resources for Russian livestock in 1950-1985

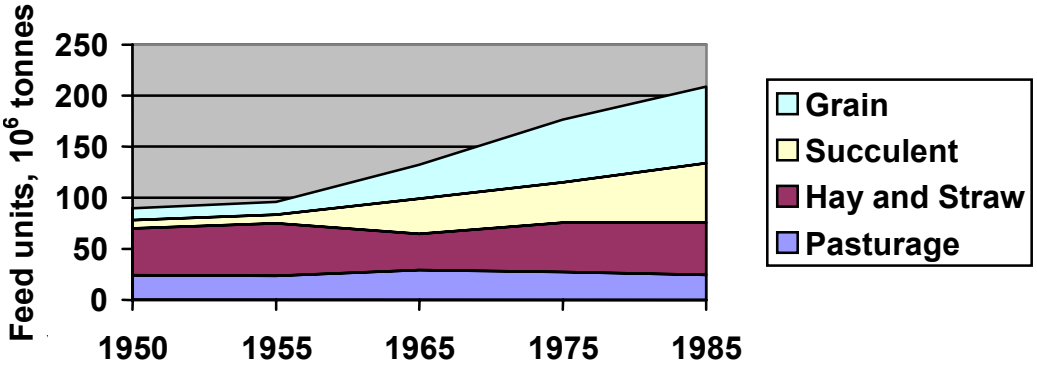


Table. 7. Share of grains fed to livestock in major grain producer countries in 1992-94

Country	Grain production, million tonnes	Grain fed to livestock, million tonnes	Share of total grain production fed to livestock, %
France	56,6	16,7	29
Germany	35,6	18,6	52
United Kingdom	20,4	8,9	44
Canada	49,3	17,9	36
United States	323,0	162,0	50
China	401,1	93,6	23
Russia	92,8	67,5	73

Source: calculated based on data presented in the report: Roberts, L. (ed.). World Resources. The Urban Environment. 1996-97, Oxford University Press, 1996.

Again the increase in the volume of grain fed to livestock was not unique to the USSR. The worldwide use of grain for feed, which includes the by-products of grain milling, increased from 289 million tonnes in 1960 to 650 million tonnes in 1986, accounting for 40 percent of total grain use, an all time high (Brown et al., 1994, p.192). However, in the USSR the tendency to use grain for feeding purposes developed in an exponential way (see Table 7.). To get one additional kilogram of meat, about 10-11 kilograms of feed grain were required. Additional waste of feed grain was associated with the Russian climate which is not favorable for cultivating grain crop rich in protein (maize). While between 1950 and 1990, the output of meat in the USSR increased 3.9-fold, grain consumed by livestock increased 6-fold. As a result, the demand for feed grain had climbed at level that was above the actual sustainable grain production potential of the country. Grain deficits took place in the USSR even during average years. As one western expert put it “in such a stretched economy as the Soviet one, the loss of one percent of production can lead to a crisis in food supply” (Unger, 1982).

Chapter 3.
Droughts and food crises in Russia

The most noticeable social consequences of droughts were numerous food crises which the USSR went through during the 20th century. Regarding the food problems of Russia over the last hundred years, two major periods may be distinguished. In the first half of the century, the level of food consumption had been below the physiological minimum (i.e. 2400 kcal. per capita per day). Bread was the major component in the diet of Russians. The share of bread reached 55-60 percent of daily caloric intake while meat was only 5 percent. In the mid 1920s, Russia was still an agrarian country with 82 percent of the population living in rural areas. The majority of the population was directly dependent on cereal crops produced on their small plots. Mass famine reportedly took place in the 1920s and 1930s in regions affected by drought. The Soviet authorities conducted a devastating policy expropriating from collective farms (kolkhozes) and individual farmers as much grain and meat as the state needed at that moment. As a result, the regions that suffered most were the productive regions of Soviet Russia whereas cities and non-productive regions were supplied with food by the state. Thus, the history of famine in the 1920s, and especially in the 1930s, proves the idea that "droughts are a natural phenomenon; famines are not" (Desai, 1989, p.217). The last famine in the Soviet Union took place in 1946 when a severe drought - the first one in the postwar period - affected the largest part of the productive zone of the country.

The year 1950 seems to be a dividing line between a period of risk of absolute food shortages and that of relative food shortages. During the 1950s, the urban population grew to surpass the rural population in the Soviet Union. The majority of the population depended on the total harvest of the country rather than the crops of a particular region or district. Priorities of domestic policy of the Soviet Union had changed to some extent. The state was determined to raise the level of food consumption of the population. The level of food consumption became an important planning target of the so-called "Five-years period plans". The growth of agricultural (grain and meat) production already allowed the Soviet Union to reach a relatively high average level of food consumption in the USSR by 1960. However, grain shortages became crucial in years of drought when they caused panic slaughtering of livestock in the country as happened in 1963. Since 1963, the Soviet Union had to make regular purchases of considerable amounts of grain (mainly maize) in western countries. In the 1970s and 1980s, the Soviet Union became the largest importer of grain in the world.

In 1970, the caloric level of food consumption in the USSR had reached about that one of western countries, although the structure of food consumption was still far from optimum (see Table 8.). Some experts argued that the permanent food deficit at the time was associated rather with determination of the state to keep food prices unchanged although cost of food production

and savings of the population had increased considerably. The state heavily subsidized food production and supply. Although many staple foods were in short supply in Soviet stores, the country stayed far from the risk of mass famine. The country faced problems, however, in keeping the same level of consumption in unfavorable years. Different options of food rationing implemented throughout the country were main indicators of food shortages in these years. In the 1980s, food problems caused a serious disappointment with socialism by the Soviet people. There was a feeling of stagnation, and no one seemed to know why. The press and television dealt with this food shortage more frequently than ever before. As a result, the society urged political changes, and these came very soon.

Table 8. Food consumption in Russia in 1913-1998 (kg per person per year)

Year	Bread	Potatoes	Vegetables	Meat	Milk	Egg	Fish	Sugar	Oil	Caloric intake a day, kcal	Share of bread, %	Share of meat, %
1913	200	75	40	27	154	48	6,0	8,1	1,7	2109	58	7
1940	195	112	64	21	130	59	4,9	8,7	2,6	2112	56	5
1952	190	190	61	24	159	69	7,3	16,2	3,7	2452	47	5
1960	164	147	69	41	255	128	12	31	5,6	2762	36	8
1970	144	139	82	50	331	182	18,6	41,7	7,1	3088	29	9
1980	126	118	94	62	328	279	22,5	46,7	9,1	3069	25	11
1990	119	106	89	75	386	297	20	47	10,2	3182	23	13
1998	118	123	78	48	221	218	9	33	8,9	2471	29	10,5
Norm	**110**	**97**	**146**	**82**	**405**	**292**	**18,2**	**40**	**7**	**3150**	**21**	**14**

The table shows that up to the 1950s, the Soviet Union's level of food consumption was below even the physiological minimum of 2400 calories a day. The share of bread consumption was still very high - over 50 percent - while meat consumption - 24 kg per capita per year - was even less than in 1913. The level of milk consumption had not changed since the first quarter of the century. A progress had been made after 1960, and in late 1980s, the total level of food consumption reached the expected level, although the composition of food consumption was still unsatisfactory.

Source: Materials on the country's history, Vol. 2 (1946-1995), Moscow, 2001.

Chapter 4. Conclusions
To what extent should Russian agriculture be changed in order to cope with climate change?

Climatic dependence has always been an essential feature of Russian agriculture. It is mostly a result of the geographical location of the Russian agricultural zones in marginal environments. Two major climatic factors have played a decisive role in geography of Russian agriculture: (1) the short growing season (longevity and severity of winter) in the northern (forest) part of the country, and (2) frequent droughts in the main agricultural (steppe) zone of Russia. The former factor limits crop composition while the latter determines the instability of grain production from year to year. Evidently these two factors will determine the performance of Russian agriculture in the future, and they should be evaluated in a model of climate change.

The division of the country into "production" and "consumption" zones is another essential feature of Russian agriculture. This division will remain one of the major factors of the future development of Russian agriculture due to the gap in cost of grain production in these zones. Any hope to shift grain production into the forest zone (in order to avoid vulnerability to droughts) is limited due to the lack of area available for cultivation, poor state of soils and lack of infrastructure there.

During the 20th century, Russian agriculture was unbalanced and over-reliant upon grain production. This resulted in a disproportion in the development of the grain and livestock sectors. In the Russian Empire, a drive to increase cereal production led to plowing major pasture and grasslands, especially in the forest steppe and steppe zones. The USSR was strongly determined to raise grain production in order to become a grain exporter. Grain production was the main plan target and indicator of agricultural performance for all regions. Attempts to raise the livestock sector were based on increasing the share of grain fed to Soviet livestock. The extremely high consumption of feed grain led to a grain deficit even in average years and food crises in years of droughts.

At present, the economic crisis and the fall in purchasing power of the population of the former Soviet Union has lowered grain and meat demand. However, this situation could change rapidly once the economy is restored. Now Russia produces only 35 kilogram of meat per capita or half the amount as during Soviet times and has to import about 35-40 percent of meat and milk products. A predictable rate of growth of the GDP by 4-5 percent a year would result in an increase in meat consumption by five percent or two kilograms per capita per year (Zhurnal, 4 February, 2003). If there is no change in the way of current farming, this growth of meat demand will lead to a restoration of excessive consumption of feed grain in the near future, and thus, to a strong dependence of Russian agriculture on weather variability in the main agricultural zone. At present, the main agriculture zone is able to meet the domestic demand and to produce a good

grain surplus in average years. An improvement in infrastructure and a decrease in grain losses would make grain production in these regions more stable. The forest zone of Russia should be re-oriented exclusively for development of the livestock sector based on local fodder resources. Radical improvement in natural grasslands is needed there, which will demand a strong state support for the livestock sector for a relatively long period. Such a restructuring of the Russian agriculture will, however, minimize consequences of an increasing aridity in some grain producing regions (the Northern Caucasus) due to climate change.

References

Anon. (2000) Agriculture in Russia. Statistical Report, Goscomstat, Moscow, p. 130 (in Russian)

Anon. (1933) Experience of Preliminary Analysis: Eight Catastrophic Droughts over the Last Forty Years, Part 1, TsUEG, Moscow (in Russian)

Anon. (1982) Livestock Production in Europe: Perspectives and Prospects. Livestock Production Sc. 1982, Vol. 9, No. 1

Anon.(1996) Materials on the Country's History, Vol. .2 (1946-1995), Moscow, p. 39 (in Russian)

Anon.(1989) People's Economy of the RSFSR in 1988 (Statistical Yearbook), Goscomstat, Moscow (in Russian)

Berelovich, A.; Danilov, V. (eds.) (2000a) The Soviet Village through the Eyes of the KGB. 1918-1939. Documents and Materials. Vol. 1. 1918-1922. Rosspan, Moscow (in Russian)

Berelovich, A.; Danilov, V. (eds.) (2000b) The Soviet Village through the Eyes of the KGB. 1918-1939. Documents and Materials. Vol. 2. 1923-1929. Rosspan, Moscow (in Russian)

Brown, L. R.; et al. (1998) State of the World, A Worldwatch Institute Report on Progress toward a Sustainable Society, N.Y. - London

Brown, L. R.; et al. (1994) State of the World, A Worldwatch Institute Report on Progress toward a Sustainable Society, N.Y. - London

Central Industrial Region (1925) Proceeding of the State Planning Committee (in Russian)

Danilov, V.; Manning, R.; Violy, L. (eds.) (2000) Tragedy of the Soviet Village. 1927-1939. Documents and Materials. Vol. 1. 1929-1930. Rosspan, Moscow (in Russian)

Danilov, V.; Manning, R.; Violy, L. (eds.) (2001) Tragedy of the Soviet Village. 1927-1939. Documents and Materials. Vol. 2. 1930-1933. Rosspan, Moscow (in Russian)

Danilov, V.; Manning, R.; Violy, L. (eds.) (2002) Tragedy of the Soviet Village. 1927-1939. Documents and Materials. Vol. 3. 1934-1936. Rosspan, Moscow (in Russian)

Desai, M. (1989) Modeling on Early Warning System for Famines. In: Dreze,J.; Sen, A.(eds.). Hunger and Public Action. Claredon Press, Oxford

Field, N.C. (1968) Environmental Quality and Land Productivity: A Comparison of the Agricultural Land Base of the USSR and North America. Canadian Geographer, 12:1-14

Gatrell, P.(2000) "Poor" Russia: Role of Environment and Governmental Management in Long-term Prospects of Economical History of Russia, Economical History of Russia in the 19th-20th Centuries: Modern View. Rosspan, Moscow, p. 206-253 (in Russian)

Khomyakov, P.M.; Kuznetsov, V.I.; et al. (2001) Impact of the Global Climate Changes on the Functioning of Major Sectors of the Economy and Health of the Population of Russia. Editorial, Moscow (in Russian)

Khrushchev, N. (1963) About Some Questions of Specializing in Agriculture of Belarus, the Baltic Republics and the Northwestern Regions of the Russian Federation. Pravda, 18 March (in Russian)

Kruchkov, V.G.; Rakovetskaya, L.I. (1990) Grain Farming: Territorial Organization and Efficiency of Production. Moscow State University, Moscow (in Russian)

Meshcherskaya, A.A.; Blazhevich, B.G. (1990) Catalogs of Temperature and Humidity Characteristics According to the Economical Regions of the Main Productive Zone of the USSR (1891-1983). Leningrad (in Russian)

Milov, L.V. (2001) Russian Ploughmen and Peculiarities of Russian Historical Processes. Rosspan, Moscow (in Russian)

Nove, A. (1969) The Soviet Economy. New York

Parker, W.N. (1972) The Superpowers. The United States and the Soviet Union Compared. New York

Protserov, A.V. (1950) Drought on European Territory of the Soviet Union: Agroclimatic Conditions of Steppes of the Ukrainian SSR and Ways to Improve Them. Academy of Sciences of the Ukrainian SSR, Kiev, p. 17-22 (in Russian)

Roberts, L. (eds.) (1996) World Resources: The Urban Environment - 1996-97. Oxford University Press

Seljaninov, G. (1966) Agroclimatic Map of the World. Leningrad Publishing Center (in Russian)

The Russian Federation for Fifty Years (Statistical Report) (1967) (in Russian)

Unger, L. (1982) The Soviet Two-front Food Battle. The International Herald Tribune, 12 February

Wheatcroft, S.G.; Davies, R.W. (1994) The Economic Transformation of the Soviet Union, 1913-1945. Cambridge University Press

White, C. (1987) Russia and America: The Roots of Economic Divergence.

Zhurnal (2003) 4 February (in Russian)