№ 1 (1)
2025

ҒЫЛЫМИ ИННОВАЦИЯЛАР

ғылыми журналы



научный журнал

НАУЧНЫЕ ИННОВАЦИИ

scientific journal

SCIENTIFIC INNOVATIONS

«ҒЫЛЫМИ ИННОВАЦИЯЛАР» ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ «НАУЧНЫЕ ИННОВАЦИИ»

«SCIENTIFIC INNOVATIONS» SCIENTIFIC JOURNAL

Журнал 2025 жылдан бастап шығады

Журнал издается с 2025 года

The journal is published from 2025

Меншік иесі: «Неотехнология жене кауіпсіздік гылыми-зерттеу институты» ЖМ

Собственник: ЧУ «Научно-исследовательский институт Неотехнологий и Безопасности»

Owner:ChU «Research Institute of Neotechnology and Security»

Журнал Қазақстан Республикасы Ақпарат жене қоғамдық даму министрлігінін Ақпарат комитетінде тіркелген,

2025 жылы 4 карашадағы № KZ06VPY00133490 куәлік

Журнал зарегистрирован в Комитете информации Министерства информации и общественного развития Республики Казахстан,

свидетельство №KZ06VPY00133490 от 4 ноября 2025 года.

The journal is registered with the Information Committee of the Ministry of Information and Social Development of the Republic of Kazakhstan, certificate

№ KZ06VPY00133490 dated November 4, 2025

Журнал тоқсан сайын шығарылады (жылына 4 рет)

Журнал издаётся ежеквартально (4 раза в год)

The magazine is published quarterly (4 times a year)

Редакцияның мекен-жайы: 150000, Қазақстан Республикасы, Солтүстік-Қазақстан облысы, Петропавл қаласы, Бостандық көшесі, 51

Адрес редакции: 150000, Республика Казахстан, Северо-Казахстанская область, г. Петропавловск, ул. Бостандыкская, 51.

Editorial office: 150000, Republic of Kazakhstan, North Kazakhstan region, Petropavlovsk, st. Bostandyk, 51

Сайт журнала: www.nii-ntb.com

E-mail: jornal@nii-ntb.com

Телефоны редакции: +7 (7152) 33-44-35, +7 778 569 19 61, +7 707 279 85 75

РЕДАКЦИЯЛЫҚ АЛҚА
РЕДАКЦИОННАЯ КОЛЛЕГИЯ
EDITORIAL BOARD

Редакциялық алқа / Редакционная коллегия / Editorial board

Чекалёва Надежда Викторовна, *педагогика ғылымдарының докторы*
Чекалёва Надежда Викторовна, *доктор педагогических наук*
Chekaleva Nadezhda Viktorovna, *doctor of pedagogical sciences*

Савинкин Виталий Владимирович, *техника ғылымдарының докторы*
Савинкин Виталий Владимирович, *доктор технических наук*
Savinkin Vitaly Vladimirovich, *doctor of technical sciences*

Жәмпейісов Ғазиз Нұрмұратұлы, *философия докторы (PhD)*
Жампеисов Газиз Нурмуратович, *доктор философии (PhD)*
Zhampeisov Gaziz Nurmuratovich, *Ph.D.*

Шапашев Мұрат Асқаруұлы, *философия докторы (PhD)*
Шапашев Мурат Аскарович, *доктор философии (PhD)*
Shapashev Murat Askarovich, *Ph.D.*

Батаева Фроза Асанқызы, *филология ғылымдарының кандидаты*
Батаева Фроза Асановна, *кандидат филологических наук*
Bataeva Froza Asanovna, *candidate of philology*

Горковенко Людмила Александровна, *экономика ғылымдарының кандидаты*
Горковенко Людмила Александровна, *кандидат экономических наук*
Gorkovenko Lyudmila Aleksandrovna, *candidate of economics*

Кусаинова Айсұлу Әмірханқызы, *философия докторы (PhD)*
Кусаинова Айсулу Амирхановна, *доктор философии (PhD)*
Kusainova Aisulu Amirkhanovna, *PhD*

МАЗМҰНЫ / СОДЕРЖАНИЕ / TABLE OF CONTENTS

ИННОВАЦИЯЛЫҚ ПЕДАГОГИКА ЖӘНЕ БІЛІМ БЕРУ ТЕХНОЛОГИЯЛАРЫ
ИННОВАЦИОННАЯ ПЕДАГОГИКА И ОБРАЗОВАТЕЛЬНЫЕ ТЕХНОЛОГИИ
INNOVATIVE PEDAGOGY AND EDUCATIONAL TECHNOLOGIES

ЕСКАРАЕВА Р. Ж., ИБАШОВА А. Б. Развитие критического мышления и познавательной активности учащихся начальной школы с помощью интерактивных инструментов визуализации 7

ИМАНОВ А. К., АТЫГАЕВ Ж. А. Цифровая культура обучающихся в контексте информационной безопасности личности 19

МАКАЖАНОВА Ж. М. Поликультурность студентов в условиях современного образования как основа позитивных межкультурных взаимоотношений 27

ХАЛЬМЕТОВ К. Р., ПАЗЫЛОВА Д. Т., УАЛИХАНОВА Б. С. Особенности критериального оценивания виртуальных лабораторных работ по физике в условиях цифровизации среднего образования 35

ЭКОЛОГИЯ ЖӘНЕ ҚОРШАҒАН ОРТА
ЭКОЛОГИЯ И ОКРУЖАЮЩАЯ СРЕДА
ECOLOGY AND THE ENVIRONMENT

KUSAINOVA A. A., KAIGORODOVA Y. V. Assessment of the impact of changes in Heat and moisture supply regimes on grain productivity in Northern Kazakhstan 52

САРБАСОВА Л. Н., АТЫГАЕВ Ж. Ж. Метод исследования химического состава экстрактов полыни и их биологической активности на основе бумажной хроматографии 68

КЕШЕНДІ ҚАУІПСІЗДІК ЖӘНЕ ТҰРАҚТЫЛЫҚ
КОМПЛЕКСНАЯ БЕЗОПАСНОСТЬ И УСТОЙЧИВОСТЬ
INTEGRATED SAFETY AND SUSTAINABILITY

КОРАБАЕВ Ж. А., ГРОСКОП Р. В. Изделие для запирания ствола гладкоствольного ружья мр-133 и форд – 500 в шаровой опоре амбразуры бронетранспортера бтр-80 и его модификаций 81

РОМАНОВА В. В., САНДАЛА Д. Женщины на войне: подвиги и судьбы 87

UDC: 504.062
IRSTI: -

КУСАИНОВА А.А.[1], KAIGORODOVA Y.V.[2]

[1] *Доктор PhD,кандидат географических наук, Старший преподаватель, Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан, ORCID: https://orcid.org/0000-0002-4524-3765*

[2] *Senior Lecturer. Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan. ORCID: 0000-0009-0007-2862-3911, E-mail: e.kaygorodova@ktu.edu.kz*

ASSESSMENT OF THE IMPACT OF CHANGES IN HEAT AND MOISTURE SUPPLY REGIMES ON GRAIN PRODUCTIVITY IN NORTHERN KAZAKHSTAN

Annotation. The article examines the influence of climatic conditions and their interannual variability on crop yields in Northern Kazakhstan. Based on the analysis of meteorological data collected from 1999 to 2024 in the leading grain-growing regions of Northern Kazakhstan, the impact of changes in heat and moisture supply regimes on crop productivity is assessed using the method of hydrological and climatic calculations. Using regression and variance analysis, it was revealed that it is the temperature during the warm period that has the greatest impact on yield variability. Consideration of the moisture coefficient showed that during periods of low moisture, there is a decrease in yield, and in years of sufficient moisture, an increase in yield, which is confirmed by statistically significant correlation indicators (R = 0.71). The results obtained indicate that humidification explains 51% of yield variations, while the remaining 49% are due to other factors, which indicates the need for further study of the influence of complex climatic processes.

Keywords*:* climatic conditions, air temperature, precipitation, moisture coefficient, grain yield, Northern Kazakhstan

КУСАИНОВА А.А.[1], КАЙГОРОДОВА Е.В.[2]

[1] *Доктор PhD,кандидат географических наук, Старший преподаватель, Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан, ORCID: https://orcid.org/0000-0002-4524-3765*

[2] *аға оқытушы. Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Қарағанды қ, Қазақстан. ORCID: 0000-0009-0007-2862-3911, E-mail: e.kaygorodova@ktu.edu.kz*

СОЛТҮСТІК ҚАЗАҚСТАНДА АСТЫҚ ШЫҒЫМДЫЛЫҒЫНА ЖЫЛУМЕН ЖӘНЕ ЫЛҒАЛДЫЛЫҚПЕН ҚАМТАМАСЫЗ ЕТУ РЕЖИМДЕРІ ӨЗГЕРІСТЕРІНІҢ ӘСЕРІН БАҒАЛАУ

Андатпа. Мақалада климаттық жағдайлардың және олардың жыл аралық өзгергіштігінің Солтүстік Қазақстандағы ауыл шаруашылығы дақылдарының өнімділігіне әсері зерттеледі. 1999 жылдан 2024 жылға дейін Солтүстік Қазақстанның жетекші астық өндіруші өңірлерінде жиналған метеорологиялық деректерді талдау негізінде гидрологиялық - климаттық есептеу әдісін пайдалана отырып, ауыл шаруашылығы дақылдарының өнімділігіне жылу және ылғалмен қамтамасыз ету режимдерінің өзгерістерінің әсері бағаланады. Регрессиялық және дисперсиялық талдаудың көмегімен жылы кезеңдегі температура өнімділіктің өзгергіштігіне үлкен әсер ететіні

анықталды. Ылғалдылық коэффициентін қарастыру ылғалдылықтың аз болуы кезеңдерінде өнімділіктің төмендеуі байқалғанын және жеткілікті ылғалдылық жылдарында оның ұлғаюы анықталғанын көрсетті. Бұл статистикалық маңызды корреляциялық көрсеткіштермен расталады (R = 0,71). Нәтижелер ылғалдандыру өнімділіктің 51% ауытқуын түсіндіретінін көрсетеді, ал қалған 49% басқа факторларға байланысты, бұл кешенді климаттық процестердің әсерін одан әрі зерттеу қажеттілігін көрсетеді.

***Түйінді сөздер**:* климаттық жағдайлар, ауа температурасы, жауын-шашын, ылғалдылық коэффициенті, астық өнімділігі, Солтүстік Қазақстан

КУСАИНОВА А.А.[1], КАЙГОРОДОВА Е.В.[2]

[1] *Доктор PhD,кандидат географических наук, Старший преподаватель, Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан, ORCID: https://orcid.org/0000-0002-4524-3765*

[2] *старший преподаватель. Карагандинский технический университет имени Абылкаса Сагинова, г. Караганда, Казахстан. ORCID: 0000-0009-0007-2862-3911, E-mail: e.kaygorodova@ktu.edu.kz*

ОЦЕНКА ВЛИЯНИЯ ИЗМЕНЕНИЙ РЕЖИМОВ ТЕПЛО- И ВЛАГООБЕСПЕЧЕНИЯ НА УРОЖАЙНОСТЬ ЗЕРНА В СЕВЕРНОМ КАЗАХСТАНЕ

***Аннотация**.* В статье исследуется влияние климатических условий и их межгодовой изменчивости на урожайность сельскохозяйственных культур в Северном Казахстане. На основе анализа метеорологических данных, собранных с 1999 по 2024 год в ведущих зернопроизводящих регионах Северного Казахстана, оценивается влияние изменений режимов тепло- и влагообеспечения на продуктивность сельскохозяйственных культур с использованием метода гидролого-климатических расчетов. С помощью регрессионного и дисперсионного анализа выявлено, что наибольшее влияние на изменчивость урожайности оказывает температура в теплый период. Рассмотрение коэффициента влажности показало, что в периоды низкой влажности наблюдается снижение урожайности, а в годы достаточной влажности обнаружено ее увеличение, что подтверждается статистически значимыми корреляционными показателями (R = 0,71). Полученные результаты указывают на то, что увлажнение объясняет 51% колебаний урожайности, а оставшиеся 49% обусловлены другими факторами, что свидетельствует о необходимости дальнейшего изучения влияния комплексных климатических процессов.

***Ключевые слова**:* климатические условия, температура воздуха, осадки, коэффициент влажности, урожайность зерна, Северный Казахстан

Introduction.

Introduction. In the Republic of Kazakhstan, the agricultural sector is significantly determined by climatic conditions and their interannual variability. Especially important is the study of changes in heat and moisture availability regimes, which have a direct impact on the yield of grain crops, which are the main element of food security in a number of regions, including Northern Kazakhstan [1; 2]. In recent decades, research in the field of agro-climatology has demonstrated that even minor changes in temperature and precipitation conditions can significantly modify biological processes in agricultural crops

[3; 4; 5]. However, despite the accumulated experience, questions remain in terms of a reliable assessment of the contribution of climatic parameters to crop yields, as well as disagreements in assessing the contribution of individual climate factors. Some authors point to the dominant value of temperature during the warm period, while others emphasize the importance of water balance for optimizing crop growth [6; 7].

The purpose of this study is to comprehensively analyze the impact of changes in heat and moisture availability regimes on grain crop yields in Northern Kazakhstan. The importance of the work is determined by the need to create scientifically sound recommendations for adapting the agricultural sector to changing climatic conditions and increasing the sustainability of agricultural production. The main emphasis is placed on comparing the actual data obtained as a result of instrumental measurements with the calculated yield values, which makes it possible to identify key dependencies and assess the share of influence of each climatic factor [8; 9].

Thus, the presented study not only expands the understanding of climate processes affecting agriculture but also contributes to the development of strategies aimed at mitigating the negative effects of climate change on the agricultural sector, which is especially important for regions with high risks of adverse climatic events.

Materials and Methods.

Materials and methods. Methods of hydrological and climatic calculations, methods of statistical analysis: correlation dependence, regression and variance analysis, as well as mapping were used to assess changes in the modes of heat and moisture supply of the territory.

The largest concentration of sown areas of grain crops in Kazakhstan is observed in the North Kazakhstan, Kostanay, Akmola, Pavlodar, and Karaganda regions. According to statistics from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan [10] for 2024, these regions account for 77%, or 17.8 million hectares, of the total amount of cultivated land, which is 23.1 million hectares (Figure 1,2).

Figure 1- The share of the regions of Northern and Central Kazakhstan from the total sown area of the Republic of Kazakhstan, (%)

Figure 2-The sown area of the main crops of the northern regions of Kazakhstan, million hectares

To analyze the impact of climatic fluctuations on grain yields in Northern Kazakhstan, meteorological data from representative weather stations located in grain-growing areas for the period 1999-2024 were used. To determine the degree of correlation, the following parameters were used: measured values of the average monthly air temperature during the warm period (from May to August) as indicators of thermal and energy resources of

the climate, as well as the average monthly precipitation over similar time intervals as an indicator of the humidity of the region [11]. Additionally, the effect of the moisture coefficient on the productivity of grain crops was investigated.

Results.

Results. Northern Kazakhstan, which is located in an arid climate and has the largest area of agricultural crops in the country, demonstrates high productivity of grain crops (Figures 3,4). Limited water resources slow down biological processes and reduce the ability of geosystems to self-repair, which negatively affects the condition of agricultural land. As a result, the natural complexes of the region have a low potential for resistance to external influences.

The region under study is classified as a zone of risky agriculture, characterized by significant interannual variability of water and heat resources. The territory is mainly represented by dry-steppe, steppe, and forest-steppe landscapes, dominated by low-humus chernozems and chestnut soils. The climate of the region is determined by harsh winters, hot, dry summers, and pronounced variability in temperature and precipitation, which is especially noticeable in the spring and summer period, when dry and arid conditions are often observed. The limited moisture resources significantly affect the fertility of the region's soils [12; 13; 14].

Figure 3- Average grain yield (c/ha) for 1999-2024 in Northern Kazakhstan by region

Figure 4- Grain yield (c/ha) on average for 1999-2024
in Northern Kazakhstan

In 2011, when there was enough moisture, grain yields reached 20.4 c/ha in the North Kazakhstan region and 18.4 c/ha in the Kostanay region. During dry periods, there was a decrease in the yield of cultivated grain, which was especially evident in 2010 in the Akmola region (5.2 c/ha), as well as in 2008 and 2012 in the Pavlodar region, where this indicator was 3.7 c/ha and 3.8 c/ha, respectively (Figure 5).

Figure 5-Fluctuations in the yield of grain crops (c/ha) in years with sufficient moisture and dry years in 1999-2024

Based on a database containing information on grain yields and meteorological characteristics for Northern Kazakhstan, regression models were developed demonstrating the influence of key factors—air temperature and total precipitation during the warm period (May–August) (Table 1). The obtained regression equations can be used to estimate yields in a retrospective analysis in the absence of actual data.

Table 1-Regression statistical analysis used to quantify crop yields Y (c/ha), taking into account the influence of meteorological factors

Weather station	R	R2	The normalized R-square	The standard error	The regression equation
Ruzaevka (North Kazakhstan region)	0,51	0,26	0,17	2,52	Y =30,52-1,08Twp1+0,01Xwp2
Kostanay (Kostanay region)	0,66	0,43	0,37	2,24	Y =45,58-1,82Twp-0,005Xwp
Yesil (Akmola region)	0,80	0,64	0,60	1,50	Y =27,11-1,09Twp+0,02Xwp
Irtyshsk (Pavlodar region)	0,71	0,51	0,46	2,08	Y =33,94-1,60Twp+0,02Xwp
Karaganda (Karaganda region)	0,36	0,13	0,06	2,23	Y =18,62-0,62Twp+0,008 Xwp

Remarks: [1]Twp - is the average monthly temperature of the warm period (V–VIII months).

[2] Xwp - is the total amount of precipitation of the warm period (V−VIII months).

An analysis of the cumulative impact of meteorological factors on yields showed that the degree of their influence, expressed by the multiple correlation coefficient (R), is maximum in the Akmola region (using the example of Yesil, R=0.80) and in the Pavlodar region (using the example of Irtyshsk, R=0.71). In the regions of Kostanay, North Kazakhstan, and Karaganda, lower coefficient values are observed (Kostanay, R=0.66; Ruzaevka, R=0.51; Karaganda, R=0.36). The revealed dependencies make it possible to explain from 13% to 64% of the yield variance depending on the impact of the considered climatic indicators.

Given that the most pronounced relationship between meteorological factors and crop yields was established at the Yesil weather station in the Akmola region, the data from this point is used to assess the quality of the model. The value of the coefficient of determination (R^2 = 0.64) indicates that the model explains approximately 64% of the variation in the dependent variable, which is air temperature and the total amount of precipitation during the warm period. The high coefficient of multiple correlation (R=0.80) confirms a significant relationship between yield and the parameters included in the

model: air temperature and the amount of precipitation during the warm period.

The statistical significance of the regression equation was estimated based on the calculation of the Fisher F-test (Table 2), the value of which was 15.7. At the same time, the tabular value of the F-criterion for a confidence probability of 0.95 and degrees of freedom $v_1 = k - 1 = 1$ and $v_2 = n - k - 1 = 18$ is 4.41. Since the calculated value significantly exceeds the tabular value (15.7 > 4.41), the regression equation is recognized as statistically significant, which confirms the reliability of the estimate obtained [15].

Table 2-Regression statistics values

Analysis of variance				
	df - number of degrees of freedom	SS - sum of squares	MS - the average value	F- the Fisher criterion
Regression	2	71.070	35.535	15.716
Remains	18	40.699	2.261	
Total	20	111.769		
	Coefficients	The standard error	t- statistics	P- value
Y-intersection	27.11	7.68	3.53	0.002
Variable X 1	-1.09	0.39	-2.82	0.011
Variable X 2	0.02	0.01	3.01	0.007

The calculation of the average approximation error makes it possible to estimate the accuracy of the regression model (Table 3). Given that the standard value of the average approximation error does not exceed 8-10%, the achieved accuracy of the regression model at the level of 9% indicates its high reliability.

Table 3-Results of checking the significance of the regression equation based on the average approximation error

Years	Actual yield, (y)	Estimated yield, y(x)	The discrepancy,y-y(x)	(y-y(x))/y*100

1999	13.3	11.9	1.4	10.5
2000	7.9	10.9	-3	-38.6
2001	11.2	11.4	-0.2	-1.6
2002	9.1	11.02	-1.9	-21.1
2003	9.1	11.4	-2.3	-25
2004	7.1	7.8	-0.7	-9.2
2005	8.5	10	-1.5	-17.9
2006	9.6	10.2	-0.6	-5.8
2007	11.6	10.5	1.1	9.5
2008	7.5	7.9	-0.5	-6
2009	11.2	10	1.2	10.4
2010	5.2	6.5	-1.3	-25.1
2011	15.6	14.4	1.2	7.7
2012	7	6.8	0.2	3.4
2013	10.4	10.7	-0.3	-3.2
2014	11	8.9	2.1	19.2
2015	10.8	9.4	1.4	13
2016	11.6	12	-0.4	-3.8
2017	11.2	9.1	2.1	18.3
2018	11.7	11.3	0.4	3.1
2019	9.5	10.3	-0.8	-8.4
2020	11.6	9.0	2.6	22.4

2021	8.7	6.2	2.5	28.7
2022	11.6	8.6	3	25.9
2023	6.9	8.4	-1.5	-21.7
2024	13.1	11.4	1.7	13
A=1/n*∑ ((y-y(x))/y)*100% =9%				

The statistical significance of the regression coefficients was estimated using the Student's t-statistics. The initial hypothesis H_0 assumed that the coefficients of the model do not differ significantly from zero ($a = b_i = 0$). The obtained t-statistic values were $ta = 3.5$, $tb_1 = -2.8$, and $tb_2 = 3.01$, while the critical value of the t-criterion at a significance level of 5% and 18 degrees of freedom (n – k) is 2.1. Since the absolute values of the calculated indicators exceed the critical value (|3.5| > 2.1; |-2.8| > 2.1; |.01| > 2.1), the hypothesis H_0 is rejected, which indicates the statistical significance of the regression coefficients.

In climate change studies, many experts analyze the annual surface air temperature and, less often, seasonal temperature indicators (for example, winter and summer values), which is especially important in factor analysis of yields. The use of regression analysis and variance analysis for Northern Kazakhstan revealed that the greatest contribution to the yield variance is made by the average air temperature during the warm period. In this regard, the calculated yield values were compared with the data on the average temperature of the warm period, determined by the results of actual instrumental measurements at the Yesil weather station (Figure 6).

Figure 6-Comparison of grain yields in Akmola region with the average temperature of the growing season (May-August) for 1969-2024

The analysis of the data presented in Figure 6 and in the regression equations (Table 2) indicates a pronounced inverse relationship between yield and temperature conditions of the warm period, which is confirmed by the correlation coefficient R = -0.85. In particular, years with low yields are characterized by high temperatures during the warm period, accompanied by arid conditions, while years with higher yields are marked by lower temperatures, providing an optimal ratio of heat and moisture. This result is expected for the steppe regions of Northern Kazakhstan and is additionally confirmed by the analysis shown in Table 4, where there is a coincidence of periods of low yields with the highest temperature indicators of the warm period.

Table 4- Years with minimum yield and highest average temperature of warm period in Akmola region

Years	Y, c/ha	Twp,°C
1984	8.3	19.0
1987	7.8	19.0
1989	8.3	19.4
1991	8.1	19.5
1998	4.9	21.2
2004	7.1	19.6
2008	7.5	19.7
2010	5.2	20.1
2012	6.7	20.4
2021	6.2	20.3

Figure 7 shows the relationship between yield and average temperature of the warm period, characterized by the correlation coefficient R equal to 0.85. Analysis of the graph demonstrates that an increase in average temperature is associated with a decrease in yield, while lower temperature regimes contribute to an increase in yield.

In addition to heat and energy resources, the level of crop yield is also affected by the degree of moisture in the territory [16; 17].

Figure 7- Yield dependence on average air temperature warm period

Wetness of the territory is determined by the water cycle between the earth's surface and the atmosphere due to continuous heat and moisture exchange between the active layer of soil and the surface layer of air. According to V.S. Mezentsev's method of hydrological-climatic calculations, in case of inequality of atmospheric moisture content to the optimal value obtained by means of the water equivalent of heat and energy resources of evaporation, their difference expresses the value of moisture deficits (or excesses) [18].

To determine the water equivalent of heat energy resources (Z_m), we used the formulas (1-4) proposed by I.V. Karnatsevich [19], according to which evapotranspiration is calculated as a function of the sum of average monthly positive air temperatures:

$$Z_m = TZ/L \quad (1)$$

$$TZ = 17.6 \sum t + 400 \quad (2)$$

where: TZ—heat and energy resources of total evaporation in MJ/(m² year);

L - 2.512 MJ/(m²×mm) - specific heat of vaporization;

∑t—the sum of positive average monthly temperatures of the growing season.

The wetting deficit indicator (ΔKX) is calculated as the difference between precipitation (KX) and the water equivalent of heat and energy resources (Z_m).

$$\Delta KX = KX/Z_m \quad (3)$$

The structure of relations between heat and moisture resources determines the level of wetting (natural or anthropogenic); therefore, the indicator of territory wetting for any intra-annual interval of an average year is the ratio:

$$\beta_{kx} = KX/Z_m \quad (4)$$

The boundary of the optimal ratio of heat and moisture is spatially expressed by the isoline of the unit value of the wetting coefficient, zero deficit of wetting, and soil moisture (in fractions of the smallest moisture capacity) equal to one. This boundary is the upper limit of optimal moistening for most agricultural crops [18,20].

In the framework of the study, the impact of moisture supply on the productivity of grain crops is determined through the analysis of the moisture coefficient. According to the studies of Professor V.S. Mezentsev [21], the relationship between thermal and moisture resources is determined by the level of natural and anthropogenic moistening, which determines the use of the ratio given in formula (4) as an indicator of moistening for any intra-annual period.

In this paper, the influence of natural heat and moisture availability parameters, namely moisture coefficient (βkx) and moisture deficit (ΔKX), on yield by applying multivariate correlation and regression analysis is investigated (Table 6).

The multiple correlation coefficient (R = 0.77) indicates a significant relationship between yield and the two factors selected in the model, i.e., moisture coefficient and growing season moisture deficit. The statistical significance of the regression model was evaluated using Fisher's F-criterion, where the calculated F value was 12.8. At the same time, the critical value of F at the confidence level of 0.95, with degrees of freedom $v_1 = k - 1 = 1$ and $v_2 = n - k - 1 = 18$, is 4.41. The excess of the calculated value over the critical value (12.8 > 4.41) allows the regression equation to be considered statistically significant and reliable. In addition, at a 5% significance level, the observed values of Student's t-statistics for the model parameters were higher than the corresponding critical values, which confirms the significance of the regression coefficients.

Using regression models describing the relationship between grain crop yields in Akmola oblast and parameters of natural heat and moisture availability, predicted yield

values were obtained (Table 6). The value of the correlation coefficient (R = 0.71) between the predicted and observed yields for the period 1999-2024 indicates high reliability of the model.

Table 6- Comparison of actual and calculated yields in the Akmola region

Years	Actual yield, Y (y), (c/ha)	Estimated yield, y(x), (c/ha)	Divergence, y-y(x), (c/ha)
1999	13.3	11.8	1.5
2000	7.9	11.1	-3.2
2001	11.2	11.4	-0.2
2002	9.1	11.2	-2.1
2003	9.1	11.5	-2.4
2004	7.1	8.2	-1.1
2005	8.5	10.3	-1.8
2006	9.6	10.4	-0.8
2007	11.6	10.7	0.9
2008	7.5	8.4	-0.9
2009	11.2	10.3	0.9
2010	5.2	7	-1.8
2011	15.6	13.9	1.7
2012	7	7.3	-0.3
2013	10.4	10.9	-0.5
2014	11	9.2	1.8
2015	10.8	9.7	1.1
2016	11.6	12	-0.4

2017	11.2	9.5	1.7
2018	11.7	11.4	0.3
2019	9.5	10.5	-1
2020	11.6	9.3	2.3
2021	8.7	6.8	1.9
2022	11.6	9	2.6
2023	6.9	8.9	-2
2024	13.1	11.4	1.7
Correlation coefficient R=0.71			

The analysis of Figure 8 shows that in periods with a low coefficient of moisture content of the territory, in the warm period, the yield tends to decrease, while in years with sufficient moisture content, high yields are observed.

Figure 8-Synchrony of grain crop yields in the Akmola region with the moisture coefficient for the growing season (May-August), calculated by the method of V.S. Mezentsev for 1999-2024.

Discussion.

At the same time, there are certain discrepancies in establishing the relationship between these indicators, which may be due to errors in the data of the observation series and insufficient volume of meteorological data. In the aggregate, the correlation coefficient was R = 0.71, and the coefficient of determination was- 0.51, indicating a statistically significant relationship: moisture explains 51% of the variability of yields in the area of the weather station Yesil, while the remaining 49% are due to the influence of other factors.

Conclusion.

Conclusions and suggestion. The main determinants of crop productivity are the amount of precipitation and air temperature during the warm period, which for grain crops covers May-August. Aridity, as a rule, manifests itself in this time interval with a deficit of precipitation and increased temperatures, and the level of crop productivity can serve as an indicator of the climatic aridity of the territory.

In the steppe zone of Northern Kazakhstan, for the formation of optimal conditions of heat and moisture availability and increasing the productivity of agricultural production, it

is necessary to increase soil moisture. For this purpose, irrigation systems and other agrotechnical reclamation measures are used, aimed at changing the soil structure and improving its physical properties in order to artificially increase the level of moisture.

СПИСОК ЛИТЕРАТУРЫ:

1. Kalugin A. Hydrological and meteorological variability in the Volga River Basin under global warming by 1.5 and 2 degrees // Climate.2022. Vol.10(7), P.107.
2. Khoroshev A. V., Tkach K. A., & Murtazina D. U. Influence of landscape conditions on grain crop yield in the steppe zone of Northern Kazakhstan // Vestnik Moskovskogo Universiteta.2018. Seriya 5, Geografiya, (3). P. 1.
3. Chekalin, S. G. Agroclimatic assessment of the onset of spring in enhancing spring wheat productivity // Izvestiya OGAU. 2010. Vol. 28-1. P.1.
4. Daramola F., Osemwegie O., Ighodaro I., Kioko, J. & Lewu, F. Impacts of climate change on soil microbial interactions: Echoes of the new normal // AGRIVITA Journal of Agricultural Science.2024. Vol.46(1), P.183–195.
5. Strashnaya A. I., Birman B. A., & Bereza O. V. Features of the 2012 drought in the Urals and Western Siberia and its impact on the yield of spring grain crops // Hydrometeorological Research and Forecasting. 2018. Vol. 2 (368). P. 154–169.
6. Chub O. V., Strashnaya A. I. On the possibility of using a new agrometeorological moisture coefficient for monitoring atmospheric-soil droughts // Proceedings of the Hydrometeorological Research Centre of the Russian Federation. 2012. Vol. 347.P. 190–206.
7. Schmidt N., Zinkernagel J. Crop coefficients and irrigation demand in response to climate-change-induced alterations in phenology and growing season of vegetable crops // Climate. 2024. Vol. 12(10), P.161
8. Kusainova A. A., Mezentseva O. V., & Tusupbekov Z. A. Influence of precipitation variability and temperature conditions on the yield of grain crops in Northern Kazakhstan // In IOP Conference Series: Earth and Environmental Science. 2020. Vol.548(4). P. 042026.
9. Niels T., Kumar A. Water consumption of industrial hemp (Cannabis sativa L.) from a site in Northern Kazakhstan // Central Asian Journal of Water Research. 2022. Vol. 8(2). P.19–30.
10. Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. (n.d.). Official statistics portal.
11. Daramola F., Osemwegie O., Ighodaro I., Kioko J., & Lewu F. Impacts of climate change on soil microbial interactions: Echoes of the new normal // AGRIVITA Journal of Agricultural Science. 2024. Vol.46(1), 183–195.

12. Baisholanov S., Akshalov K., Mukanov Ye., Zhumabek B., & Karakulov E. Agro-climatic zoning of the territory of Northern Kazakhstan for zoning of agricultural crops under conditions of climate change // Climate.2025. Vol.13(1), P. 3.
13. Belonenko G. V., Rotanova I. N., Tsimbaley Y. M. et al. Cartographic analysis of the spatiotemporal distribution of moisture flux elements in the Ob Basin // Mir Nauki, Kultury, Obrazovaniya. 2010. Vol.1(20). P. 95–99.
14. Kusainova A., Mezentseva O., & Tusupbekov Zh. Trends of long-term fluctuations of atmospheric humidification of the growing season in the steppe zone of Northern Kazakhstan// In Proceedings of the III International Conference on Actual Problems of the Energy Complex: Mining, Production, Transmission, Processing and Environmental Protection (ICAPE 2024).2024. Vol. 498. P. 3009.
15. Kopysov S. G., Eliseev A. O. Assessing hydrological and climate conditional productivity of ecosystems in the southeast of Western Siberia // Contemporary Problems of Ecology.2024. Vol. 17. P. 337–344.
16. Mezentseva O. V., Karnatsevich I. V., & Berezin, L. V. Investigation of the spatiotemporal dynamics of the characteristics of natural thermal–moisture provisioning in Western Siberia and issues of sustainable agricultural development // Vestnik Tomskogo Gosudarstvennogo Universiteta.2010.Vol. 331. P. 210–212.
17. Kazhydromet. (n.d.). Kazakhstan Hydrometeorological Service.
18. Mezentseva O. V., Bikbulatova G. G. Use of meteorological characteristics for determining the thermal and water resources of the lands of the Omsk Region // Vestnik Omskogo Gosudarstvennogo Agrarnogo Universiteta.2016. Vol. 2(22). P. 109–114.
19. Karnatsevich I. V., Bikbulatova G. G., & Ryapolov K. V. Prospects of the genetic method for calculating elementary runoff based on daily intervals // Omsky Nauchny Vestnik, 2011. Vol.1(104). P.224–231.
20. Shayakhmetova A., Bakirov A., Savenkova I., Nasiyev B., Akhmetov M., Useinov A., Temirbulatova A., Zhanatalapov N., Bekkaliyev A., Mukanova F., & Auzhanova M. Optimization of productivity of fodder crops with green conveyor system in the context of climate instability in the North Kazakhstan region // Sustainability. 2024.Vol.16(20). P. 9024.
21. Karnatsevich, I. V. Mass calculations of daily evaporation sums from catchment surfaces based on meteorological station observations // Omsky Nauchny Vestnik, 2013. Vol.1(118). P. 241–246.

REFERENCES:

1. Kalugin A. Hydrological and meteorological variability in the Volga River Basin under global warming by 1.5 and 2 degrees // Climate.2022. Vol.10(7), P.107.

2. Khoroshev A. V., Tkach K. A., & Murtazina D. U. Influence of landscape conditions on grain crop yield in the steppe zone of Northern Kazakhstan // Vestnik Moskovskogo Universiteta.2018. Seriya 5, Geografiya, (3). P. 1.
3. Chekalin, S. G. Agroclimatic assessment of the onset of spring in enhancing spring wheat productivity // Izvestiya OGAU. 2010. Vol. 28-1. P.1.
4. Daramola F., Osemwegie O., Ighodaro I., Kioko, J. & Lewu, F. Impacts of climate change on soil microbial interactions: Echoes of the new normal // AGRIVITA Journal of Agricultural Science.2024. Vol.46(1), P.183–195.
5. Strashnaya A. I., Birman B. A., & Bereza O. V. Features of the 2012 drought in the Urals and Western Siberia and its impact on the yield of spring grain crops // Hydrometeorological Research and Forecasting. 2018. Vol. 2 (368). P. 154–169.
6. Chub O. V., Strashnaya A. I. On the possibility of using a new agrometeorological moisture coefficient for monitoring atmospheric-soil droughts // Proceedings of the Hydrometeorological Research Centre of the Russian Federation. 2012. Vol. 347.P. 190–206.
7. Schmidt N., Zinkernagel J. Crop coefficients and irrigation demand in response to climate-change-induced alterations in phenology and growing season of vegetable crops // Climate. 2024. Vol. 12(10), P.161
8. Kusainova A. A., Mezentseva O. V., & Tusupbekov Z. A. Influence of precipitation variability and temperature conditions on the yield of grain crops in Northern Kazakhstan // In IOP Conference Series: Earth and Environmental Science. 2020. Vol.548(4). P. 042026.
9. Niels T., Kumar A. Water consumption of industrial hemp (Cannabis sativa L.) from a site in Northern Kazakhstan // Central Asian Journal of Water Research. 2022. Vol. 8(2). P.19–30.
10. Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. (n.d.). Official statistics portal.
11. Daramola F., Osemwegie O., Ighodaro I., Kioko J., & Lewu F. Impacts of climate change on soil microbial interactions: Echoes of the new normal // AGRIVITA Journal of Agricultural Science. 2024. Vol.46(1), 183–195.
12. Baisholanov S., Akshalov K., Mukanov Ye., Zhumabek B., & Karakulov E. Agro-climatic zoning of the territory of Northern Kazakhstan for zoning of agricultural crops under conditions of climate change // Climate.2025. Vol.13(1), P. 3.
13. Belonenko G. V., Rotanova I. N., Tsimbaley Y. M. et al. Cartographic analysis of the spatiotemporal distribution of moisture flux elements in the Ob Basin // Mir Nauki, Kultury, Obrazovaniya. 2010. Vol.1(20). P. 95–99.

14. Kusainova A., Mezentseva O., & Tusupbekov Zh. Trends of long-term fluctuations of atmospheric humidification of the growing season in the steppe zone of Northern Kazakhstan// In Proceedings of the III International Conference on Actual Problems of the Energy Complex: Mining, Production, Transmission, Processing and Environmental Protection (ICAPE 2024).2024. Vol. 498. P. 3009.
15. Kopysov S. G., Eliseev A. O. Assessing hydrological and climate conditional productivity of ecosystems in the southeast of Western Siberia // Contemporary Problems of Ecology.2024. Vol. 17. P. 337–344.
16. Mezentseva O. V., Karnatsevich I. V., & Berezin, L. V. Investigation of the spatiotemporal dynamics of the characteristics of natural thermal–moisture provisioning in Western Siberia and issues of sustainable agricultural development // Vestnik Tomskogo Gosudarstvennogo Universiteta.2010.Vol. 331. P. 210–212.
17. Kazhydromet. (n.d.). Kazakhstan Hydrometeorological Service.
18. Mezentseva O. V., Bikbulatova G. G. Use of meteorological characteristics for determining the thermal and water resources of the lands of the Omsk Region // Vestnik Omskogo Gosudarstvennogo Agrarnogo Universiteta.2016. Vol. 2(22). P. 109–114.
19. Karnatsevich I. V., Bikbulatova G. G., & Ryapolov K. V. Prospects of the genetic method for calculating elementary runoff based on daily intervals // Omsky Nauchny Vestnik, 2011. Vol.1(104). P.224–231.
20. Shayakhmetova A., Bakirov A., Savenkova I., Nasiyev B., Akhmetov M., Useinov A., Temirbulatova A., Zhanatalapov N., Bekkaliyev A., Mukanova F., & Auzhanova M. Optimization of productivity of fodder crops with green conveyor system in the context of climate instability in the North Kazakhstan region // Sustainability. 2024.Vol.16(20). P. 9024.
21. Karnatsevich, I. V. Mass calculations of daily evaporation sums from catchment surfaces based on meteorological station observations // Omsky Nauchny Vestnik, 2013. Vol.1(118). P. 241–246.