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AGRO-CLIMATIC ZONING OF ALMATY REGION USING GIS TECHNOLOGIES

Abstract. Climate change and climatic factors over the past few decades on a regional and global scale, in particular in the south-east of Kazakhstan, affect the restructuring of the agro-industrial complex. Agro-climatic zoning is one of the fundamental actions in determining the quantitative and qualitative characteristics of agro-climatic resources, as well as important factors in agriculture, thereby updating the reliability and accessibility of climatic indicators.

This study is devoted to the definition of agro-climatic zones on the territory of the Almaty region using GIS technologies. The purpose of the scientific work is to study favorable agro-climatic indicators for the growth and development of agricultural crops. To achieve this goal, the tasks of a comprehensive and geospatial study of agro-climatic components were performed, including the calculation of the sums of active temperatures and precipitation, the Selyaninov hydrothermal coefficient and the coefficient of humidification of the growing season, and their relationship is also assumed when constructing an agro-climatic model.

As a result of the study, 5 agro-climatic zones were identified with interpretation and information on the sum of active temperatures and precipitation, hydrothermal coefficient and humidification coefficient in tabular form. Aggregates of data indicate the main characteristics of agro-climatic resources and the potential of growing certain types of crops with rational use of water resources relevant for irrigation crops.

This study is carried out under the project “BR10764908 - To develop a system of agriculture for the cultivation of agricultural crops (cereals, leguminous oilseeds and industrial crops) using elements of cultivation technology, differentiated nutrition” in Kazakh Research Institute of Agriculture and Plant Growing for further introduction in manufacture.

Key words: GIS technologies, agricultural lands, remote sensing, open climate data, climate change, agro-climatic zoning.

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ГАЖ-ТЕХНОЛОГИЯЛАРЫ НЕГІЗІНДЕ АЛМАТЫ ОБЛЫСЫН АГРОКЛИМАТТЫҚ АУДАНДАСТЫРУ

Аннотация. Климат және климаттық факторлардың өзгеруі соңғы бірнеше онжылдықта өңірлік және жаһандық масштабта, соның ішінде Қазақстанның оңтүстік-шығысындағы агроөнеркәсіптік кешеннің құрылымына біраз өзгеріс енгізді. Агроклиматтық аудандастыру ресурстардың сандық және сапалық сипаттамаларын анықтауда климаттық көрсеткіштердің сенімділігі мен қол жетімділігін өзектендіріп, ауыл шаруашылығын жүргізудегі маңызды факторлардың бірі екендігін айқындады.

Бұл зерттеу ГАЖ-технологияларды қолдана отырып, Алматы облысының аумағындағы агроклиматтық аудандарды анықтауға бағытталған. Ғылыми жұмыстың мақсаты – дақылдардың өсуі мен дамуы үшін қолайлы агроклиматтық көрсеткіштерін зерттеу. Мақсатқа жету үшін агроклиматтық компоненттерді кешенді және геокеңістіктік зерттеу міндеттері орындалды, соның ішінде белсенді температура мен жауын-шашынның, Селяниновтың гидротермиялық коэфициенті мен вегетациялық кезеңнің ылғалдану коэфицентінің қосындысын есептеу жүзеге асты. Тиісті көрсеткіштерді анықтау нәтижесінде ашық қолжетімділікті климаттық деректер пайдаланылды. CSV форматында алынған мәліметтер ГАЖ ортасына одан әрі интеграциялау үшін shapefile-ге түрлендірілді. Растрлық форматтағы климаттық көрсеткіштер алдыңғы ковариациялармен анықталған Гаусс процесі арқылы модельденетін интерполяция - кригинг (criging) әдісін қолдана отырып, нүктелік объектілерді кеңістіктік өзгерту арқылы құрастырылды.

Зерттеу нәтижесінде белсенді ауа температурасы мен жауын-шашынның қосындысы, гидротермиялық коэффициент және ылғалдану коэффициенті негізінде 5 агроклиматтық ауданның шекарасы анықталды. Деректер жиынтығы агроклиматтық ресурстар және ауыл шаруашылығы дақылдарының жекелеген түрлерін өсіру әлеуетін су ресурстарын ұтымды пайдалану негізінде жүзеге асыру бағытында анықталады.

Ғылыми зерттеу жұмысы Қазақ егіншілік және өсімдік шаруашылығы ғылыми-зерттеу институтында «BR10764908 - Ауыл шаруашылығы дақылдарын (дәнді дәнді-бұршақты майлы және техникалық дақылдарды) өңдеу технологиясы элементтерін қолдана отырып, егіншілік жүйесін әзірлеу» жобасы бойынша, болашақта өндіріске енгізу мақсатында жүргізілуде.

Түйін сөздер. ГАЖ-технологиялары, ауылшаруашылық алқаптары, Жерді қашықтықтан зондтау, ашық климаттық деректер, клииматтың өзгеруі, агроклиматтық аудандастыру.

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АГРОКЛИМАТИЧЕСКОЕ РАЙОНИРОВАНИЕ АЛМАТИНСКОЙ ОБЛАСТИ С ПРИМЕНЕНИЕМ ГИС-ТЕХНОЛОГИЙ

Аннотация. Изменение климата и климатических факторов за последние несколько десятилетий в региональном и глобальном масштабе, в частности юго-востока Казахстана, воздействуют на перестроение агропромышленного комплекса. Агроклиматическое районирование является одним из основопологающих действий при определении количественных и качественных характеристик агроклиматических ресурсов, а также немаловажным фактором при ведении сельского хозяйства, тем самым актуализируя достоверность и легкодоступность климатических показателей.

Данное исследование посвящено определению агроклиматических районов на территории Алматинской области с применением ГИС-технологий. Целью научной работы является исследование благоприятных агроклиматических показателей для роста и развития сельскохозяйственных культур. Для достижения цели выполнены задачи комплексного и геопространственного изучения агроклиматических компонентов, в том числе вычисление сумм активных температур и осадков, гидротермического коэфициента Селянинова и коэфициента увлажнения периода вегетации, а также предполагается их взаимосвязь при построении агроклиматической модели.

В результате исследования определены 5 агроклиматических зон с интерпретацией и информацией о сумме активных температур и осадков, гидротермическом коэфициенте и коэфициенте увлажнения в табличной форме. Совокупность данных указывает на главные характеристики агроклиматических ресурсов и потенциале выращивания отдельных видов сельскохозяйственных культур с рациональным использованием водных ресурсов, актуальных для оросительных сельскохозяйственных культур.

Данное исследование проводится по проекту «BR10764908-Разработать систему земледелия возделывания сельскохозяйственных культур (зерновых, зернобобовых, масличных и технических культур) с применением элементов технологии возделывания, дифференцированного питания» в Казахском НИИ земледелия и растениеводства для дальнейшего внедрения в производство.

Ключевые слова: ГИС-технологии, сельскохозяйственные угодья, дистанционное зондирование Земли, открытые климатические данные, изменение климата, агроклиматическое районирование.

Introduction. Climate change over the past decade on a global and regional scale has an impact on agricultural productivity, which is one of the fundamental factors of the economic well-being of each country. The increase in the number of industrial enterprises over the past 50 years has been the main factor in the excess concentration of CO_2 in the atmosphere, thereby causing global warming. Climatic indicators, such as air temperature, precipitation, evaporation rate, etc. and their trends of change over time change the usual ways of cultivating crops. Global warming affects the water consumption of irrigated lands, increasing the total evaporation. This statement implies a study of the relationship between irrigation methods for each crop and changes in climatic indicators.

The main task of the agro-climatic classification is to identify zones that differ from each other in terms of agro-climatic indicators and conditions of agricultural production, to establish their geographical boundaries and to draw up a map of agro-climatic zoning (Balgabekov, 1999).

Many scientists, when allocating agro-climatic zones, take into account the peculiarities of the development of a certain type of agricultural crop with certain metereological indicators. Taking into account the climate and weather as environmental conditions, it is necessary to evaluate the combination of agro-climatic conditions with the growth, development and formation of crop yields, based on taking into account the needs of culture to environmental factors (Bajsholanov et all, 2017a).

Araya et al (2010) investigated the agro-climatic resources of the Giba watershed in northern Ethiopia, including climatic suitability for growing teff (Eragrostis tef) and barley (Hordeum vulgare). The authors determined the beginning and duration of the growing season, evaluated the traditional method of climate classification, and also compiled complex agro-climatic zones of the studied region (Araya et all, 2010).

Nabati (2020) and others researched the relationship and complex of climatic factors, topography parameters, soil and land use in chickpea cultivation using GIS technologies. The corresponding maps of the territory were also developed. The authors proved that agro-climatic zoning and agro-land zoning play an essential role in determining the optimal areas for growing chickpeas in rain-fed and irrigated conditions (Nabati et all, 2020).

The work of Tanasijevic and others (2014) focuses on the impact of climate change on olive cultivation in the Mediterranean region, taking into account possible changes in acreage, phenological dates, crop evapotranspiration and irrigation requirements using agro-climatic zoning (Tanasijevic et all, 2014).

Zhou (2009) and other scientists conducted a spatial analysis to create maps of the climatic zoning of the irrigation zone of East Murambidji, Australia. 4 climatic indicators were selected - the average annual precipitation, the average annual evaporation value, the average annual degree of growth per day and the average daily temperature. These indicators were used to differentiate the studied region into climatic zones and subzones based on long-term metereological studies (Zhou et all, 2009).

In this study, methods are being determined and maps of agro-climatic components are being developed for the territory of the Almaty region using GIS technologies. The determination of the corresponding agro-climatic indicators was accompanied by the methods of calculating the sum of active temperatures and precipitation, the coefficient of humidification (K) and the HTC according to Selyaninov.The purpose of the scientific work is to create a geoinformation model based on open climate databases, which are available information for the analysis of agro-climatic indicators and their relationship.

Materials and methods. Almaty region is located in the south-east of the Republic of Kazakhstan, between 42^0 20' and 47^0 12' north latitude, 73^0 47' and 82^0 34' east longitude. The area of Almaty region is 223,911 km^2. It is divided into 17 districts and 3 cities of regional significance on an administrative-territorial basis.

The climate of Almaty region is mainly continental. Winter is moderately cool. The average January temperature in the northern lowland part is 10-16^0C, in the southern -4-9^0C. Summers are hot and dry. The average temperature in July is +25^0C in the north and +27^0C in the south. The average annual precipitation in the lowland regions is 110-250 mm. The climatic conditions of the foothills are mild. The average temperature in January is 5-9^0C, there are often thaws. The average temperature in July in the foothills is +21+23^0C, in the mountain valleys +19+22^0C. Precipitation in the foothills is 400-600 mm, in mountain valleys 700-1000 mm. Precipitation falls mainly in the spring and early summer on the territory of the region. On the plains and foothills of the Northern region, the average thickness of the snow cover is 10-30 cm, on the mountain slopes-40-100 cm. There is a breeze on the shores of Balkhash and Alakol (Almaty region, 2022).

Indicators of agro-climatic zoning. Agro-climatic indicators are quantitative expressions of the relationship between the development, growth, condition and productivity of agricultural production facilities with climate factors. When studying the agro-climatic resources of territories, agro-climatic indicators obtained by averaging data in a multi-year section of the growing season are used.

This study uses such agro-climatic indicators as the sum of active temperatures (air temperature above +10^0C) and precipitation, indicators of aridity and moisture availability, as well as modes of humidification of the air and the temperature of the earth's surface for the growing season (Mishchenko, 2009).

Duration of the growing season. The duration of the growing season is defined as the period during the year when average temperatures exceed or equal +10°C (Tmean >=10°C), and precipitation plus moisture stored in the soil exceeds half of the potential evaporation (P>0.5PET). The normal growing season is defined as the period when precipitation exceeds the norm (i.e. the wet period). This period fully satisfies the needs of agricultural crops in evaporation and makes up for the lack of moisture in the soil profile. The intermediate growing season is defined as the period during which precipitation usually does not exceed the potential evaporation. The absence of a growing season occurs when the temperature does not promote crop growth or P does not exceed PET (Sauvage et all, 2022; FAO, 2014; Length of growing period, 2022).

The sum of active temperatures and precipitation during the growing season. The sum of active temperatures is an indicator characterizing the amount of heat exceeding the biological minimum temperature set for a certain period of plant development. This indicator is used to determine the heat needs of most plants, as well as to assess the thermal resources of the territory. It is defined as the sum of the average daily air temperatures for the period of time during which the vehicle was above +10^{0}C. In many studies, the air temperature above +10^{0}C is mentioned as a stable indicator of the growth and development of many crops. The total amount of precipitation is determined by summing up the daily precipitation indicators for the growing season.

Aridity and moisture availability of the growing season. Moisture availability is the ratio of the stock of productive moisture available in the soil to its stock at the lowest moisture capacity. Moisture availability in this study was determined using the moisture coefficient. The moisture coefficient (K) is calculated by the ratio of the average amount of precipitation to the amount of evaporation during the growing season:

$$K = R/E \qquad (1)$$

where, R is the average amount of precipitation during the growing season, E is the amount of evaporation.

The assessment of moisture availability according to the coefficient of humidification (CU) is carried out according to the following gradation:less than 0.2 – dry; 0.2 – 0.3-moisture deficiency; 0.3-0.5 – moderate moisture deficiency; 0.5-0.7 – insufficient moisture supply; 0.7-1.0 – sufficient, but unstable moisture supply.

Climatic aridity is calculated with the Hydrothermal coefficient of humidification (HTC) of Selyaninov:

$$\mathrm{HTC} = \Sigma \mathrm{R} \cdot 10 / \Sigma \mathrm{T_c} \qquad (2)$$

where, ΣR is the total amount of precipitation during the growing season, ΣT_C is the sum of active air temperatures for the same period.

The HTC assessment is conducted on a scale of: less than 0.3 - very dry; 0.3-0.5 - dry; 0.6-0.7 - arid; 0.8-1.0 - insufficient moisture; 1.0 - equality of the arrival and consumption of moisture; 1.0—1.5 - sufficient moisture; more than 1.5 - excess moisture; more than 2.0 - excess moisture for the tropics (Mishchenko, 2009; Bajsholanov et all, 2017 b).

Data sets and processing. The data from the National Aeronautics and Space Administration (NASA) POWER Data Access Viewer v2.0.0 includes long-term averages of climatology, estimates of meteorological quantities and solar energy fluxes on the surface. The average daily values of basic meteorological and solar data are presented in time series format. Many studies have shown that satellite and model-based products are accurate enough to provide reliable data on solar and meteorological resources in regions where surface measurements are rare or absent. The products offer two unique functions: the data is global and, as a rule, continuous in time (Kelley, 2013; POWER Data Methodology, 2022).

Spatial interpolation methods predict values for locations on a raster (grid) surface using values from sample data points. Spatial interpolation assumes that attribute data is continuous in space (Flowerdew et all, 1992), and is widely used to create continuous data when data is collected in separate locations, as well as in a Geographic Information System (GIS).

Geostatistical methods are based on statistical models that include autocorrelation, which is defined as a tendency for the observed value of a variable in one locality to depend on the values of neighboring points. In addition to creating an interpolated (predicted) surface, kriging also provides some degree of reliability and accuracy of forecasts, unlike other types of interpolation. Kriging uses the principle of weighing sample values when predicting interpolated values. Kriging is best suited for well-distributed data without discontinuities (Munyati et all, 2021).

Algorithm of work execution. The algorithm of work execution (Figure 1) includes the procedure for determining agro-climatic zones.

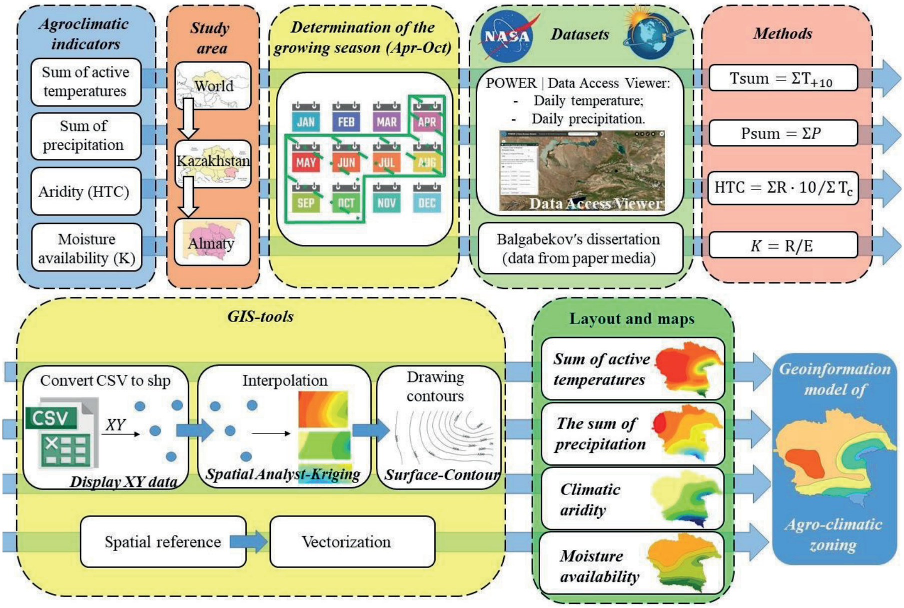
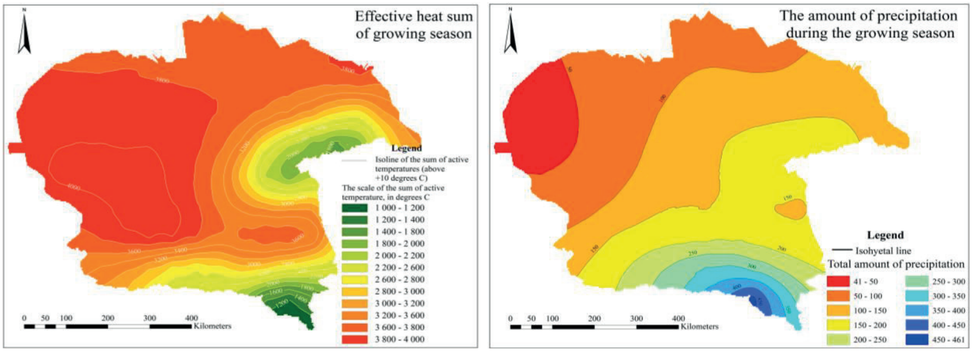


Figure 1. Sequence of work (indicators, datasets, methods, tools, result)

The agro-climatic indicators of the sum of active temperatures and precipitation, the coefficient of humidification and climatic aridity were determined within one administrative unit. The period of vegetation was chosen between April and October. The open climate data used in this research are downloaded from the POWER Data Access Viewer website and integrated into the GIS environment in the form of air temperature and precipitation data. The data on the moisture coefficient were obtained from the dissertation work of Balgabekov (1999). The method of calculating agro-climatic indicators was carried out using mathematical formulas (1,2). Geospatial data processing using GIS tools (display XY, kriging interpolation, data converter) was carried out in the ArcGIS program. Based on the processed data, cartographic models of agro-climatic indicators were developed, followed by the implementation of a geoinformation agro-climatic model of the Almaty region.

Results and discussion. Analysis of heat supply data and the amount of precipitation during the growing season. The determination of the amounts of active temperatures and precipitation was carried out according to the POWER Data Access Viewer (link to the Web application: *https://power.larc.nasa.gov/data-access-viewer/*). The period from April to October 2021 (the growing season) was chosen as the studied interval. Climate indicators of daily air temperature values have been uploaded in CSV format for further integration into the ArcGIS environment. Files of this type included fields with coordinate data, as well as data on daily air temperature indicators. To allocate days with indicators above +10⁰C, a sample was performed where the conditions were greater than or equal to 10 (=>10). The resulting point layers were interpolated using the Kriging method (Figure 2). Isolines of the sum of active temperatures were carried out using the Contour GIS tool (ArcToolbox/Spatial Analyst tools/Surface) with an interval of 200⁰C (McMastera et all, 1997).



a) b)

Figure 2. Results of analyses of heat supply (a) and precipitation (b) during the growing season

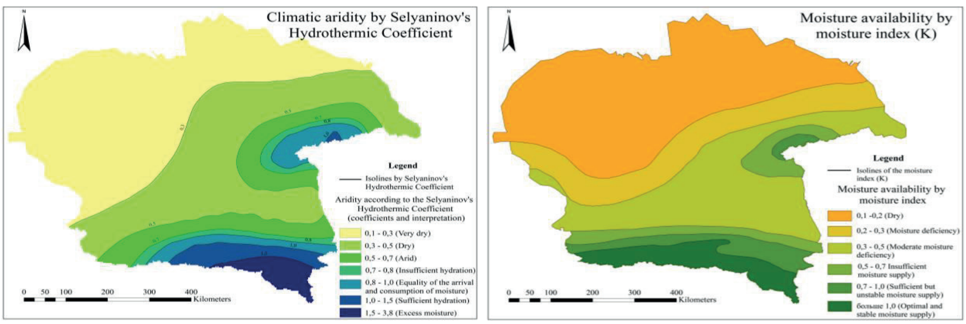
Figure 2a illustrates the sums of active temperatures by geospatial distribution. The temperature range includes values from 1000 to 4000. The highest indicator (4000⁰C) is inherent in the western part of the Almaty region. The sum of active temperatures varies gradually by natural and altitude zonality. The lowest index of 1000⁰C is observed in the high mountain massif of the Eastern Tien Shan (Khan Tengri Peak).

The amount of precipitation for 2021 (Figure 2b) is determined in the period from April to October. The data was also converted into a GIS environment to build an interpolated surface. The kriging method in processing the amount of precipitation was the most optimal option, due to the same distances between the point objects. Precipitation is distributed in the study area in the range from 41 mm to 461 mm. The spatial distribution of climatic indicators occurs from the smaller (north-west of the region) to the larger (south-east). Precipitation changes are correlated with changes in natural zones and altitude zonality. The highest precipitation rates (over 400 mm during the growing season) are inherent in the south-eastern part of the Almaty region, and the least amount falls in the arid north-western part.

Determination of the degree of aridity and moisture availability of the studied territory. The climatic aridity was determined using the POWER Data Access Viewer. Processing CSV files of 2021 (April-October), raster data on climatic aridity according to the Selyaninov′s HTC (2) were obtained (Figure 3a).

As a result, zones with corresponding indicators from 0.1 to 3.8 were obtained. The range of indicators from 0.1 to 0.3 covers the northern and western parts of the studied region and is interpreted as a very dry indicator. Further, the range of 0.3-0.5 (dry indicator) extends from the southwest to the east of the Almaty region, covering a significant part of the central region. 0.5-0.7 covers the plain and the foothill part and is designated as an arid indicator. On the foothill part, it covers the range of 0.7-0.8 and is interpreted as an insufficiently moistened indicator. The range from 0.8 to 1.0 covers the mountainous area and is designated as an indicator of the equality of the arrival and consumption of moisture. Indicators over 1.0 of the indicator are located in mountainous areas with difficult terrain and are interpreted as indicators of sufficient and excessive moisture (Bajsholanov et all, 2017b; Młyński et all, 2021).

Moisture availability by moisture coefficient was obtained from the scientific work of Balgabekov (1999), and integrated into this study (Figure 3b). The coefficient was calculated using a special formula (1), shown in the Materials and methods section. Based on the formula, raster data of average precipitation and evaporation values in mm were needed to process the data and obtain the result. Cartographic data from paper media is scanned and digitized in ArcGIS, using ArcScan and Editor tools. The mentioned tools are focused on vectorization with pixel data information. As a result, shapefiles with attribute information about moisture availability were obtained.



a) b)

Figure 3. Indicators of climatic aridity (according to the Selyaninov HTC) (a) and moisture availability (according to the moisture coefficient - K) (b) of the territory

As a result, zones with a moisture coefficient with a step of 0.1 were obtained. It was confirmed that moisture availability decreases from north to south. The range of 0.1-0.2, which are interpreted as a dry indicator, are located in the northern and central parts of the region. 0.2-0.3 extends from west to east and is designated as an indicator of moisture deficiency. 0.3-0.5 covers the central and part of the foothill area of the study area, also interpreted as an indicator of moderate moisture deficiency. In this case, irrigation of agricultural land occurs with additional irrigation measures. Indicators 0.5-0.7 cover the foothill area of the Northern Tien Shan and the Dzungarian Alatau and are interpreted as insufficient moisture supply. Indicators above 0.7 cover the entire south of the Almaty region and are designated as areas with sufficient, but unstable, as well as further south as optimal and stable moisture supply (Balgabekov, 1999; Bajsholanov, 2017b) (Balgabekov, 1999; Bajsholanov, 2017b).

Construction of a geoinformation model of agro-climatic zoning of the Almaty region. In many studies (Araya et all, 2010; Nabati at all, 2020; Tanasijevic et all, 2014; Zhou et all, 2009) agro-climatic zoning is carried out taking into account the sum of active temperatures and humidification coefficients (Bajsholanov, 2017b). However, in this work, the development of zones of agro-climatic zoning implied a combination of thermal characteristics, data on aridity, moisture availability, as well as indicators of the amount of precipitation in the studied region (Figure 4).

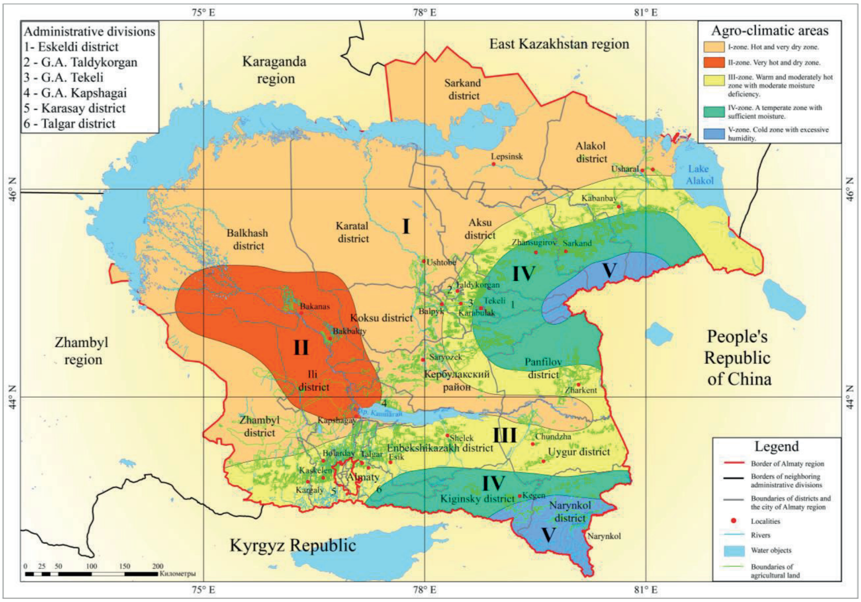


Figure 4. Agro-climatic zoning of Almaty region

As a result of the superposition of the above-mentioned indicators, agro-climatic zones on the territory of the Almaty region have been determined. Differentiation was reproduced on the basis of natural zones and altitude zonality. The results of the study identified 5 agro-climatic zones: I-hot and very dry zone; II-very hot and dry zone; III-warm and moderately hot zone with moderate moisture deficiency; IV-moderate zone with sufficient moisture; V-cold zone with excessive humidity. The complex characteristics are shown in Table-1.

The I-zone is characterized by a dry climate and covers a significant part of the studied region, including the territories of Balkhash, Zhambyl, Karatal, Koksu, Aksu, Sarkand, Alakol, Kerbulak districts and administrative units. For this zone, the sums of active temperatures in the range from 3600^0C to 3800^0C are inherent. The growing season lasts from 30 to 120 days. The coefficient of humidification (K) has a range of 0.1-0.2. The hydrothermal coefficient of Selyaninov varies from 0.1 to 0.5 indicators. The amount of precipitation during the growing season ranges from 41 to 200 mm.

II-zone. The second agro-climatic zone covers the territories of the southern part of Balkhash, the north-eastern part of Zhambyl and a significant part of Ili districts. The sum of active temperatures is the highest above 4000^0C. The duration of the period is 60-150 days. The coefficient of humidification is 0.1-0.3 indicators. The HTC for Selyaninov has a range of 0.3-0.5. The amount of precipitation during the growing season is 100-250 mm. Irrigation of agricultural land requires a sufficient amount of water resources.

Table 1. Agro-climatic zones and their complex characteristics.

Agro-climatic zone	**Duration of the growing season, days**	**The sum of active temperatures, in ^{0}C**	**Humidification coefficient (K)**	**HTC by Selyaninov**	**Precipitation amount, in mm**
I-zone. Hot and very dry zone.	30-120	3600-3800	0.1-0.2	0.1-0.5	41-200
II-zone. Very hot and dry zone.	60-150	4000 and higher	0.1-0.3	0.3-0.5	100-250
III-zone. Warm and moderately hot zone with moderate moisture deficiency.	60-150	3000-3600	0.2-0.3	0,3-0,7	150-350

IV-zone. A temperate zone with sufficient moisture.	60-120	1800-2800	0.5-0.7	1.0-1.5	150-400
V-zone. Cold zone with excessive humidity.	60-90	1000-1800	0.7-1.0	0.8 and higher	400 and higher

III-zone. The third zone covers the foothill part, including the territory of Enbekshikazakh, Karasai, Talgar, Uygur, the southern parts of Zhambyl, Panfilov and Sarkand districts, the northeastern part of Kerbulak, the central parts of Aksu and Alakol districts. The sum of active temperatures is 3000-3600^{0}C. The duration of the growing season lasts 60-150 days. The humidification coefficient has a range of 0.2-0.3. The Selyaninov HTC covers ranges of 0.3-0.7. The total amount of precipitation in this zone is higher compared to the previous two zones and is 150-350 mm.

IV-zone. The zone covers the mountainous region, including the territories of Kegen, the northern parts of Panfilov and Narynkol districts, the eastern parts of Kerbulak and Eskeldi districts, as well as the southern parts of Aksu, Sarkand, Alakol districts. The sum of active temperatures is 1800-2800^{0}C, the vegetation period is equal to 60-120 days. The humidification coefficient is measured in 0.5-0.7 diapason, and the HTC is 1.0-1.5 indicators. The amount of precipitation is 150-400 mm .

The V-zone covers most of the Narynkol district, and minor territories of Kegen, Kerbulak, Aksu, Sarkand and Alakol districts. The sum of active temperatures and precipitation is 1000-1800^{0}C and 400 mm. The humidification coefficient is 0.7-1.0, and the HTC be Selyaninov has a range of 0.8 and higher indicators. The duration of the growing season is 60-90 days.

Conclusion. This article presents a study on the agro-climatic zoning of the Almaty region. Climate change has a tremendous impact on the cultivation of agricultural crops, thereby making relevant scientific work in the agro-climatic direction.

During the study, open-access climatic data were used to determine the sum of active temperatures and precipitation, the coefficient of humidity and HTC according to Selyaninov. The aggregates of the above-mentioned components were the basis for compiling a geoinformation model of agro-climatic zoning.

Agro-climatic research on the territory of the Almaty region allowed to draw the following conclusions:

1. Agro-climatic indicators change from north to south, taking into account natural zones and high-altitude zonality;

2. In most of the studied region there is insufficient humidification and high temperatures, thereby increasing the amount of water resources allocated for irrigation.

The model proposed in our article can be supplemented and modified using other climatic sources, trend analysis and error measurement. Our future research plans include a more comprehensive analysis of the relationship between climatic factors, water resources in relation to the zoning of agricultural irrigated lands, as well as the biological characteristics of individual crops.

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REFERENCES

Almaty region [Almaty oblysy]. Available at: https://kk.wikipedia.org/wiki/Алматы_облысы. (accessed 2 Apr. 2022).

Araya A., Keesstra S.D., Stroosnijder L. (2010). A new agro-climatic classification for crop suitability zoning in northern semi-arid Ethiopia, Agricultural and Forest Meteorology, 150: 1057-1064. DOI: *https://doi.org/10.1016/j.agrformet.2010.04.003*.

Bajsholanov S.S. Agro-climatic zoning of agricultural crops in northern Kazakhstan: scientific and applied reference. Astana, Kazakhstan. ISBN: 978-601-7150-83-9.

Bajsholanov S.S., ZHakieva A.R., Gabbasova M.S., Chernov D.A. (2017) Agro-climatic zoning of agricultural crops in northern Kazakhstan [Agroklimaticheskoe rajonirovanie sel'skohozyajstvennyh kul'tur v severnom Kazahstane] 3: 17-28.

Balgabekov K.B. (1999). Hydromodule zoning and soil protection from irrigation erosion in the south-east of Kazakhstan [Gidromodul'noe rajonirovanie i zashchita pochv ot irrigacionnoj erozii na yugo-vostoke Kazahstana]. [Doctoral dissertation, Williams Kazakh Research Institute]. Williams Kazakh Research Institute.

FAO, IFAD, WFP, 2014. The State of Food Insecurity in the World 2014. Strengthening the Enabling Environment for Food Security and Nutrition. Technical Report, Rome, FAO.

Flowerdew R., Green M. (1992). Developments in areal interpolation methods and GIS, Mathematics, Economics, 26:67-78. DOI: 10.1007/BF01581481.

Kelley O.A. (2013). Adapting an existing visualization application for browser-based deployment: A case study from the Tropical Rainfall Measuring Mission, Computers & Geosciences, 51:228-237. DOI: https://doi.org/10.1016/j.cageo.2012.10.004.

Length of growing period. Available at: https://www.arcgis.com/home/item.html?id=3ac478a468c245ef9bfd5533f7edbf93. (accessed 2 Apr. 2022).

McMastera G.S., Wilhelm W.W. (1997). Growing degree-days: one equation, two interpretations, Agricultural and Forest Meteorology, 87: 291-300. DOI: https://doi.org/10.1016/S0168-1923(97)00027-0.

Mishchenko Z.A. (2009). Agroclimatology [Agroklimatologiya]. Odessa State Ecological University, Ukraine. ISBN: 978-966-373-481-1.

Munyati C., Sinthumule N.I. (2021). Comparative suitability of ordinary kriging and Inverse Distance Weighted interpolation for indicating intactness gradients on threatened savannah woodland and forest stands, Environmental and Sustainability Indicators. DOI: https://doi.org/10.1016/j.indic.2021.100151.

Młyński D., Wałęga A., Kuriqi A. (2021). Influence of meteorological drought on environmental flows in mountain catchments, Ecological Indicators, DOI: *https://doi.org/10.1016/j.ecolind.2021.108460*.

Nabati J., Nezami A., Neamatollahi E., Akbari M. (2020). GIS-based agro-ecological zoning for crop suitability using fuzzy inference system in semi-arid regions, Ecological Indicators, 117. DOI: https://doi.org/10.1016/j.ecolind.2020.106646.

POWER Data Methodology. Available at: https://power.larc.nasa.gov/docs/methodology/. (accessed 2 Apr. 2022).

Sauvage J.S., Vitasse Y., Meier M. Delzon, S., Bigler C. (2022). Temperature rather than individual growing period length determines radial growth of sessile oak in the Pyrenees, Agricultural and Forest Meteorology. DOI: https://doi.org/10.1016/j.agrformet.2022.108885.

Tanasijevic L., Todorovic M., Pereira L.S., Pizzigalli C., Lionello P. (2014). Impacts of climate change on olive crop evapotranspiration and irrigation requirements in the Mediterranean region, Agricultural Water Management, 144:54-68. DOI: https://doi.org/10.1016/j.agwat.2014.05.019.

Zhou D., Khan S., Abbas A., Rana T., Zhang H., Chen Y. (2009). Climatic regionalization mapping of the Murrumbidgee Irrigation Area, Australia, Progress in Natural Science, 19:1773-1779. DOI: https://doi.org/10.1016/j.pnsc.2009.07.007.

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