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Brief Communication

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Influence of climate change on yield of agricultural crops in the north of Russia

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Abstract

The published report of the Intergovernmental Panel on Climate Change (IPCC) on the effects of global warming of 1.5°C (Global warming of 1.5°C) caused another resonance among the scientific community, experts, politicians and ordinary people. The presented report requires serious decisions from the world community to minimize the impact of climate change on human life and the economy in order to achieve the seventeen sustainable development goals adopted by the United Nations. In this regard, the effects of climate change in the northern and Arctic territories are of particular relevance. The observed effects of climate change in the North and the Arctic affect not only human health, but also all sectors of the economy that operate there. The ongoing climate change requires certain measures to taken to minimize the negative impact. Agriculture is the sector of the economy that is most sensitive to climate change. The work is devoted to assessing the impact of climate change on the productivity of the main agricultural crop of the northern region of Russia, using the Komi Republic as an example. An analysis of the relationship of pair correlation between potato productivity and the corresponding climatic indicators is carry out. The risks and potential opportunities for farming in the region analyzed. Measures are propose for adapting the impact of climate change on agriculture in the Komi Republic.

Key-words: Climate Change, North, Arctic, Agriculture, Productivity, Potential, Risks

The average growth rate of the average annual air temperature in Russia in 1976-2018 according to the data of the Federal State Budgetary Institution "Institute for Global Climate and Ecology, Academician Yu.A. Israel 0.47°C/10 years. This is 2.5 times the growth rate of global temperature over the same period: 0.17-0.18°C/10 years. Was revealed that over the past 30 years, at meteorological stations on the coast of the Arctic seas of Russia, the increase in average annual temperature during this period exceeded 1.0°C/10 years. In the Northern Polar Region, 2018 was very warm - the second in a row since 1936: the average annual temperature anomaly was +2.5 ° C 3. (Doklad, 2019). The data presented prove how much research is need today in the field of the impact of climate change on sectors of the economy that are climate-dependent, and people's livelihoods, especially in the North.

In the summary of the report V.M. Kattsova and B.N. Porfiryev, entitled «Assessment of the macroeconomic consequences of climate change in the territory of the Russian Federation for the period up to 2030 and the future perspective» noted that the greatest warming should be expect in Siberia and the northern regions of Russia, as well as in the Arctic (Katcov and Porfir'ev, 2011). Some domestic scientists are studying the impact of climate change in the North on livelihoods, human health (Karyagin, 2009; Davydov and Mihajlova, 2013; Shcherbakova, 2019). In a changing climate, agriculture and forestry

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will become increasingly important in the structure of the economy of the Arctic region (Kompleksnye, 2009).

Agriculture belongs to those sectors of the economy that are most sensitive to climate change. Dangerous phenomena for agriculture include: droughts, dry winds, frosts, waterlogging of the soil, hailstorms and some others, as well as complexes of adverse hydro meteorological phenomena that cause lodging of crops, a sharp decrease in their productivity, death and hindering field work, especially harvesting. Hydro meteorological phenomena of the cold period of the year, which lead to freezing, soaking and aging of winter crops, as well as damage to perennial plantations, are also dangerous. Crop production as a food base determines the risks in animal husbandry. Indirect risks in the livestock sector due to changes in climatic conditions can be associated with a shortage of drinking water, diseases, etc., and overheating of animals under abnormal weather conditions (abnormally hot weather, dry winds) can be attributed to direct risks (Doklad, 2017). The determining climate-dependent factors for agriculture (animal husbandry and crop production) are different depending on the natural and climatic zones of the region. For northern and humid regions, the invasion of cold air masses from the north, excessive moistening, and freezing can be classify as vulnerability factors (Rosgidromet, 2014).

In Europe, over the past decade, quite a lot of research has been conduct to identify the impact of climate change on agriculture (Passel and Massetti, 2019; Vasileiadou et al., 2019). Russian scientists are just beginning to study this problem (Druzhinin, 2013; SHkiperova and Druzhinin, 2014).

The purpose of the study is to study the effect of climate change on crop productivity in the North of Russia (on the example of the Komi Republic).

Consider the example of one of the northern regions of Russia, the Komi Republic, how climate change affects agriculture and crop yields. The region is located in the northeast of the European part of the Russian Federation and is part of the non-black Earth zone, the length from north to south reaches about 1000 km. On the long territory of the region, there is a regular change in soil-climatic and socio-economic conditions. At the beginning of the 1990 XX century after a series of studies, the republic was divided into 4 agro-climatic regions and their specialization (APK, 1991).

Note that this development currently requires revision and improvement in connection with the new changing climatic conditions in the North. The ongoing climatic changes in weather conditions do not allow sustainable agriculture in the North, which already operates in severe climatic conditions.

There are obvious risks associated with losses during the harvest and crop yields. Risk can be defined as the probability of expected losses in crop yields due to adverse weather conditions. The state station of the agrochemical service «Syktyvkarskaya» until 2000 prepared reports for the Ministry of Agriculture and the consumer market of the region. The report included a section on the climatic features of the development of agricultural production for each past year, but today this section is missing. The preparation of these reports should be restore. After all, the risks in agriculture associated with climate change should be minimize. For the Komi Republic, the main types of crop cultivation are cereals, potatoes, and open-field vegetables (Figure 1).

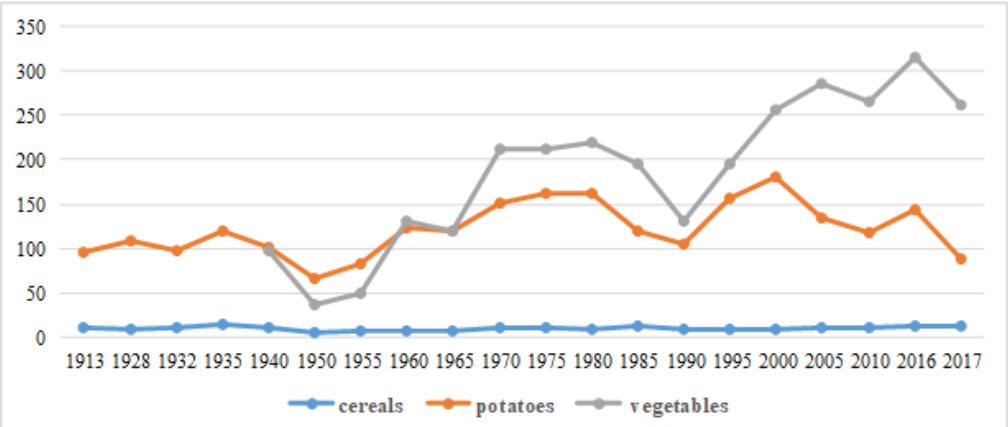

Fig. 1. Yield of crops, potatoes and vegetables by categories of farms of the Komi Republic (1 ha - harvested area).

Table 1. Sown area of crops in farms of all categories of the Komi Republic (thousand ha).

Years	1913	1922	1932	1940	1950	1960	1970	1980	1990	2000	2016	2017	Area change 2017/1913
Cereal crops	25,4	24,2	42,6	57	63,8	25,3	9,6	1	0,6	0,5	8	8	- 17,4
Potatoes	1,4	1,5	5	12,4	12,4	13,2	12,7	12,8	12,1	14,8	4,4	4,1	2,7
Vegetables	0,2	0,1	1,2	1,9	3,7	1,6	1,3	1,2	1,1	1,3	0,6	0,5	0,3
Forage crops	0,3	-	3,4	12,8	15,1	48,7	60,4	78,7	86,8	66,6	32,0	32,5	32,2

Sources: 1. Collection of agriculture in the Komi Republic. Statistical Digest / Komistat. Syktyvkar, 2018.pp. 21,36. 2. The agro-industrial complex of the Komi Republic: history and modernity: Statistical Digest / Komistat. Syktyvkar, 2011.133p.

Figure 1 shows that crop yields in recent decades have tended to increase yields, especially for vegetables, which reached 316 kg / ha in 2016 against 36 kg / ha in 1950. Vegetables are more heat-loving plants, and yields are affect by a more favorable climate. The reduction in gross harvest of crops and sown areas for the same period is characterize not only by climatic conditions but also by the reason for the failed reforms in the country of the 1990s. (Table 1).

Let us consider in more detail climatic indicators that affect the productivity of the main agricultural crop of potatoes (Table 2). During the years of "economic reforms", there was a strong reduction in agricultural production. As a result, most of the potatoes grown near the capital city of Syktyvkar. The share of crop products in agricultural products in Syktyvkar is 73% in 2017.

Let us analyze the coefficient of linear correlation to identify the relationship between the indicated climatic indicators and potato productivity in the city of Syktyvkar (Table 3). An analysis of the relationship of pair correlation on the Cheddock scale revealed both a direct and inverse relationship between the Rxy indices. A high relationship was found between potato productivity and indicators: the average temperature for the growing season, the amount of rainfall for the growing season and the amount of rainfall in % of the norm, is from 0.72 to 0.88. A very high characteristic of the relationship between R xy3 and R xy4 for 2014-2015 was established. - 0.94, as well as a functional relationship equal to 1 for 2016 between the indicators. An analysis of potato yields in Syktyvkar showed that it depends on climatic conditions, especially since 2003, where the connection is characterized as high and very high, which indicates a climate change towards warming, because the average temperature for the growing season since 2003 has not dropped below 13.1°C, with the exception of 2008.

Changing climatic conditions create potential opportunities for expanding crop production in the Komi Republic, especially in the more southern regions. In the southern regions of the Komi Republic over the past 3-5 years, the appearance of the Colorado potato beetle has been note on potatoes, which is generally not typical for the northern territories; it is distribute from the southern to the northern regions. This factor affects the yield of the main crop and proves that climate change is happening towards warming. At the same time, this condition creates new potential for the republic's agriculture to grow new types of crops.

In 2018, the Ministry of Agriculture and Food Market of the Republic of Kazakhstan conducted a large-scale experiment on growing corn as a highly nutritious silo in the Priluzsky, Syktyvdinsky and Sysolsky districts. 50 hectares allocated for corn sowing with a total area of fodder crops sowing of 9,200 hectares. As a result, this year the experiment in two regions of the Republic of Kazakhstan failed, except in the Yuzhnoye farm in the Priluzsky district. Due to the cold summer, the green mass received, but the ears did not wait.

Table 2. Climatic indicators affecting the yield of potatoes in Syktyvkar for the period 1989-2016.

Years	The average temperature during the growing season, ° C **(y_1)**	Deviation of the average temperature from the norm, ° C **(y_2)**	Amount precipitation during the growing season, mm **(y_3)**	The amount of precipitation in% of normal **(y_4)**	Potato yield, kg / ha **(x)**
1989	13,9	1,5	380	118	166
1990	13,0	0,6	302	94	91
1991	12,7	0,3	346	108	91
1992	11,5	-0,9	247	77	102
1993	13,2	0,8	395	123	71
1994	10,8	-1,6	393	122	69
1995	14,0	1,6	338	105	151
1996	13,3	0,9	347	108	139
1997	11,3	-1,1	301	94	136
1998	14,1	1,7	283	88	186
1999	13,1	0,7	292	91	168
2000	13,3	0,9	242	75	182
2001	12,9	0,5	320	100	182
2002	11,1	-1,3	307	96	148
2003	13,3	0,9	351	109	135
2004	13,1	0,7	401	125	105
2005	13,7	1,3	208	65	125
2006	13,2	0,8	307	96	131
2007	13,1	0,7	363	113	75
2008	11,8	-0,6	407	127	120
2009	13,3	0,9	388	121	106
2010	13,0	0,6	247	77	85
2011	13,8	1,4	262	82	123
2012	12,4	0,0	567	17	132
2013	14,6	2,2	190	59	157
2014	13,3	0,9	333	104	156
2015	13,4	1,0	304	95	160
2016	13,8	1,4	475	148	144

Source: Compiled according to the data of the branch of the federal state budgetary institution Northern Administration for Hydrometeorology and Environmental Monitoring and statistical collections on agriculture of the Komi Republic.

An analysis of corn cultivation in the Priluzsky district of the Republic of Komi showed that the corn seeds of most varieties and hybrids germinate at a temperature of 8-10°C. But more vigorous germination and germination of the vegetative mass is observed at temperatures above 10-12°C. Short-term freezing (-2, -3°C) damages the seedlings, but before the 3rd leaf phase they are able to recover in a week if up to 25% of the leaf surface is damaged, if 50% of the leaf surface is damaged, the plants die.

An important criterion for assessing the suitability of a locality for growing corn is the average daily temperature for overgrowth from May to September or the sum of active temperatures above 10 °C (only days with an average daily temperature of 10°C and above are taken into account). Table 4 shows the temperatures that are necessary for different ripeness groups according to D. Shpaar. Soil corn requirements are correlate with climatic conditions. In the northern regions, when there is a lack of heat and high humidity, well-cultivated, light loamy, sandy and sandy soils, which warm up faster in spring, are more suitable for growing corn.

Table 3. Analysis of the indicators of tightness of communication and the characteristic of communication on the Chaddock scale between climate-dependent indicators of potato productivity in Syktyvkar for the period 1989-2016.

Years	R xy_1	R xy_2	R xy_3	R xy_4
1989	0,37	0,37	-0,21	-0,21
1990	0,35	0,35	-0,24	-0,25
1991	0,36	0,36	-0,26	-0,27
1992	0,36	0,36	-0,26	-0,25
1993	0,32	0,32	-0,31	-0,29
1994	0,36	0,36	-0,27	-0,23
1995	0,18	0,18	-0,23	-0,16
1996	0,16	0,16	-0,23	-0,17
1997	0,16	0,16	-0,23	-0,17
1998	0,17	0,17	-0,23	-0,17
1999	0,08	0,08	-0,20	-0,17
2000	0,08	0,08	-0,18	-0,17
2001	0,07	0,07	-0,09	-0,11
2002	0,11	0,11	-0,08	-0,14
2003	0,82	-0,40	0,50	0,39
2004	0,82	-0,40	0,50	0,38
2005	0,83	-0,41	0,52	0,42
2006	0,83	-0,42	0,55	0,43
2007	0,83	-0,41	0,55	0,43
2008	0,74	-0,30	0,72	0,65
2009	0,81	-0,06	0,78	0,73
2010	0,81	-0,05	0,80	0,77
2011	0,83	-0,06	0,80	0,78
2012	0,83	-0,07	0,80	0,78
2013	0,83	0,01	0,88	0,88
2014	0,80	-0,13	0,94	0,94
2015	0,78	-0,08	0,94	0,94
2016	0,72	0,00	1,00	1,00

Note: brown cells are a weak bond; blue cells - moderate connection; yellow cells - a noticeable connection; green cells - high connection; purple cells are a very high bond; red cells - functional connection.

The analysis of long-term average data on the average daily air temperature over three decades from May to September amounted to 13.2°C, and the sum of temperatures above 10°C for the same period was 1533°C. The growing season with temperatures above 10° C and above is 105 days, which is suitable for growing this crop in silage. As a result, growing corn for grain is not advisable, and it is better to use early ripening hybrids to grow it for silage. In general, due to climate change over the past decades, the Priluzsky region has been favorable for the cultivation of new crops.

Agricultural organizations and peasant (farmer) farms of the Arctic Ust – Tsilemsky district of the Republic of Kazakhstan noted climate change towards warming and attempted to grow long flax. Analysis of agro meteorological data on the conditions for the growth of flax in the Ust-Tsilemsky district on the reserves of productive moisture in the soil, the sum of the effective air temperatures for the average daily temperature above 10°C. The duration of the growing season with temperatures above 10° C in days shows that this area not suitable for growing this crop. However, the Ust-Vym and Syktyvdinsky

Table 4. Suitability of hybrids of different ripeness groups depending on average daily temperatures and sums of temperatures for May-September.

Ripeness group / FAO number	Average daily temperature, May-September, ° C		Sum of effective temperatures, May-September, ° C		SM content	
	corn silage	corn for grain	corn silage	corn for grain	in the whole plant	in the grain
Early ripe ≤220	12,5	13,5	1450 1500	1580	32-35	65
Mid-season 230-250	13,5	15,5	1490 1540	1630	32-35	65
Mid-ripe 260-290	15,5	15,5	1540 1590	1680	32-35	65
Late ripening ≥ 300	15,5	16,0	1600 1640	1730	32-35	65
Source: Compiled according to the data of the branch of FSBI Northern Administration for Hydrometeorology and Environmental Monitoring.						

districts, which are locate in the central part of the region, are suitable for growing flax.

To summarize the above, we are convinced that attempts are being made in the region to grow new types of crops, i.e. Agricultural organizations are beginning to use the changes as potential opportunities for growing new types of crops, thereby diversifying the list of local staple foods. Emerging conditions in the north create the necessary conditions and motivation for the production of organic food products, which today have high demand in the market (Mezhdunarodnaya, 2019).

As a result, we can conclude that the impact of climate change for the northern region, using the example of the Komi Republic, carries both risks and potential opportunities. Risks are that new types of pests are emerging for the region's main farmed crops, which are detrimental to crop yields and gross yield. Potential opportunities are opening up in the cultivation of new types of crops, which will provide local residents with a wider variety of fresh food products, as well as strengthen the production of forage for livestock farming. As well as the development of agriculture focused on the production of organic products, which will be in demand not only in the region, but also beyond its borders. Undoubtedly, the considered risks and opportunities in agriculture are subject to a comprehensive assessment at the regional level.

Conflict of interest: All authors declare no conflict of interest.

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