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# Dynamics of bioclimatic potential of agricultural formations of Almaty region

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**Abstract.** The article has the new technique and formula for determining the dynamics of assessment of the bioclimatic potential of climatic zones. Empirical models of potentially possible grain yield of cultures of the agricultural organizations of the Almaty region were also developed. The data on changes in temperature and precipitation received from metrological stations of the region on Hydrometeorology and environmental monitoring, as well as data from the website of the world meteorological network for 1998-2017, which reflect changes in atmospheric circulation observed in the last twenty years are analyzed.

## 1. Introduction

Accounting and evaluation of actual and potential biological productivity have long attracted the attention of many scientists - physiologists, soil scientists, farmers, and geographers such as K.A. Timiryazev [1], V.V. Dokuchaev [2], V.R. Williams [3], etc. The work shows that the productive power of the earth and its biological productivity is determined by the amount of incoming solar energy, as well as the ratio of heat and moisture.

The basic methodology of the agro-climatic assessment of the territory was laid in the work of P.I. Brounov [4]. Further, their ideas have received and developed in the researches of G.T. Selyaninov [5 and 6], P.I. Koloskov [7], Y.I. Chirkov [8], D.I. Shashko [9 and 10] and other scientists.

Agricultural evaluation of the climate in the mentioned works is based on two indisputable established in the agronomic science positions - the equivalence of the factors of life and disparities in the environmental factors. The first law states that no single life factor can be replaced by another; the second one assumes that the life factors and environmental factors are not identical. Following this, the main and secondary factors for these objects or processes are distinguished.

The main environmental factors determining the conditions of growth, development, yield, and quality of agricultural products are, first of all, light, heat, and moisture.

The set of agro-climatic factors that create conditions for the formation of crop productivity determines the agro-climatic resources of the territory. Various scientific and practical tasks of agricultural production provide for the need to assess the bioclimatic potential since the biological productivity of land in different areas is significantly different. Therefore, the most important factor in



increasing the efficiency of agricultural production is the precise definition of the bioclimatic potential of a certain territory.

Bioclimatic potential (BCP) is a set of climatic factors that determine the possible biological productivity of the earth in a given area [9, 10 – 13]. The concept of bioclimatic potential is widely used in agronomy, climatology, etc. In agronomy, this concept is based on an objective pattern of changes in the productivity of plants depending on the main climatic factors - heat and moisture. Various mathematical formulas for obtaining numerical estimates of bioclimatic potential are known.

The dependence of agricultural production on natural and climatic conditions has long been a well-known fact and does not require justification and evidence. For example, randomly formed weather conditions of each agricultural year and climatic characteristics on a certain background of soil potential predetermine fluctuations in crop yields in the economy, district, and region, country [14 and 17].

Climatic conditions are reflected in the long-term variation of crop yields, and this variation is objectively inherent in any culture and any region. The authors [12, 13, 16, 18 and 19], as a criterion of "agricultural productivity of climate" suggest and use the yield of grain crops. Therefore, we can use with good reason in assessing the bioclimatic potential of any territory of agriculture of Almaty region systematic component of the annual natural climatic factor and the yield of grain crops.

The resource approach to the study of bioclimate uses multi-numerical complex meteorological indicators and indices of different dimensions. A means of overcoming this multidimensionality was the concept in which all the variety of indicators is reduced to a single indicator – bioclimatic potential.

The purpose of our research is to determine the value of bioclimatic potential in all climatic zones of the Almaty region.

The scientific novelty of the research results lies in the substantiation of the methodology and the development of a new formula based on which the determination of the dynamic assessment of the bioclimatic potential of climatic zones of Almaty region, as well as the development of empirical models of the potential crop yield in the agricultural organizations of the region.

## 2. Methods

To determine the value of bioclimatic potential, data of metrological stations of the Almaty region on Hydrometeorology and environmental monitoring for 1998-2017 were used, as well as the website: [20], data of the world meteorological network. All meteorological stations of the region are included in the world meteorological network. "The weather knows no bounds". Therefore, all information is processed not only in the regional center but also in the world data center.

This, in turn, increases the level of responsibility of each observer, at any station for their work. Data were collected and pre-processed for all administrative 16 districts and 3 cities engaged in the production of agricultural products (hereinafter-the Object of study) of the Almaty region. For all objects of study (20 units) formed an array of data – tables object-properties of dimension 20×13 15- and climate indicators. In particular: the average amplitude of the air temperature at a height of 2 m, °C; mean monthly surface soil temperature, °C; point rosy for a height of 2 m, °C; mean monthly maximum air temperature at a height of 2 m, °C; mean monthly minimum air temperature at a height of 2 m, °C; mean monthly air temperature at a height of 2 m, °C; monthly average daily sludge per day, mm; specific monthly average relative humidity, g kg<sup>-1</sup>; average relative humidity, %; the average atmospheric pressure at the level of metrological stations of the cross, Mbar (kPa); average monthly minimum wind speed at the height of 10 m, m/s; average monthly maximum wind speed at the height of 10 m, m/s; the average monthly amplitude of wind speed fluctuations at the height of 10 m, m/s; average monthly descending thermal infrared (long-wave) radiation flux, kWh/m<sup>2</sup> per day and average monthly insolation clarity index.

To identify the close relationship between the calculated values of BCP and grain yield in the objects of research, the method of correlation and regression analysis was used. Parameters of regression models are estimated by the least-squares method. The modeling process is performed in

Excel. The study was completed all stages of correlation and regression analysis – data collection and processing, the construction of the regression equation, quality assurance models and regression coefficients, interpretation of the results. In the study of the dynamics of agro-climatic and economic indicators used mathematical and statistical methods. Statistical characteristics of data from the applied model built with the help of the "data analysis" add-in of the Microsoft Office Excel spreadsheet processor.

### **3. Results and discussion**

In studies on the calculation of climate impact on crop productivity, almost all authors consider the duration of the growing season [9 – 15] and limited the collection of information only for this period. We did not take into account the annual accumulation of features of the climate regime of a particular year of the horoscope. Attention is drawn to the work "Secrets of the harvest year" [14], where it is noted that "the soil and all plants are natural batteries." Besides, it should be borne in mind that in mass field farming, the productivity of grain crops is formed with a natural combination of heat, moisture, without fertilizers, and other special techniques of agricultural technology. Therefore, when assessing the bioclimatic potential of land for research objects, it is necessary to take into account large amounts of data on natural laws.

To determine the most significant modes of climate indicators that form the BCP of the territory of administrative 16 districts and 3 cities, we studied the closeness and directions of connection of all the above climatic indicators with the yield of grain crops. With the help of the package "data Analysis" MS Excel built a rectangular sub-matrix of correlation coefficients for all objects of study. Figure 1 shows a fragment of one of these matrices, built on the example of the Aksu district of Almaty region.

	Y	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>
Y	1															
X <sub>1</sub>	-0,61	1														
X <sub>2</sub>	-0,04	-0,172	1													
X <sub>3</sub>	0,441	-0,823	0,37	1												
X <sub>4</sub>	-0,07	-0,119	<b>0,97</b>	0,365	1											
X <sub>5</sub>	0,143	-0,443	<b>0,93</b>	0,606	<b>0,943</b>	1										
X <sub>6</sub>	<b>0,046</b>	-0,291	0,97	0,507	<b>0,982</b>	<b>0,98</b>	1									
X <sub>7</sub>	<b>0,444</b>	-0,535	-0,2	0,701	-0,23	-0,03	-0,1	1								
X <sub>8</sub>	0,387	-0,831	0,14	<b>0,952</b>	0,154	0,42	0,3	0,75	1							
X <sub>9</sub>	0,475	-0,689	-0,3	0,757	-0,31	-0,05	-0,2	<b>0,91</b>	0,85	1						
X <sub>10</sub>	0,305	-0,282	0,19	0,294	0,177	0,25	0,24	0,17	0,28	0,21	1					
X <sub>11</sub>	0,082	0,1203	-0	0,157	-0,06	-0,09	-0	0,45	0,09	0,25	-0,3	1				
X <sub>12</sub>	-0,21	0,4478	0,25	-0,19	0,171	0,01	0,13	0,01	-0,3	-0,3	-0,3	0,76	1			
X <sub>13</sub>	-0,27	0,4936	0,3	-0,27	0,213	0,03	0,17	-0,11	-0,4	-0,4	-0,3	0,62	<b>0,98</b>	1		
X <sub>14</sub>	<b>0,316</b>	-0,445	0,59	0,653	0,642	0,73	0,69	0,31	0,53	0,21	0,06	0,17	0,06	0,014	1	
X <sub>15</sub>	-0,42	0,2239	-0,1	-0,3	-0,12	-0,18	-0,2	-0,4	-0,3	-0,2	-0,2	-0,4	-0,3	-0,25	-0,56	1
	The yield of grain crops, center from 1 hectare	Average monthly amplitude of air temperature fluctuations at a height of 2 m, °C	Average monthly surface soil temperature, °C	Dew point at a height of 2 m, °C	Aver. monthly max. air temp. at a height of 2 m, °C	Aver. monthly min. air temp. at a height of 2 m, °C	Average monthly air temp. at a height of 2 m, °C	Monthly average daily precipitation, mm per day	Monthly average specific humidity of air, kg <sup>-1</sup>	Average monthly relative humidity of air, %	Mean monthly atmospheric pressure, Mbar (kPa)	Ave. Mon. min. wind speed at a height of 10 m, m / s	Ave. mon. max. wind speed at a height of 10 m, m / s	Ave. mon. amplitude of wind speed fluctuations at a height of 10 m, m / s	Ave. mon. descending thermal infrared radiation flux, kWh / m <sup>2</sup> per day	Monthly average index of insolation

**Figure 1.** Sub-matrix of correlation coefficients between yield and climatic indicators of Aksu district of Almaty region.

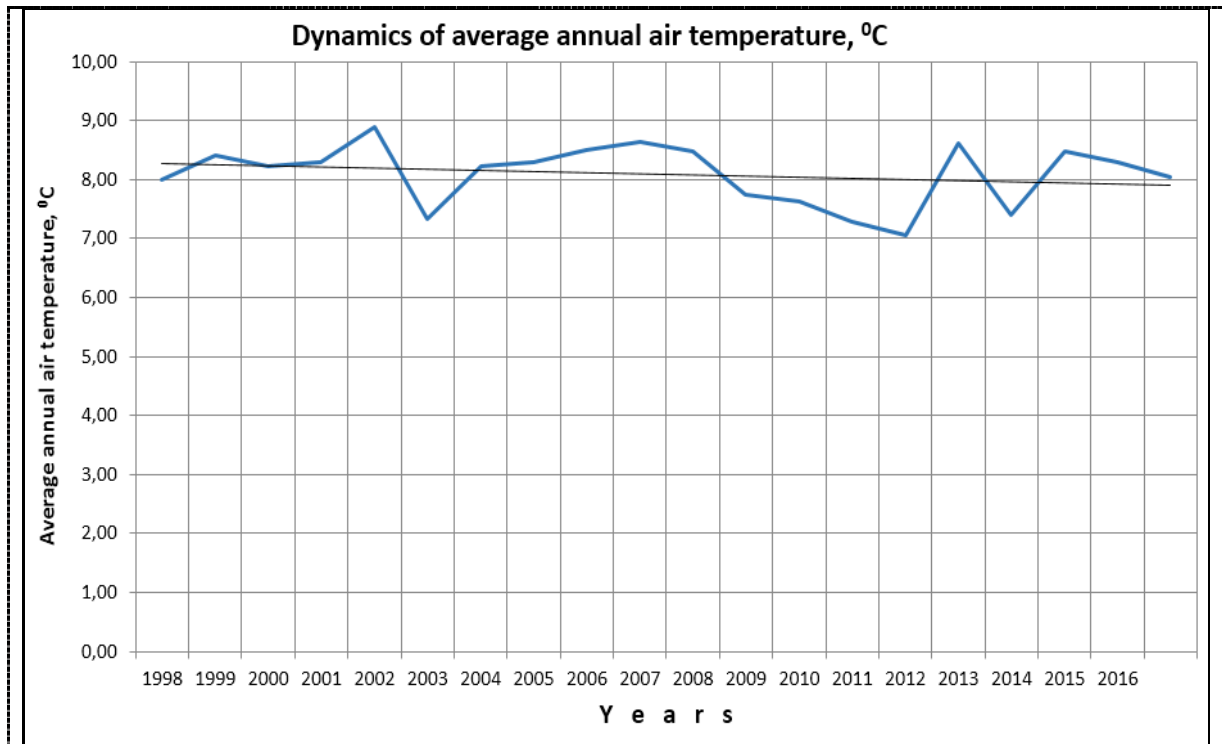
As can be seen from figure 1 with the resulting indicator, Factors have a positive and significant relationship: X<sub>3</sub>, X<sub>5</sub>, X<sub>6</sub>, X<sub>7</sub>, X<sub>8</sub>, X<sub>9</sub>, X<sub>10</sub>, and X<sub>14</sub>. Between some factors, there is multicollinearity and therefore one variable should be excluded from consideration, in most cases, leave one of two variables that has a greater correlation coefficient with the dependent variable. However, this rule is not always feasible from a practical point of view. For example, the pair correlation coefficient between X<sub>7</sub> and X<sub>9</sub> is 0.91, and their particular values  $r_{yx_7} = 0.444$  and  $r_{yx_9} = 0.475$ . In practice,

agriculture is essential to average daily, average monthly, and average annual rainfall. Therefore, this indicator is left (X<sub>7</sub>), but the relative humidity is not excluded (X<sub>9</sub>) from further study.

Analyzing and eliminating multicollinearity of the same submatrix of other objects of study and taking into account the research work performed on this problem, we concluded that the most significant among the possible climatic indicators are: X<sub>6</sub> is the average monthly air temperature at an altitude of 2 m, X<sub>7</sub> is monthly average daily precipitation, mm per day (X<sub>9</sub> is average monthly relative humidity, %) and X<sub>14</sub> is average monthly descending thermal infrared radiation flux, kWh/m<sup>2</sup> per day. It should be noted that the climate indicators we have reasonably chosen correspond to the traditionally accepted indicators.

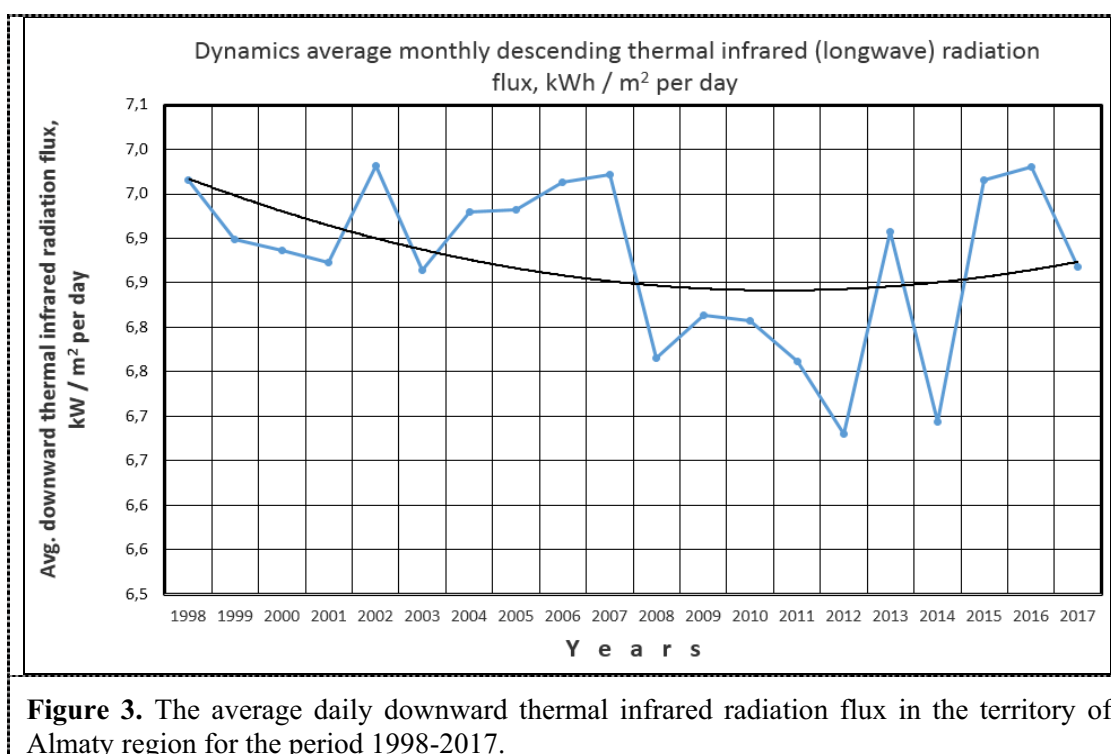
According to the metrological stations of the Almaty region and the world meteorological network, the average annual air temperature has decreased over the past 20 years (by an average of 0.4°C/20

years) (Figure 2). The warmest for the study period were: 2002, 2007, 2013, 2015 and the coldest were 2003, 2012 and 2014 [21, 23].



**Figure 2.** The average annual air temperature in the Almaty region for the period 1998 – 2017.

The consequence of the decrease in temperature over the past twenty years in the study area was a decrease in the duration of the growing season. At the same time, the last decade has seen an increase in the amounts of active temperatures compared to the previous decade (Fig. 3). At the end of the XX century, due to the increase in the total duration of blocking processes, there was a tendency to increase the annual amplitude of the average monthly thermal infrared radiation flux. This thermal regime, since 2012, tends to increase according to the law of the second-order polynomial (Fig. 3). The obtained data clearly show the improvement of the heat supply of agricultural crops. One of the reasons for the observed changes in the temperature regime is changes like atmospheric circulation.



An analysis of the dynamics of precipitation data showed that there has been a slight increase in precipitation in recent years (Fig. 4), which leads to an increase in evaporation with an increase in the average annual temperature [22]. During the study period, the most humidified was 2016 (500 mm), and 2014 was marked as the driest, since the annual rainfall this year was 2.5 times less.

Table 1 shows the average monthly precipitation for the different averaging periods. Attention is drawn to the decrease in precipitation in August and September in all study periods; this is a consequence of the fact that at a high-temperature background of these months there is an increase in evaporation. The increase in precipitation in May and June does not compensate for the decrease in the supply of productive moisture in the arable layer since the evaporation values exceed the amount of precipitation in these months by almost half.

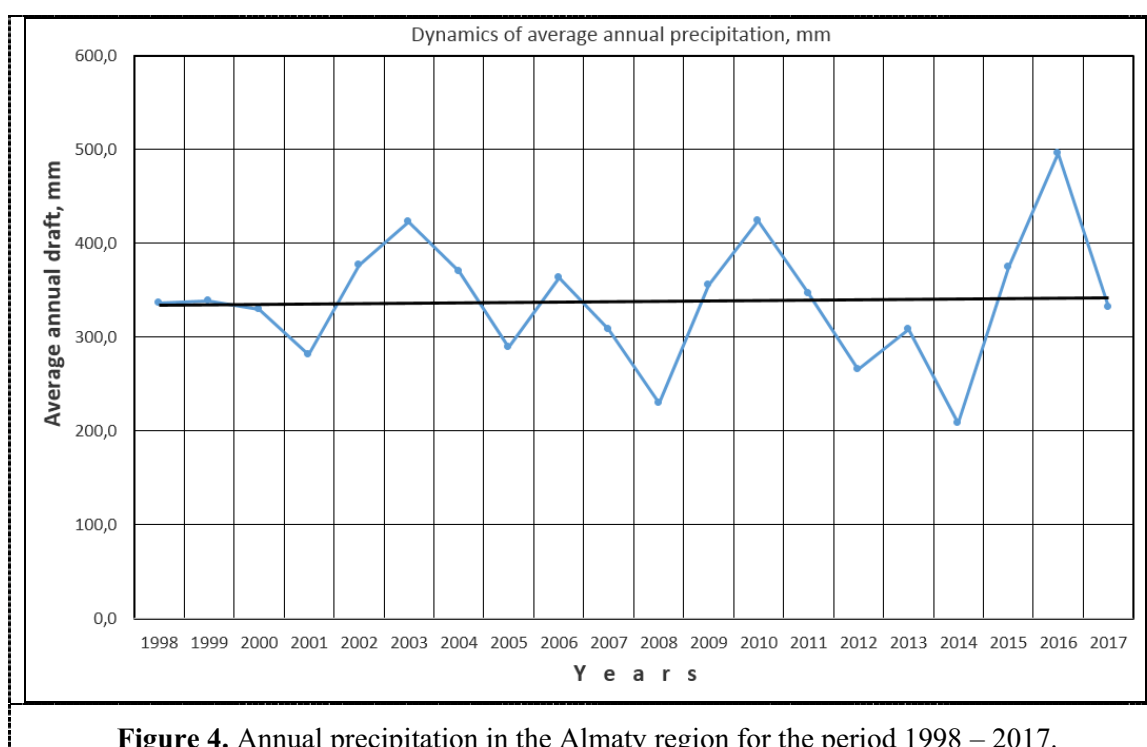
Thus, the changes observed in the last twenty years are as follows: the increase in the number of active temperatures for August–September determines the increase in evaporation, which is not compensated by precipitation; August and September differ in particular aridity.

The limiting factor for the optimal development of a large number of crops in the study area is humidification resources, as evidenced by the values of the average monthly relative humidity (AMRH) for different averaging periods, given in Table 3. The value of AMRH for the period from June to August ranges from 27.26 % to 35.59 % and characterizes the conditions of moisture as insufficient, therefore, the conditions become arider. This is a consequence of the location of the regional center (c. Taldykorgan) in the middle mountain zone and the prevalence of anticyclonic weather.

**Table 1.** Precipitation weather stations in Taldykorgan, averaged over different periods, mm.

Months	1998-2002 y	2003-2007 y	2008-2012y	2013-2017 y
January	17.88	16.86	15.06	20.58
February	19.22	21.27	25.23	15.13
March	18.35	21.76	25.02	14.26

April	27.06	22.68	22.08	29.16
May	23.62	29.92	21.7	32.05
June	29.64	24.84	16.92	21.6
July	20.03	24.43	14.94	12.83
August	7.874	9.672	9.486	11.16
September	15.00	10.85	18.17	11.97
October	36.02	16.18	24.18	38.07
November	24.72	33.18	26.28	34.50
December	25.54	34.29	22.88	21.95
In a year	267.10	255.19	244.03	267.10



**Figure 4.** Annual precipitation in the Almaty region for the period 1998 – 2017.

Now let's move from the analysis of individual indicators to a comprehensive assessment of agro-climatic conditions in the region over the past twenty years.

The bioclimatic potential is the most important indicator of assessing the natural conditions of the territories, synthesizing the influence on the biological productivity of the main factors – heat and moisture.

As the analysis of the works of the authors [11, 12, 13 and 15], engaged in the study of the problem of agrometeorology, almost all of them in their studies on the calculation of climate impact on crop products use the method of D. I. Shashko [9 and 10], developed in 1967 to assess the bioclimatic potential (BCP). In this technique, the author considers a comparative interregional assessment of land, through the relative values of bioclimatic potential, synthesizing the impact on the biological productivity of the main factors of climate – heat, and moisture. At the same time, the BCP was estimated in comparison with the basic productivity at the border of possible mass field farming (at a base temperature of 1000°C) for the period of 1961-2000 yy.



Table 2. Average Monthly relative humidity of Taldykorgan weather station, averaged over different periods, %

Months	1998-2002 y	2003-2007 y	2008-2012 y	2013-2017 y
January	70.76	72.00	70.09	71.08
February	64.65	65.43	75.60	68.11
March	52.00	55.84	57.84	56.45
April	44.29	46.61	46.72	48.35
May	37.13	40.26	37.72	38.54
June	33.23	33.97	33.97	35.59
July	32.00	34.89	31.39	30.42
August	27.26	29.61	29.37	31.20
September	30.35	30.49	36.10	33.74
October	47.46	43.56	50.81	51.19
November	58.28	62.07	62.11	63.75
December	69.47	69.07	69.50	67.96
In a year	47.16	48.58	49.98	49.60

Linking bioclimatic potential (BCP) with yield and extending the area of the territory to: high, high, medium, and low in percentage terms, respectively, according to the value of BCP gradation in 1967, D.I. Shashko using the usual principle of proportion, developed a table of biological productivity gradation.

D.I. Shashko believes that the comparative assessment of soil fertility should be carried out in close connection with climatic conditions. The author proposes a technique that is based on objective indicators of biological productivity and is expressed by the relative values of soil-bioclimatic potential (SBP). The comparative assessment of biological productivity of the earth is made in points where for 100 points the value of SBP corresponding to average productivity at the given technical and economic level of development of the economy is accepted. The average yield of grain crops on the value of SBP is approximately 1.9. This value is taken as 100 points at this technical and economic level of development of the economy. To obtain points of the remaining territories of the SBP, calculations are carried out through proportions.

Of course, the author proposed an original simple technique, and of course, when information technology was still not developed, he focused on the availability and the ability to simply perform computational operations.

Based on its methodology for the calculation of bioclimatic potential, the following formula is used:

$$BCP = K_{p(au)} \frac{\sum t_{ak}}{\sum t_{ak(baz)}} \quad (1)$$

Where:

$BCP$  are the relative values of bioclimatic potential;

$K_{p(au)}$  is the growth coefficient for the annual indicator of atmospheric moisture;

$\sum t_{ak}$  is the sum of the average daily air temperatures for the period of active vegetation in a given place;

$\sum t_{ak(baz)}$  is the basic sum of the average daily air temperatures for the period of active vegetation.

In the formula used, the coefficient of growth of  $K_{p(au)}$  is equal to the ratio of yield in these conditions of moisture to the maximum yield in conditions of optimal moisture supply. Next, a formula is proposed to determine its calculated value, which takes into account the coefficient of

annual atmospheric moisture, equal to the ratio of precipitation to the sum of the average daily values of the air humidity deficit. It should be noted that in our opinion all these data are collected in limited conditions, as a result of practical experience and experiment in a certain area, which does not characterize the scale of the entire object of study. We can replace the formula of the growth coefficient with the ratio of each grain yield to its average value of the General population in the region as a whole for the period under study (1998-2017).

Based on formula (1) and considering that bioclimatic potential is an integral assessment of a set of climatic factors determining the possible biological productivity of land in a given territory or otherwise, a bioclimate of integral estimates of its basic regimes, it is proposed to determine BCP for all object of research of Almaty region by the new formula developed by us:

$$BCP_{ij} = \frac{Y_{ij}}{Y_{cp}} \left( \frac{t_{ij}}{t_{cp}} + \frac{B_{ij}}{B_{cp}} + \frac{U_{ij}}{U_{cp}} \right) \quad (2)$$

where  $Y_{ij}$  is the yield of grain crops in the  $i$  – the entity (district, city, and oblast) for the  $j$  – year (from 1998 to 2017), 100kg/ha;

$t_{ij}$  is the average annual air temperature at a height of 2 m in the  $i$  – object at the  $j$  – year,  $^{\circ}\text{C}$ ;

$B_{ij}$  is the average of sediment in the  $i$  – object at the  $j$  – year, mm;

$U_{ij}$  is the average the downward thermal infrared radiation, the heat flux in the  $i$  – object at the  $j$  – year,  $\text{kWh/m}^2$ ;

$Y_{cp} = \sum_{i=1}^m \sum_{j=1}^n Y_{ij} / m \cdot n$  – is the average grain yield (mathematical expectation) of the whole population;

$t_{cp} = \sum_{i=1}^m \sum_{j=1}^n t_{ij} / m \cdot n$  – is the average annual air temperature at a height of 2 m of the whole population;

$B_{cp} = \sum_{i=1}^m \sum_{j=1}^n B_{ij} / m \cdot n$  – is the average annual precipitation of the whole population;

$U_{cp} = \sum_{i=1}^m \sum_{j=1}^n U_{ij} / m \cdot n$  – is the average annual descending thermal infrared radiation heat flow of the whole population;

$m$  is the number of objects of study (in our case  $m=20$ ) and  $n$  is the number of years in the period under consideration (in our case  $n = 20$ ).

Based on the collected materials for each indicator, a sub-matrix with the size:  $20 \times 20$ , the average annual values of these indicators, and according to this formula, the dynamics of the BCP of agriculture of the Almaty region was calculated, which is shown in table 3.

On the basis of these calculations (Table 3), it can be concluded that the biological productivity in the whole region has increased significantly in recent years, in the Eastern-Northern part of the Almaty region is reduced, which is associated with insufficient moisture. Analyzing the annual data of the bioclimatic potential of the table. 3, we see that from 2009 to 2017 distinguished by increased levels of BCP compared to other years, and the high yield of grain crops in these years is in good agreement with the data obtained. According to the obtained values of the BCP, it is impossible to obtain high yields of agricultural crops without agrotechnical measures in the territory of the Almaty region regularly.

To assess whether the characterized calculated values BCP-cally, the level of grain crop yield, we carried out correlation and regression calculation over all the objects of the study  $r$ . The calculation results are shown in Table 4.

As can be seen from this table in all the studied objects, the yield of grain crops is close, it is associated with the calculated value of the BCP, which shows the calculated values of the correlation coefficient, ranging from  $R = 0.890 \div 0.995$ . At the same time, in all the studied objects the calculated value of the Student's criterion:  $t_{cal} = 74.17 \div 42.34 > t_{tab} = 2.1$  is greater than its table value, which shows the reliability of all the calculated values of the correlation coefficients.

The form of communication, built in the form of a linear empirical model, was also reliable. Since in all cases the significance of the Fisher F-test ( $5.92 \cdot E-11 \div 1.45 \cdot E-07$ ) is much lower than the accepted significance level ( $\alpha = 0.05$ ). It should be noted that given in the work [9] developed by us by the method of astrological modeling, predicting the above-considered modes of climatic parameters, we can calculate the prospective yield of grain crops for all objects of study of the Almaty region.

The gradations of bioclimatic potential values reflect the natural zonality and zonality, as the sums of temperatures according to the natural scale of heat supply classification are used for their determination [157]. Therefore, the climate orientation of agriculture is relevant, aimed at regulating soil formation processes, as well as the management of factors of accumulation of the studied indicator during the year and plant development in terms of variability of agricultural meteorological parameters. The results of the analysis are also presented in Table 4.

**Table 3.** Results of assessment of bioclimatic potential of the agricultural territory of Almaty region.

The name of the district and the city	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oblast	1.8	2.0	2.0	2.2	3.3	3.2	2.9	2.6	2.8	3.0	2.0	3.5	3.2	3.1	2.8	3.3	2.6	3.7	4.3	3.8
Aksu	1.3	1.2	1.7	1.6	2.4	2.4	1.9	1.7	1.9	1.9	0.8	2.1	1.6	1.4	1.3	1.5	1.2	1.9	2.5	2.1
Alakol	1.0	1.2	1.6	1.5	2.7	2.5	1.8	1.7	1.9	2.1	1.2	2.9	2.3	2.1	2.2	2.5	2.1	2.9	2.9	2.8
Balkhash	1.1	2.9	3.1	3.1	3.8	3.3	3.5	3.3	4.1	3.9	3.6	4.2	4.4	4.0	3.8	4.5	3.9	4.5	5.0	4.6
Embekshikazakh	2.8	3.0	3.6	3.5	4.7	5.0	4.8	4.3	4.9	4.8	3.8	5.2	5.4	5.6	5.1	6.3	5.0	6.8	8.7	7.4
Eskeldi	2.0	2.0	1.9	1.8	2.8	2.6	2.4	2.1	2.4	2.5	1.7	2.8	2.9	2.8	2.5	2.9	2.0	2.9	3.3	2.7
Zhambyl	2.0	2.5	1.0	1.2	3.0	2.9	1.8	1.8	1.9	2.2	0.6	3.0	3.0	3.0	2.2	2.8	2.4	3.4	4.0	3.3
Ili	1.4	1.8	0.9	1.5	3.4	3.6	2.2	2.1	2.9	2.7	1.8	3.6	2.9	2.7	2.5	3.2	2.0	3.3	4.3	4.1
Karasai	2.0	2.4	3.5	3.0	5.0	5.5	2.3	2.5	3.7	3.5	1.9	3.8	3.8	3.5	2.7	3.3	2.2	3.3	4.2	3.4
Karatal	3.5	2.6	2.6	2.6	3.3	2.9	3.0	3.0	3.5	3.3	2.9	3.8	3.4	3.4	3.2	3.8	3.2	4.0	4.6	4.3
Kerbulak	1.7	1.8	1.6	1.7	3.0	2.8	2.3	2.3	2.1	2.3	0.8	3.0	2.3	2.5	1.9	2.5	1.9	2.7	3.3	2.8
Koksu	2.4	1.6	1.7	1.9	3.0	2.8	2.9	2.1	2.3	2.8	1.6	2.9	3.2	3.1	2.4	2.8	2.4	3.3	3.7	3.5
Panfilov	2.2	2.5	2.7	3.2	4.1	4.4	4.6	3.6	4.7	5.4	4.7	5.7	6.6	5.9	5.7	6.1	5.8	7.1	7.8	6.7
Rayimbek	1.3	1.2	1.6	1.6	2.3	2.3	2.2	1.7	2.0	2.2	1.3	2.7	2.7	2.5	1.9	2.2	1.1	2.4	2.8	2.4
Sarkand	1.8	1.4	1.8	1.8	2.7	2.6	2.1	2.1	2.3	2.4	0.9	2.6	2.3	2.1	1.9	2.1	1.3	2.4	2.9	2.4
Talgar	2.2	3.3	2.2	2.8	3.6	3.8	3.5	3.0	3.4	3.3	2.3	4.0	3.9	3.8	3.2	4.0	3.4	4.6	6.2	5.8
Uigur	2.0	1.6	2.8	3.3	4.2	4.3	4.3	4.3	4.7	4.9	4.7	5.8	6.3	6.0	5.9	6.9	6.5	8.0	8.8	7.5
Kapchagai	2.2	2.4	2.2	3.5	4.0	3.8	4.7	3.9	4.2	4.0	1.4	3.4	3.7	2.6	1.5	1.9	1.7	2.6	4.5	3.9
Taldikorgan	1.6	1.8	1.8	1.8	2.9	2.6	2.8	2.5	2.8	2.7	2.0	2.4	2.4	2.5	2.2	2.7	2.2	2.8	3.3	2.9
Tekeli	1.5	0.8	1.1	1.0	2.4	2.5	2.5	2.3	2.5	2.4	1.9	2.5	2.9	2.9	2.8	3.2	2.0	3.5	3.4	2.9

**Table 4.** Variability and closeness of connection with the yield of grain crops BCP soil and climatic zones of Almaty region for 1998-2017 yy.

Agricultural areas	The name of the district and the city	Bioclimatic potential (BCP)				Empirical and correlation of grain yield with BCP	
		<i>Max</i>	<i>Min</i>	<i>X<sub>cp</sub></i>	<i>V, %</i>	<i>Y=f(x)</i>	<i>R</i>
<b>I</b>	Aksu	2.5	0.8	1.7	20.9	$Y=3.505 + 7.738 \cdot X_{bcp}$	0.960
	Alakol	2.9	1.0	2.1	23.1	$Y = 2.022 + 6.742 \cdot X_{bcp}$	0.967
	Sarkand	2.9	0.9	2.1	18.0	$Y = 4.63 + 7.543 \cdot X_{bcp}$	0.995
	Karatal	4.6	2.6	3.3	12.1	$Y = 4.732 + 6.579 \cdot X_{bcp}$	0.890
<b>II</b>	Balkhash	5.0	1.1	3.7	15.8	$Y = 2.419 + 7.093 \cdot X_{bcp}$	0.945
	Zhambyl	4.0	0.6	2.4	29.0	$Y = 2.291 + 5.97 \cdot X_{bcp}$	0.954
	Ili	4.3	0.9	2.6	28.7	$Y = 3.109 + 6.153 \cdot X_{bcp}$	0.955
<b>III</b>	t.Kapchagai	4.7	1.4	3.1	30.6	$Y = 2.365 + 5.394 \cdot X_{bcp}$	0.983
	Karasai	5.5	1.9	3.3	21.8	$Y = 5.066 + 5.434 \cdot X_{bcp}$	0.955
	Talgar	6.2	2.2	3.6	19.6	$Y = 5.666 + 5.8 \cdot X_{bcp}$	0.919
<b>IV</b>	Eskeldi	3.3	1.7	2.4	14.9	$Y = 5.052 + 6.552 \cdot X_{bcp}$	0.911
	Kerbulak	3.3	0.8	2.3	20.3	$Y = 2.41 + 6.031 \cdot X_{bcp}$	0.966
	Koksu	3.7	1.6	2.6	19.8	$Y = 2.877 + 6.793 \cdot X_{bcp}$	0.956
	t.Taldykorgan	3.3	1.6	2.4	15.3	$Y = 3.804 + 6.481 \cdot X_{bcp}$	0.924
<b>V</b>	t.Tekeli	3.5	0.8	2.3	25.0	$Y = 1.423 + 8.022 \cdot X_{bcp}$	0.968
	Embekshikazakh	8.7	2.8	5.0	20.5	$Y = 6.745 + 6.044 \cdot X_{bcp}$	0.914
	Rayimbek	2.8	1.1	2.0	22.9	$Y = 2.678 + 6.793 \cdot X_{bcp}$	0.975
	Panfilov	7.8	2.2	5.0	26.2	$Y = 1.64 + 8.276 \cdot X_{bcp}$	0.97
	Uigur	8.8	1.6	5.1	30.1	$Y = 1.788 + 6.978 \cdot X_{bcp}$	0.979
	Total on Oblast	4,3	1.8	2.9	18.9	$Y = 4.213 + 6.322 \cdot X_{bcp}$	0.941

The calculation of the value of the bioclimatic potential index for the period from 1998 to 2017 revealed its relatively low value and significant variability. Its minimum value for the analyzed period was measured in the territory of Zhambyl (0.6), Aksu (0.8) and Kerbulak (0.8) regions, and the maximum – in the V-South-Eastern zone (2.8 to 8.8).

Higher minimum, maximum, and average values of bioclimatic potential are characterized by the territory of Uighur, Enbekshikazakh, and Panfilov districts (table 4).

The tendency of increasing the average value of bioclimatic potential in the plain-steppe zone from the North-East (1.7) to the South-West (3.7) direction is noted.

The variability of the bioclimatic potential index is strong regardless of the soil-climatic zone and increases from the plain-steppe zone to the South-Eastern zone. The maximum variability of bioclimatic potential is characterized in the territory of Kapchagay (30.6 %) and districts: Uighur (30.1 %), Zhambyl (29.0 %), and Ili (28.7%).

#### 4. Conclusions

For the first time, based on complex research, the moisture and warm-power resources of the productivity of agricultural cultures on the territory of the Almaty region have been studied. Based on the offered new formula, a twenty-year dynamic assessment of bioclimatic potential and adequate

empirical models of potentially possible grain yield of cultures of the agricultural organizations of the Almaty region are developed.

The proposed approach and a new formula for assessing the bioclimatic potential reflect the natural explanation and zoning, using the sum of temperatures on the natural scale of the classification of heat supply. It takes into account the climatic orientation of agriculture, aimed at regulating soil formation processes, as well as management of factors of accumulation of the studied indicator during the year and plant development in terms of variability of agricultural meteorological parameters.

The analysis of the data carried out in the course of the work testifies to the growth of average annual and monthly values of air temperature in the territory of Almaty region for the studied period. The increase in the total duration of blocking processes contributes to the increase in summer temperatures, mainly in July and August, which leads to an increase in the number of active temperatures and as a consequence – to an increase in evaporation. A slight increase in precipitation does not compensate for increased evaporation, hence conditions become arider. Insufficient moisture determines the reduced bioclimatic potential of the territory.

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