INTERNATIONAL SCIENCE REVIEWS

AIU

No. 1 (1) 2020

Natural Sciences and Technologies series

www.aiu.kz

ISSN: 2707-4862

ASTANA INTERNATIONAL UNIVERSITY

INTERNATIONAL SCIENCE REVIEWS
Natural Sciences and Technologies series

Has been published since 2020

№1 (1) 2020

Editorial address: 8, Kabanbay Batyr avenue, of.316, Nur-Sultan,
Kazakhstan, 010000
Tel.: (7172) 24-18-52 (ext. 316)
E-mail: natural-sciences@aiu.kz

International Sciense Reviews NST - 76153
International Science Reviews
Natural Sciences and Technologies series
Owner: Astana International University
Periodicity: quarterly
Circulation: 500 copies
The cover design is Alexander Oksak’s "The shine of autumn forest" replica

CONTENT

Saken Baisholanov and Anatoly Polevoy VULNERABILITY OF GRAIN PRODUCTION OFTHE REPUBLIC OF KAZAKHSTAN TOCLIMATE CHANGE 21

Vulnerability of grain production of the Republic of Kazakhstan to Climate Change

Saken Baisholanov[1] and Anatoly Polevoy[2]

[1] International Scientific Complex Astana
[2] Odessa State Environmental University
Email: saken baisholan@mail.ru

Agriculture occupies a significant share in the economy of Kazakhstan, which is based on crop production. Today, the agricultural turnover of the republic is more than 21 million hectares of land. Of these, more than 1.0 million hectares are irrigated (about 5%), i.e. agricultural crops are cultivated in conditions of natural moisturizing on 95% of the land area. Grain production is a priority in the country crop production.

The purpose of this work is to assess the vulnerability of grain production in Kazakhstan to climate change, forecast of its possible state in the conditions of climate change until 2050. To achieve this purpose, the assessment of current and expected to 2050 agro-climatic conditions, unfavorable weather phenomena for agriculture, as well as the yield of wheat and sunflower.

Climate change is known to have both positive and negative impacts on agriculture. The negative consequences include an increase in the increased frequency of droughts and reduction of agricultural crops yield [5, 9, 12, 15].

Keywords: climate change, agroclimatic conditions, heat availability, moisture availability, drought, crop yield

INTRODUCTION

Agriculture occupies a significant share in the economy of Kazakhstan, which is based on crop production. Today, the agricultural turnover of the republic is more than 21 million hectares of land. Of these, more than 1.0 million hectares are irrigated (about 5%), i.e. agricultural crops are cultivated in conditions of natural moisturizing on 95% of the land area. Grain production is a priority in the country crop production.

The purpose of this work is to assess the vulnerability of grain production in Kazakhstan to climate change, forecast of its possible state in the conditions of climate change until 2050. To achieve this purpose, the assessment of modern and expected to 2050 agro-climatic conditions, unfavorable weather phenomena for agriculture, as well as the yield of wheat and sunflower.

Climate change is known to have both positive and negative impacts on agriculture. The negative consequences include an increase in the increased frequency of droughts and reduction of agricultural crops yield [5, 9, 12, 15].

METHODS

The article presents the results of studies obtained in the framework of the preparation of the Seventh National Communication of the Republic of Kazakhstan on climate change [12].

The study used data from the meteorological station (MS) of RSE "Kazhydromet".

For the characterization of the future climate, were used probabilistic forecasts of the average monthly air temperature and monthly precipitation amounts prepared by the expert group of climatologists of RSE "Kazhydromet". They used the combined models of the general circulation of the atmosphere and the ocean (MGCAO), prepared within the framework of the 5th phase of the CMIP5 International Comparison Project. The CMIP5 was based on the estimation of the climate of the 20th century, given in accordance with the observed concentrations of greenhouse gases and aerosols, as well as scenario estimations of the climate of the 21st century, taking into account a new group of anthropogenic emissions scenarios – Representative Concentration Pathways

(RCP) [12].

Us in the calculations was used the scenarios of air temperature and precipitation amounts for two successive 20 year periods: 2020-2039 years, with the middle in 2030 and the years 2040-2059, with a midpoint in 2050. The forecasts for two scenarios of climate change were used: RCP4.5 – climate change under the scenario of stabilization of greenhouse gas emissions; RCP8.5 – climate change under the scenario with very high level of greenhouse gas emissions [12].

In temperate latitudes, the vegetation period of most crops corresponds to the duration of the period with an average daily air temperature above 10^0C. Therefore, the thermal resources of the vegetation period were estimated by the sum of active air temperatures above 10^0C.

We have used humidification coefficient "K" to assess the crop moisture availability analogous to humidification coefficients proposed by D.A. Brinken, S.A. Sapozhnikova and Yu.I. Chirkov, L.S. Kelchevskaya [8], L.S. Kelchevskaya and Yu S. Melnik [4]. For the conditions of Kazakhstan, the accumulation coefficient of precipitation of the cold period was taken equal to 0.5, and the coefficient of air temperature – 0.12 [2]:

$$K = \frac{0.5\sum R_{11-4} + \sum R_{5-8}}{0.12\sum T_{5-8}} \tag{1}$$

where: $\sum R_{11-4}$ – precipitation amount for November–April; $\sum R_{5-8}$ – precipitation amount for May–August; $\sum T_{5-8}$ – sum of air temperatures in May–August.

At values "K" is less than 0.60, there is a deficit of moisture, at values 0.60 – 0.79 – insufficient moisture availability, at values 0.80–0.99 – sufficient, but non–sustainable moisture availability, at values 1.00–1.20 – optimal and sustainable moisture availability.

Agrometeorological phenomena that are dangerous for crops include: light frosts, droughts, dry hot winds, heavy rains and hail, strong winds and dust storms. The most widespread and dangerous in Kazakhstan are droughts and dry hot winds.

The productive reserves of moisture in the soil (PRM) serve as a direct indicator of drought. Given the rare network of PRM identification in Kazakhstan, it is very difficult to conduct a full– valuable assessment of drought based on PRM data.

Various indirect methods are used to assess drought: the hydrothermal coefficient of G.T. Selyaninov (HTC), the humidification coefficients of D.I. Shashko (Md), P.I. Koloskov, A.V. Protserov, N.N. Ivanov, L.D. Kelchevsky, D.A. Brinken, S.A. Sapozhnikova and J.I. Chirkov, the index of aridity of D.A. Ped, the agrometeorological coefficient humidifying (ACH), the Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI), the Critical Water Content Index for Crops (CWCIC), the Index of Surface Moisture Reserve (ISMR) [7, 13, 14].

Long–term practice has shown that the hydrothermal coefficient of G.T. Selyaninov (HTC) for the assessment of drought in Kazakhstani conditions is the most suitable is [1, 2]:

$$HTC_{5-8} = \frac{\sum R_{5-8}}{0.1\sum t_{5-8}} \tag{2}$$

where: $\sum R_{5-8}$ – the total of precipitation over the period of May to August; $\sum t_{5-8}$ – the total of average daily air temperatures above 10 over the period of May to August.

If the HTC is 0.40–0.59, the drought is considered to be of medium intensity, less than 0.40 – strong intensity.

Also, the generalized criterion of drought is the level of decline in the yield of the main crop. Crops yield is formed under the influence of a set of factors that can be divided into two components: level of field husbandry and weather conditions [6]. Drought can be determined by calculating the share of weather in yield formation (dP, %) [1]:

$$dP = \frac{Y - Y_T}{Y_{TS}} \tag{3}$$

where: $Y-$ the average regional yields, c/ha; Y_T – trend value of crop yield, c/ha; Y_{TS} – average trend yield, over a long period, c/ha; 100 $-$ the coefficient for transfer to the interest.

If dP is minus 20 – 50%, the drought is considered to be of medium intensity, more minus 50% – strong intensity.

Dry hot wind – is a complex weather phenomenon that occurs at a wind speed of more than 5 meters/second, at high air temperature above 25^0C and a low air humidity of less than 30%. As a result of the effects of dry hot wind, the plants wither and die, even if there is a sufficient supply of moisture in the soil, since the root system does not have time to supply water [8, 10].

For the conditions of Kazakhstan, E.I. Buchinsky and N.F. Samokhvalov offer the following dry hot wind criteria: air temperature above 25C, low relative humidity of air below 20%, wind speed 5 meters / second and more, and at a temperature of over 30^0C, wind speed 3 meters/second and more. According to the research by E.A. Tsuberbiller a day is considered to be dry if at noon the air humidity deficit exceeds 20 hPa (weak), 30 hPa (moderate) and 40 hPa (intense) at a wind speed of less than 8 meters/second.

RESULTS AND DISCUSSION

To assess the current agro climatic conditions and unfavorable weather phenomena for agriculture, we will take into account the heat and moisture availability of the vegetative period, drought and dry hot wind in Northern Kazakhstan (North Kazakhstan, Kostanay, Akmola and Pavlodar regions). In these regions concentrated 72% of the sown areas of Kazakhstan, 80% of grain and leguminous crops areas.

Heat availability. The duration of the vegetation period in the territory of Northern Kazakhstan is increasing from north to south from 130 to 170 days, and in the Kokshetau upland area is less than 135 days. On the territory of 4 regions of Kazakhstan, the sum of active air temperatures above 10C increases from north to south from 2100C to 3400C. In area of Kokshetau upland and Bayanaul mountains, the sum of temperatures is less than 2200C [3].

To estimate the change in thermal resources, the expected values of the sums of average daily air temperatures for May–August (T5–8) were calculated for the future climatic conditions (2030 and 2050) according to RCP4.5 and RCP8.5 scenarios, and compared with the values of the current climate (1981–2016).

Calculations have shown that the heat availability of the vegetation period in the expected climate of the 2030 years will significantly increase in comparison with the current climate. In the northern oblasts of Kazakhstan, the sum of average daily air temperatures for May–August (T5–8) will increase according to RCP4.5 scenario by 161–180, i.. by 8%, and under the scenario of RCP8.5 – by 182–205, i.. by 9%.

Heat availability of the vegetation period will increase even more by 2050. The sum of average daily air temperatures for May–August (T5–8) will increase according to RCP4.5 scenario by 265–282C, i.. by 12%, and under the scenario of RCP8.5 – by 340–355, i.. by 16%.

Thus, in conditions of further climate warming by 2050 in North Kazakhstan is expected to increase thermal resources by 12–16%, which can expand the set of cultivated heat–loving crops and will have a positive impact on their growth and development.

Moisture availability. An average of 250–400 mm of precipitation falls during the year on the territory of the 4 northern regions of Kazakhstan. From May to August (vegetatively active period), 170–201 mm of precipitation falls on the territory of North Kazakhstan region, 122–190 mm in Akmola region, 76–195 mm in Kostanay region and 129–188 mm in Pavlodar region.

The humidification coefficient "K" makes 0.8–1.2 in the territory of North Kazakhstan region, 0.8–1.2 in Akmola region, 0.3–1.0 in Kostanay region, 0.6–0.9 in Pavlodar region. To estimate the changes in moisture resources, we have calculated the expected values of annual precipitation and the amount of precipitation for the vegetatively active period (May–August), as well as the humidification coefficient (K) for future climatic conditions (2030 and 2050) under the scenarios of RCP4.5 and RCP8.5. These values were compared with the values of the current climate (1981–2016).

The sum of precipitation for the vegetatively active period according to the scenario of climate change of RCP4.5 will increase slightly by 2030 and 2050. The largest change (+ 8 percent) is expected in Kostanay region. Under the scenario RCP8.5 there are no significant changes in the amount of precipitation for May–August.

Calculation of the humidification coefficient (K) for future climatic conditions has shown that until 2050 in the northern regions moisture availability of the vegetation period will gradually deteriorate. The greatest changes are expected under the RCP8.5 climate change scenario. For example, by 2050, these changes will be in the scenario RCP45 – minus 8–12 V, and the scenario RCP85 – minus 12–17 percent.

Thus, in conditions of further climate warming until 2050, no significant changes in the amount of precipitation are expected in Northern Kazakhstan, however, the moisture availability of the vegetation period will gradually deteriorate. This is due to the increase in evaporation due to the increase in air temperature.

Expected climate change will lead to a shift in thermal zones and humidification zones to the north. Figure 1 and 2 shows the spatial distribution of the humidification coefficient K in the northern half of Kazakhstan, in the conditions of current and expected climates for 2050.

In comparison with the current climate, in 2050 K isolines will have some northward shift. "Optimum and stable moisture availability" zone (= 1,0–1,2) will completely disappear in the north of North–Kazakhstan region, and in the Kokshetau Upland area it will decrease in size.

"Sufficient but not stable moisture availability" (= 0,8–1,0) will completely disappear in Aktobe region, decrease in Kostanay, North Kazakhstan, Akmola, Karagandy, Pavlodar and East Kazakhstan regions. At the same time, this zone will almost completely disappear in the North of Pavlodar region, and in the border part of Pavlodar and Karagandy regions from the main zone will separate its small part "Korneevka–Karkaraly–Bayanauyl".

"Insufficient moisture availability" zone (= 0,6–0,8) will also move to the north in West Kazakhstan, Aktobe, Kostanay, Akmola, Karagandy, Pavlodar and East Kazakhstan regions. In the border part of Pavlodar and East Kazakhstan regions, there will appear a zone of "Moderate moisture deficit" with K humidification coefficient of = 0.5–0.6.

"Moderate moisture deficit" zone (= 0,4–0,6) will also move to the north in West Kazakhstan, Aktobe, Kostanay,

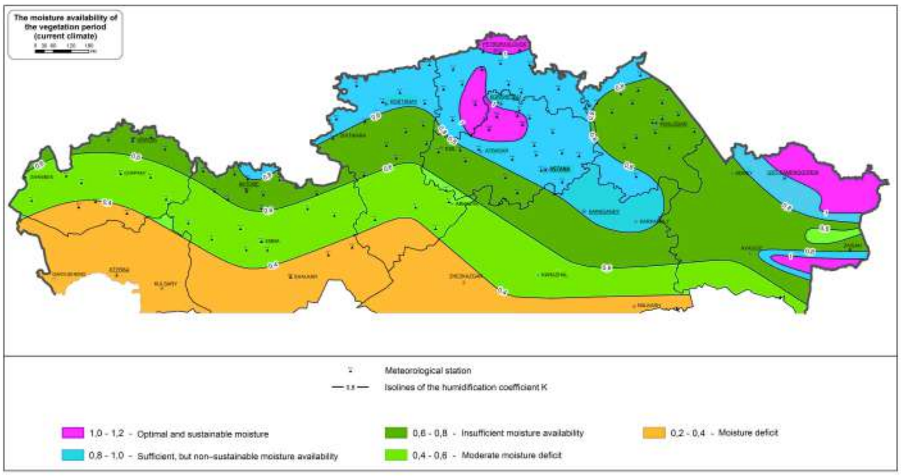

FIGURE 1. Spatial distribution of the humidification coefficient K in the Northern half of Kazakhstan in the current climate

Akmola, Karagandy and East Kazakhstan regions. This area will expand somewhat in the area of the lake Zhaysan in the East Kazakhstan region.

In the mountainous areas of East Kazakhstan region, no significant changes in moisture availability of the vegetation period are expected.

The expected shifts in moisture availability zones of the vegetation period will have a negative impact on the transitional areas of the zones, i.e. they may lead to a revision of the existing production relations. For example, changing the species or varieties of cultivated crops or increasing the proportion of livestock. Undoubtedly, it is necessary to introduce adaptation measures.

Arid phenomena. To assess the likelihood of severe droughts, HTC was calculated as per MS data for the period May–August from 1981 to 2016. The frequency of severe drought was determined as per the 36 summer series of HTC data. The probability of a severe drought was calculated on the basis of repeatability. Repeatability of severe droughts, which cause significant losses to agriculture, grows from 5% (probability of 1 every 20 years) in the north of North–Kazakhstan region to 70% (probability of 1 every 2 years) in the south of Kostanay region.

We also carried out an assessment the drought on average regional yield of spring wheat for 1966–2016, based on the calculation of the percentage of weather in the crop formation (dP).

The probability of a drought repeating in the Pavlodar and Akmola regions is approximately 1 time every 3 years, in the Kostanay and North Kazakhstan regions – 1 time every 4–5 years. At the same time, severe droughts reoccur in the North Kazakhstan region once every 50 years, in the Akmola regin – 1 time every 17 years, and in the Pavlodar and Kostanay regions – 1 time every 10 years.

In the work of L.E. Pasechniuk and V.A. Sennikov (1983) provides an agroclimatic assessment of dry hot winds in northern and western Kazakhstan [10]. According to their data, the average number of days with dry hot winds (d 20 hPa) for the period from April to October is 90–50 days in West Kazakhstan and Aktobe regions, in Kostanay, North Kazakhstan, Akmola and Pavlodar regions – 50–40 days.

Our calculations showed that dry hot winds of moderate and strong intensity, which have a significant negative impact on the growth and development of crops, occur in North Kazakhstan region for about 5 days a year. In Kostanay region from north to south, the number of days with dry hot winds increases from 5 to 70 days a year. In Akmola region, also from north to south, it increases from 5 to 25 days, and in Pavlodar region – from 5 to 20 days per year.

In the context of climate warming, the main unfavorable weather phenomenon for agriculture is drought. It is impossible to forecast drought for the long–term period. However, it is possible to estimate the expected aridity of the climate, to which all arid phenomena are closely related, including atmospheric drought and dry hot winds.

To estimate the change in the aridity of the climate, the expected values of the HTC for the vegetatively active period (May–August) were calculated for the future climatic conditions (2030 and 2050) according to RCP4.5 and

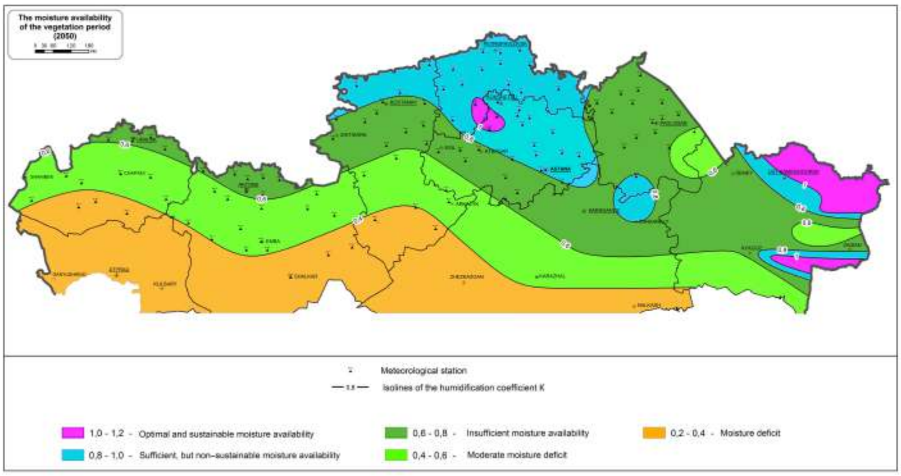

FIGURE 2. Spatial distribution of the humidification coefficient K in the Northern half of Kazakhstan in the climate of 2050

RCP8.5 scenarios, and compared with the values of the current climate (1981–2016).

Calculations of the HTC for future climatic conditions showed that by 2050 in the Northern regions is expected to gradually increase the aridity of the climate. The greatest changes of the values of the HTC are expected under the scenario of climate change RCP8.5. Thus, according to RCP4.5 scenario by 2050 these changes will be minus 7–10%, and under RCP8.5 scenario – minus 12–15%.

Thus, in the conditions of further warming of the climate until 2050 in Northern Kazakhstan, the aridity of the climate will increase, with a decrease in HTC values by 7–15%. Accordingly, the repeatability of droughts and dry hot winds will increase.

The yield of agricultural crops. Spring wheat – is the main grain and food culture. In Kazakhstan, mainly soft varieties of spring wheat are cultivated.

To study the effect of climate change on the yield of spring wheat, the yields of spring wheat were estimated for the 4 grain–growing regions in Northern Kazakhstan as per current and expected climatic conditions until 2050. The difference in their values is an indicator of vulnerability to climate change. For the forecast of yield of spring wheat was used a dynamic model of yield formation of crops [11], adapted for the conditions of the above–mentioned regions of Kazakhstan. The process of crop yield formation is a complex set of physiological processes, the intensity of which determined by the biological characteristics of plants and environmental factors. The model describes the processes of photosynthesis, respiration, growth and development of plants, as well as the influence of agrometeorological conditions on the intensity of these processes.

Current actual dates of spring wheat sowing in the northern regions of Kazakhstan fall to the third decade of May–beginning of June. According to climate change scenarios until 2050, an increase by 1.0–1.5C in air temperature is expected in June. Therefore, the yield calculations were carried out taking into account the expected earlier sowing dates: by 2030, the shift in sowing dates 4-5 days earlier than the current date, by 2050 – a shift of 8-10 days. At that used data of climate change scenarios RCP4.5, which shows a moderate change of temperature. Calculations showed that in the conditions of expected climate of 2030 the yield of spring wheat would average 63–82% of the current level (the average for 2000–2016) in the regions, and in the conditions of 2050 it would be 51–71%. This means that, while maintaining the current level of field husbandry, the yield of spring wheat will drop by 18–37% by 2030 and by 29–49% by 2050.

The main reasons for the decline in wheat yield are:

an increase in evaporation leading to a decrease in humidification of the territory, despite the expected increase in precipitation up to 10%;

an increase in air temperature above the optimal value for the growth and development of spring wheat.

If we consider that 82% of the areas under wheat are in the Northern regions, it can be argued that grain production in Kazakhstan is very vulnerable to climate change.

Under the expected conditions of 2030 and 2050, higher yields of wheat are possible with a high level of field husbandry, i.e. with the introduction of adaptation measures and cultivation technologies.

Sunflower is the main oilseed crop in our country. Sunflower is photophilic and thermophilic culture. Sunflower is also demanding for moisture, despite the fact that it is considered a drought–resistant plant. Due to the powerful root system, sunflower is resistant to short–term droughts.

Mainly early ripening, early mid ripening and mid ripening varieties and hybrids are cultivated in the northern part of Kazakhstan. Here the sunflower is sown in early May.

To study the dependence of the yield of sunflower seeds on the expected climate change, were selected Kostanay and Pavlodar regions, where the sunflower is cultivated in conditions of natural moistening (without irrigation), and for which a dynamic model of crop yield formation was adapted [11].

Calculations showed that in condition of the expected climate by 2030, the yields of sunflower seeds will make up an average of 102–106% of their current level (the average for 2000–2016) in the regions, but by 2050 – 100–105%. This means that, the yield of sunflower seeds is not expected to decrease until 2050. On the contrary, due to the optimization of the thermal regime, the yield of sunflower seeds can be increased by 2–6% by 2030, by 2050 – up to 5%, compared to current norms. This indicates the need for the gradual expansion of heat–loving crops in the Northern territories of Kazakhstan. Naturally, the introduction of adaptation measures and agricultural technologies will ensure higher yields of sunflower seeds than in current conditions.

SUMMARY

On the territory of Northern Kazakhstan, the duration of the vegetation period is increasing from north to south from 130 to 170 days. The sum of active air temperatures above 10C is from 2100C to 3400C. During the year 250–400 mm of precipitation falls. The humidification coefficient "K" makes 0.8–1.2 in the territory of North Kazakhstan region, 0.8–1.2 in Akmola region, 0.3–1.0 in Kostanay region, 0.6–0.9 in Pavlodar region. Repeatability of severe droughts, which cause significant losses to agriculture, raises from 5% (probability of 1 every 20 years) in the north of North–Kazakhstan region to 70% (probability of 1 every 2 years) in the south of Kostanay region. In conditions of further climate warming until 2050 in North Kazakhstan, an increase in thermal resources by 12–16% is expected. The moisture availability of the vegetation period will gradually deteriorate, with a decrease of 8–17%. This will lead to a shift of humidification zones to the north. The aridity of the climate will increase. As a result of the impact of a complex of climatic factors in the northern part of the country, the yield of spring wheat is expected to decline. However, due to the optimization of the thermal regime in the north of Kazakhstan, a slight increase in the yield of sunflower seeds is possible.

REFERENCES

1. Baisholanov S.S. About repeatability of droughts in the regions of Kazakhstan sowing grain. –Hydrometeorology and ecology, . 3. – Almaty, 2010, p. 27–38. [in Russian]
2. Baisholanov S.S., Pavlova B.N., Zhakieva A.R., Chernov D.A., Gabbasova M.S. Agroclimatic resources of the North Kazakhstan. – Hydrometeorological studies and forecasts, 1(367). – Moscow: Proceedings of the Hydrometeorological Center of Russia, 2018, p. 5–13. [in Russian]
3. Baisholanov S.S., Polevoy A.N. The assessment of the thermal providing of vegetation period in Northern grain–seeding territory of Kazakhstan. – Ukrainian hydrometeorological journal, 2016, 18, p. 97–104. [in Russian]
4. Gringof I.G., Kleschenko A.D. Fundamentals of agricultural meteorology. Volume 1. Demand of agricultural crops in agrometeorological conditions and dangerous weather conditions for agricultural production. – Obninsk: FSBI "RRIHI–WDC", 2011, 808 p. [in Russian]
5. Report on climate risks in the Russian Federation. – Sankt–Petersburg, 2017, 106 p. [in Russ.]
6. Dmitriyeva L.I. Estimation of temporal variability of crop yield /Methodical instruction/. – Odessa: OGMI, 1985, 19 p. [in Russian]
7. Zoidze E.K., Khomyakova T.V. Basis of the operational system for the evaluation of drought and its pilot operation experience. – Proceedings of the RRIAM, 2002. Vol. 34, p. 48–66. [in Russian]
8. Losev A.P. Workshop on agroclimatic support of crop production. – St–Pb.: Gidrometeoizdat, 1994, 243 p. [in Russian]
9. Pavlova V.N., Varcheva S.E. Estimating the level of territory vulnerability and climate-related risk of significant grain crop failure in grain-producing regions of Russia. – Russian Meteorology and Hydrology, 2017, Vol. 42, Issue 8, p. 510–517.
10. Pasechnyuk L.E., Sennikov V.A. Agroclimatic assessment of droughts and the productivity of spring wheat. – L.: Hydrometeoizdat, 1983, 126 p. [in Russian]

11. Polevoy A.N. Theory and calculation of crop productivity. – L.: Hydrometeoizdat, 1983, 175 p. [in Russian]
12. Seventh National Communication and Third Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change. – Astana, 2017, 288 p.
13. Handbook of Drought Indicators and Indices. WMO, 173, 2016, 60 p.
14. Strashnaya A.I., Purina, I.E., Chub O.V., Zadornova, O.I., Chekulaeva T.S. Automated technology for monitoring and calculating the number of decades with soil and atmospheric–soil drought under crops. – Proceedings of the Hydrometeorological Center of Russia, 2013, Vol. 349, p. 150–160. [in Russian]
15. Impact of climate change on Canadian agriculture. [Electronic resource], 2018. URL: http://www.agr.gc.ca/eng/science–and–innovation/agricultural–practices/agriculture–and–climate/future–outlook/impact–of–climate–change–on–canadian–agriculture/?id =1329321987305