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Assessment of agro-climatic potential in agricultural areas in the vicinities of Nur-Sultan (Kazakhstan), Barnaul (Russia, Altai Krai) and Novokuznetsk (Russia, Kemerovskaya Oblast)

V.I. Belyaev[1], L.V. Sokolova[2], A.V. Matsyura[2*]

[1]Altai State Agricultural University
Krasnoarmeyskiy Avenue, 98, Barnaul, 656049, Russia.
[2]Altai State University
Lenina Avenue, 61, Barnaul, 656049, Russia.
**Corresponding author E-mail: amatsyura@gmail.com*

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In this article we present the results of the comparative assessment of agro-climatic potential for agricultural areas in the vicinities of Nur-Sultan (Kazakhstan), Barnaul (Russia, Altai Krai) and Novokuznetsk (Russia, Kemerovskaya Oblast). The proposed approach for comparing of agricultural territories with the precipitation and heat supply indexes takes considered the relationship between heat and moisture supply, allows to assess the agroclimatic potential and economic values of agricultural lands.

Key words: climat; agro-climatic potential; agricultural areas; precipitation; air temperature

Introduction

The problem of sustainability of agricultural production in the changing climatic and economic conditions is currently very relevant. Agriculture, in particular crop production, is one of the most weather-dependent sectors of the economy. As the analysis of long-term data on crop yields shows, their value significantly depends on the variability of natural and climatic factors (Proskuryakova, 2003; Bischoff et al., 2016; Belyaev, Sokolova, 2018; Sandakova et al., 2019). The process of climate change, which has been observed, necessitates a detailed study of the agro-climatic potential of agricultural territories and clarification of the boundaries of agro-climatic regions (Gathara et al., 2006; Fisher et al., 2012; Gulyanov et al, 2019). This will make it possible to more accurately form the zonal structures of the sown areas of cultivated crops on the basis of their requirements for heat and moisture supply, which will further lead to an increase in agricultural production.

The aim of the work is a comparative assessment of the agro-climatic potential of agricultural territories on the example of the conditions of the environs of the cities of Nur-Sultan (Kazakhstan), Barnaul (Russia, Altai Krai) and Novokuznetsk (Russia, Kemerovskaya Oblast).

Methods

At present, the hydrothermal coefficient of G.T. Selyaninov (1928) is widely used for a general assessment of the climate and the allocation of zones of different levels of moisture supply in order to determine the possibility of growing certain agricultural crops. (State Customs Committee). It is determined by the formula (1):

$$HTC = \frac{10\sum \mathrm{P}}{\sum \mathrm{T}_{>10°C}} \qquad (1)$$

where ΣP is the sum of the precipitation in mm for the period with the daily mean air temperatures above +10 °C;
ΣT> 10 ° C is the sum of temperatures above 10 °C for the same period.

As a result, it is possible to compare the potential of territories for the cultivation of agricultural crops in terms of moisture supply for each degree of temperature above 10 °C. The lower the HTC, the drier the terrain and the more extreme conditions of the growing season.

However, for the maturation of each of the types of crops, a certain sum of temperatures of the growing season is required, which varies within a fairly wide range over the years, even within the same agroclimatic zone. In addition, at present, winter crops are widely cultivated, for which the coefficient cannot be used to assess the cultivation conditions. How, in general, can we compare the agro-climatic conditions of various agricultural territories and give their quantitative assessment? This requires a criterion that would reflect the averaged characteristics of the potential of the territories as a whole for a certain long-term period. Undoubtedly, temperatures, precipitation and their distribution in dynamics are the most important characteristics on which the temperature and water regime of soils, their quality and conditions for cultivation of crops depend. Therefore, it is proposed to use the ratio of the sum of temperatures and precipitation for a certain period (week, month, year) as such an evaluation criterion - the coefficient of heat supply of precipitation $K_{T/P}$, calculated by the formula (2):

$$K_{T/P} = \frac{\sum T}{\sum P} \quad (2)$$

where ΣT is the sum of the temperatures of the analyzed period, °C; ΣP is the sum of the precipitation of the same period, mm.

Thus, in this case, the heat supply of each millimeter of precipitation is estimated for any analyzed period. This makes it possible to compare different territories and periods of the year both with each other and in terms of the requirements for the cultivation of various types of crops during the growing season in terms of the sum of temperatures and moisture, both under natural conditions and with the use of irrigation.

Results and Discussion

As an example, consider the change in annual and monthly temperatures and precipitation, as well as their ratios in relation to the conditions of Nur-Sultan (Kazakhstan), Barnaul (Russia, Altai Krai) and Novokuznetsk (Russia, Kemerovskaya Oblast), which differ significantly by agroclimatic conditions. The dynamics of changes in annual precipitation and average temperatures are presented in Figures 1-2, the statistics of annual precipitation, average temperatures and their ratios for 2001-2017 are shown in Table 1.

Table 1. Annual precipitation (mm), average annual temperature (°C) and their ratio in Nur-Sultan (N), Barnaul (B) and Kemerovo (K).

Indicators	Annual sum of precipitation, mm			Average annual temperature, °C			Ratio of the annual sum of temperatures to the annual sum of precipitation, °C/mm		
	N	B	K	N	B	K	N	B	K
Mean	345.5	444.9	530.9	4.2	2.8	1.6	4.6	2.4	1.1
-95%	314.7	410.1	491.8	3.9	2.3	1.1	4.1	1.9	0.8
+95%	376.4	479.7	570.1	4.5	3.3	2.2	5.0	2.8	1.5
Σ	60.0	67.7	76.1	0.6	1.0	1.1	0.9	0.8	0.7
Cv, %	17.4	15.2	14.3	14.6	34.8	67.4	20.7	35.3	63.9
SEM	14.5	16.4	18.5	0.2	0.2	0.3	0.2	0.2	0.2

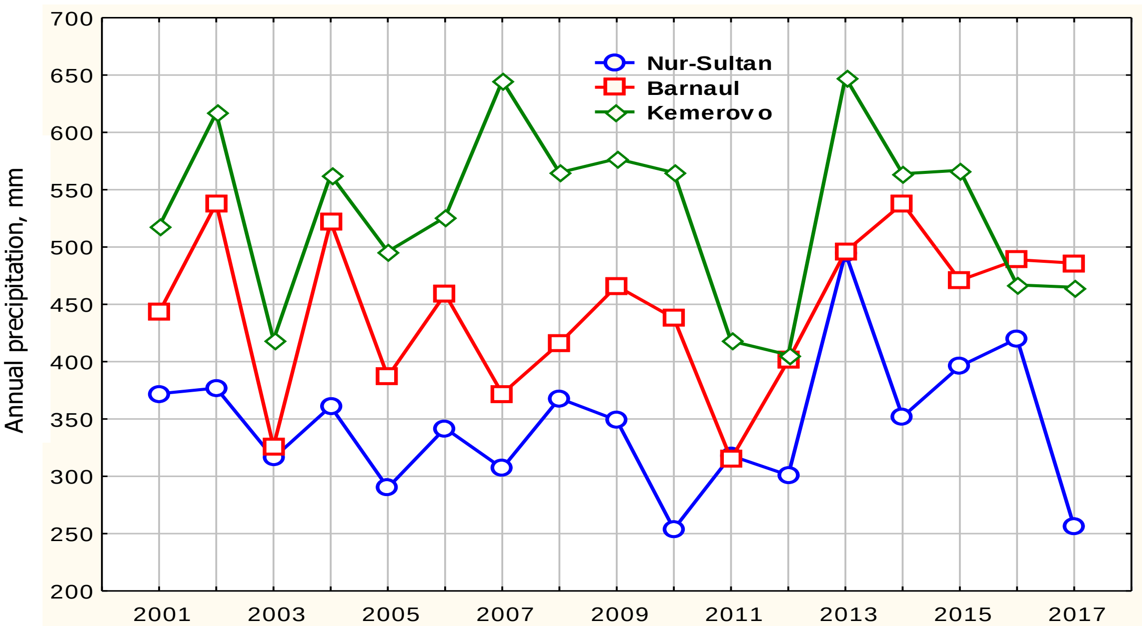

Figure 1. Dynamics of changes in annual precipitation (mm) in Nur-Sultan, Barnaul and Kemerovo for 2001-2017.

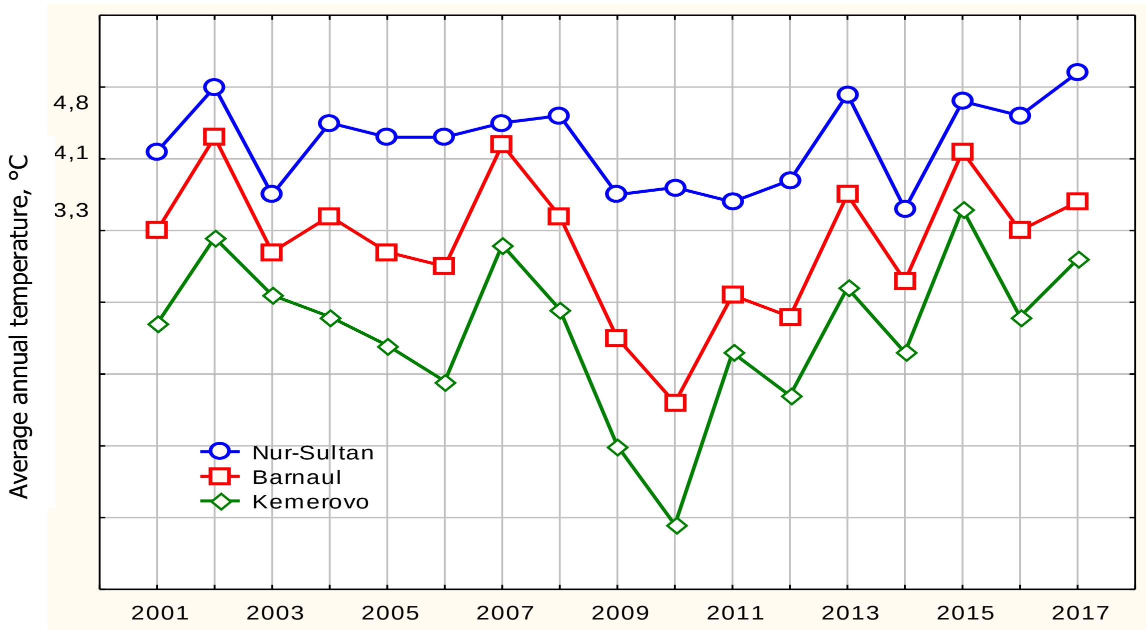

Figure 2. Dynamics of changes in average annual temperatures (°C) in Nur-Sultan, Barnaul and Kemerovo for 2001-2017.

The analysis of the data indicates a high variability of weather conditions in the compared territories. Thus, the minimum average annual sum of precipitation for the observed period was obtained for the city of Nur-Sultan (345.5 mm), and the maximum for the city of Kemerovo (530.9 mm), the city of Barnaul occupies an intermediate position (444.9 mm). At the same time, the variation in precipitation is maximum in Nur-Sultan (17.4%), and is minimum in Kemerovo (14.3%). Temperatures change even more significantly: the maximum variation was obtained for the city of Kemerovo (67.4%), and the lowest for the city of Nur-Sultan (14.6%), (for the city of Barnaul there is also an intermediate value of 34.8%), with average annual values of 1.6, 4.2 and 2.8 °C, respectively. The general trend is the increase in average temperatures with the decrease in precipitation.

The heat supply for the each millimeter of annual precipitation also differs significantly: the highest average value is in Nur-Sultan (4.6 °C/mm), the average is in Barnaul (2.4 °C/mm), and the minimum is in the city of Kemerovo (1.1 °C/mm). The variation is 20.7, 35.3 and 63.9%, respectively.

We consider how the ratios of monthly precipitation and temperatures are changed by region and the relationship between them. As a base for the comparison, we selected the city of Nur-Sultan, where the maximum value of the coefficient of heat supply of precipitation was obtained. As a result of the analysis, the highly significant constraint equations were obtained (Figures 3-4).

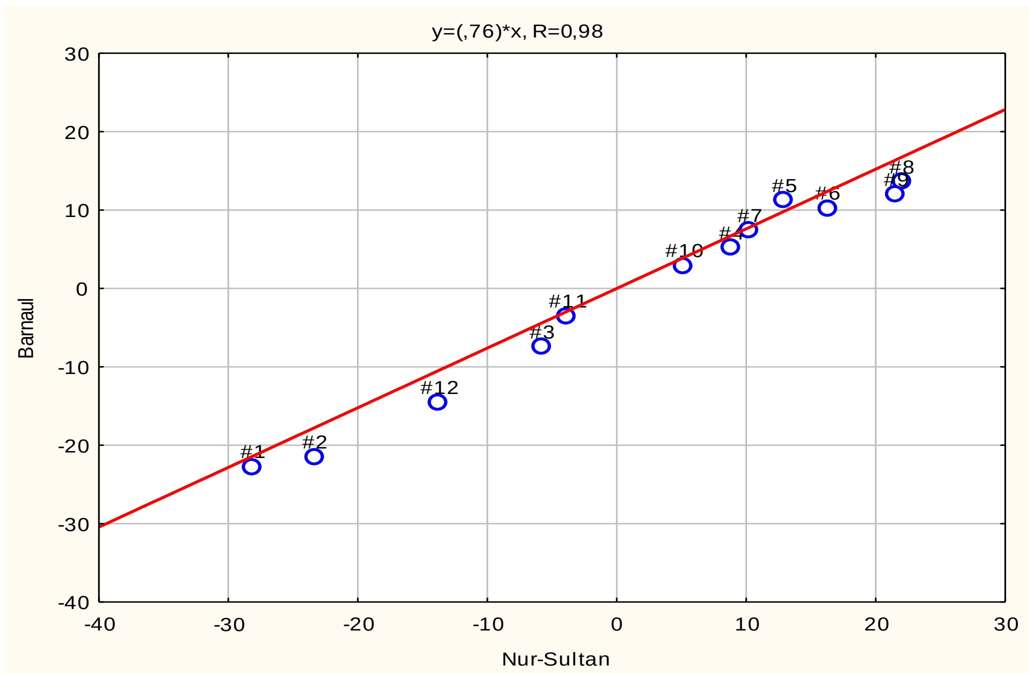

Figure 3. Dependence between monthly temperatures sum–precipitation ratios in Barnaul and Nur-Sultan (where 1-12 are the months of the year).

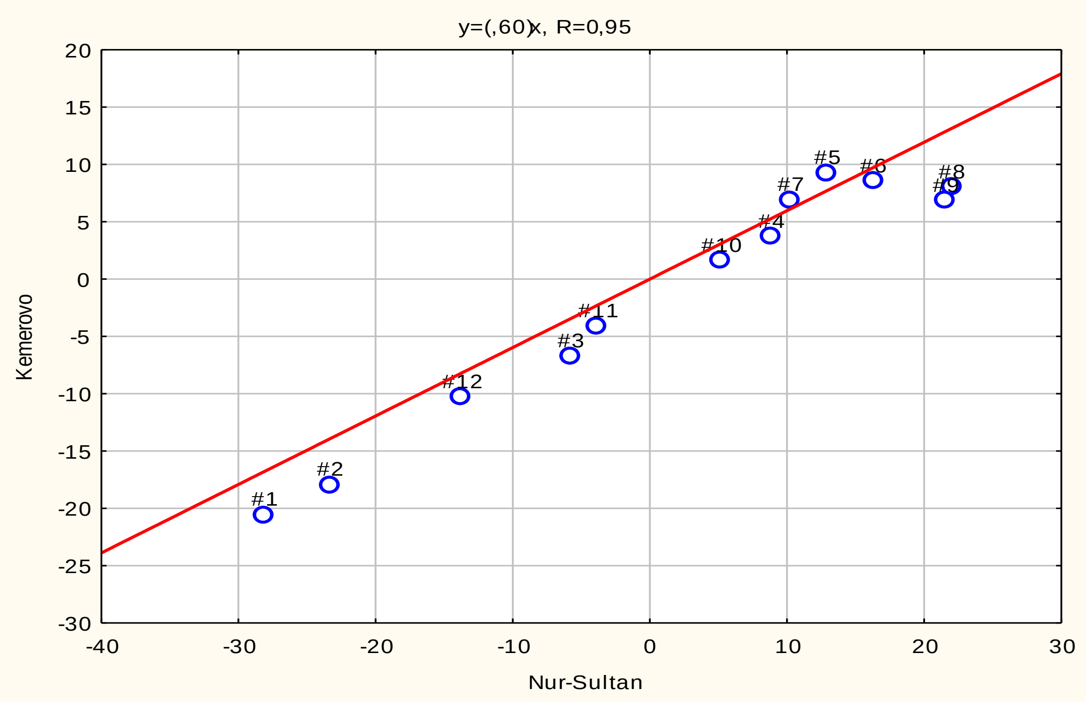

Figure 4. Dependence between monthly temperatures sum–precipitation ratios in Kemerovo and Nur-Sultan (where 1-12 are the months of the year).

Thus, the heat supply for each millimeter of precipitation on average in Barnaul is 0.76 from Nur-Sultan, and Kemerovo - 0.60. The value inverse to the coefficient of heat supply of precipitation will determine the agroclimatic potential of the region (moisture supply for each degree of temperature). So, if we take the city of Nur-Sultan as the base, then the agroclimatic potential in the vicinities of Barnaul is 1.31 and of Kemerovo is 1.66 times higher. Thus, the application of this approach allows a comparative assessment of the agro-climatic potential of different regions, as well as an assessment of their potential for the cultivation of various crops. At the same time, it is possible to select crops for each region (zone) based on the needs of heat supply, moisture and economic feasibility.

Conclusion

The proposed approach for comparing the agricultural territories using the coefficients of precipitation and heat supply considered the long-term heat and moisture supply and could asses the agroclimatic potential and economica values of agriculture lands. We could also provide zonation and structure of cultivated crops sown areas in terms of their requirements in heat and moisture supply.

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