Engineering Journal of Satbayev University
Volume 147 (2025), Issue 2, 40-49

https://doi.org/10.51301/ejsu.2025.i2.06

Comparative analysis of the state of desertification of the lands of West and East Kazakhstan

M.E. Amirkhanov, Y. Zhakypbek*, S.V. Tursbekov, T.B. Nurpeissova
Satbayev University, Almaty, Kazakhstan
**Corresponding author: y.zhakypbek@satbayev.university*

Abstract. The study performs an analysis and comparison of two completely different, but in some cases similar regions of West and East Kazakhstan. The influence of climate data changes, soil structure and its sensitivity on desertification in Kazakhstan over the decades of the 2000s, 2010s and from 2020 to 2024 is described using the example of West and East Kazakhstan. The author compared and detected that the soil types: Zg, XI, So, WR and KI are found both in the West and in the East of Kazakhstan exposed to degradation of soil structure. Climatic parameters, such as the temperature of the area fixed range between 3.6-4.9°C, humidity change significantly, all the time within 64% and 77%, and precipitation in different time periods changed from 416 mm to 605 mm. Using remote sensing data, the author analyzed changes in the natural environment, created visualizations and 3D modeling during the monitoring process. Thus, a set of existing research papers, statistical information and own experience were presented, since in the course of the work the results of scientific research on desertification were presented. The results of the study showed that there is an accelerated process of land desertification in Kazakhstan.
Keywords: *desertification, climate, temperature, humidity, precipitation, remote sensing, monitoring*.

Received: 06 January 2025
Accepted: 15 April 2025
Available online: 30 April 2025

1. Introduction

Desertification is the process of transforming fertile land into desert or semi-desert. This phenomenon occurs due to various factors such as climate change, improper agriculture, overgrazing, deforestation, the use of chemical fertilizers, and other human and natural impacts. As a result of desertification, soil fertility is lost, water quality deteriorates, and biodiversity decreases, which can lead to economic and social problems, especially in rural areas.

Before starting a study, it is necessary to find the differences and understand what desert and desertification mean, and in what ways they differ. Desertification and desert are two concepts that are often confused, but there are important differences between them. Desert is a natural ecosystem characterized by extreme climatic conditions (hot or cold, dry), where there is little precipitation and vegetation is limited. Deserts have a specific landscape, such as sand dunes, rocky plains, rare plants and species of flora and fauna adapted to arid conditions. Desertification is a process of land degradation, during which fertile territories lose their properties and become unsuitable for agriculture or life. This phenomenon can occur due to various factors, including climate change, land misuse, deforestation, or intensive cattle breeding. This phenomenon includes soil degradation, water loss, and deterioration of plant growth conditions. Desertification can occur in different climatic zones, not necessarily in actual deserts. Thus, a desert is a stable ecosystem, and desertification is a process that can affect even areas that were once green or fertile. The process of desertification is most often observed in arid and semi-arid areas, where the preservation of fertile soil and access to water resources are key factors in agricultural activity and population viability. The process of desertification is related to soil sensitivity and ecological vulnerability [1]. Ecological soil degradation occurs in ecologically vulnerable areas, and ecological sensitivity factors and ecological exposure factors are the basic elements for assessing ecological vulnerability [2].

The Republic of Kazakhstan is the largest landlocked country in the world that does not have direct access to the World Ocean. Most of the country's territory is desert – 44% and semi-deserts – 14%. Steppes occupy 26% of the area of Kazakhstan, forests – 5.5%. There are 8.5 thousand rivers in the country. The northeastern part of the Caspian Sea is included in the republic borders. The Aral Sea is divided between Kazakhstan and Uzbekistan. There are 48 thousand large and small lakes in Kazakhstan. The largest of them are Balkhash, Zaysan and Alakol. The remoteness from the oceans determines the sharp continental climate of the country which means ecological sensitivity is mainly reflected by desertification sensitivity [3]. The higher the desertification sensitivity is, the greater the risk of land desertification. The phenomenon of soil structural degradation and desertification has been actively expressed in Kazakhstan since the 1960s, and attention should be paid especially to the Western part of Kazakhstan, the Caspian region [4].

m.amirkhanov@satbayev.university; y.zhakypbek@satbayev.university; s.tursbekov@satbayev.university; t.nurpeissova@satbayev.university
Engineering Journal of Satbayev University. eISSN 2959-2348. Published by Satbayev University

In 1994, the United Nations Convention to Combat Desertification (UNCCD) was adopted, which is the main international legal instrument aimed at combating desertification and land degradation. The signatory countries committed to develop and implement national and regional plans to prevent desertification, restore degraded lands, and use sustainable land tenure and agriculture.

Kazakhstan became a party to the United Nations Convention to Combat Desertification (UNCCD) on December 30, 1997. On July 7, 1997, Kazakhstan took part in this process and presented its National Action Program in the form of the state program «Combating desertification in the Republic of Kazakhstan for 2005-2020» with a three-stage list of main goals and objectives [5].

The susceptibility of the soil to desertification is its tendency to degradation in conditions of lack of moisture and vegetation, which leads to loss of its productivity and transformation into desert or semi—desert areas. This process depends on a complex of factors, both natural and anthropogenic. Here are the main points that affect the susceptibility of the soil to desertification:

Climatic conditions. Low humidity: the main factor contributing to desertification is lack of precipitation. Soils in arid and semi-arid areas (such as Central and Western Kazakhstan) are susceptible to erosion and degradation, especially if precipitation does not compensate for moisture evaporation. High temperature: Intense heat also accelerates the evaporation of moisture from the soil surface, which can lead to deterioration of its structure and loss of organic matter. Republic of Kazakhstan makes up about 179.9 million ha or 60% of its territory, mostly in desert, semi desert and steppe zones. Almost all the administrative regions suffer from desertification which shown in Figure 1 [6].

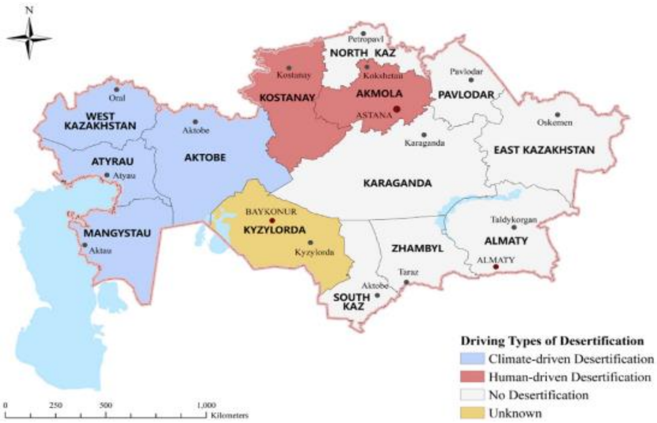

Figure 1. Driving types of desertification in Kazakhstan

Type of soil. Sandy and sandy loam soils: These soils have a low ability to retain moisture, which makes them particularly vulnerable in arid conditions. They are easily destroyed by wind (wind erosion) and water. Clay soil: Although such soils retain moisture better, they can be subject to water erosion and waterlogging if the correct water balance is not maintained. A Loamy soil: They are more stable, but if mismanaged (for example, excessive arable land or intensive grazing), they can also degrade.

The presence of vegetation: Vegetation plays a key role in protecting the soil from erosion. The presence of grass cover and shrubs helps to retain moisture and prevent the removal of the topsoil. If vegetation is destroyed (for example, because of uncontrolled grazing or agricultural activities), the soil becomes vulnerable [7].

The root system of plants helps strengthen the soil, improving its structure and ensuring water retention.

Anthropogenic factors. Excessive farming: Frequent tillage without observing crop rotation and without applying organic fertilizers can lead to a decrease in organic matter and deterioration of soil structure. This, in turn, increases the susceptibility of the soil to desertification. Pasture pressure: Overgrazing destroys vegetation cover and compacts the soil, which reduces its water retention capacity and promotes erosion. Disturbance of the water balance: Changes in the use of water resources (for example, irrigation without considering soil characteristics) can lead to soil degradation through salinization or an increase in the groundwater level [8].

Soil degradation. Erosion: Soils exposed to strong wind or rain lose their upper fertile layer. This can lead to a loss of soil structure and deterioration of its fertile qualities. Salt stress: In arid areas where there is high evaporation and lack of precipitation, salt deposits can accumulate on the soil surface, making it less suitable for plant growth. An absence of organic matter: The lack of organic matter reduces the soil's ability to retain water and nutrients, making it more vulnerable to degradation and desertification. Soils with a disturbed structure (for example, compacted or with a low content of organic matter) lose their ability to retain water and air, which contributes to their degradation and increased susceptibility to desertification.

Soil sensitivity is its ability to respond to various impacts, such as climate change, agricultural stress, or pollution. One of the main factors affecting soil sensitivity is the type and structure of the soil: Different types of soils (for example, sandy, clay, loamy) have different water retention and aeration capacities. Soils with a fine-grained structure (for example, clay soils) may be more sensitive to changes in humidity, while sandy soils may dry out faster, making them sensitive to droughts. To obtain a systematic analysis of the soil structure, it is necessary to understand in detail the soil structure of Kazakhstan [9].

The natural zones of Kazakhstan successively change from North to South: from forest-steppes to deserts, and it is shown in Figure 2.

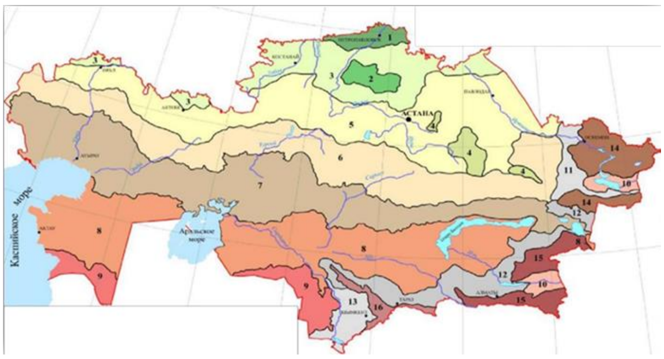

Figure 2. Map of natural zones, subzones of altitude zones of Kazakhstan in 2023

Forest steppe. A small area of the northern part of the country. This zone is characterized by a flat land surface with lowlands. This territory consists of two types: (1) – forest-steppe and mixed (Kolochnaya) steppe of plains; (2) – forest-steppe of Low Mountains.

Steppe. They occupy almost a third of the country's territory. The climate is more severe than in the forest-steppe: precipitation is much less in summer, and the average temperature in July varies from +18°C in the northern regions to +23°C in the southern regions. The steppe zone with white and green consists of: (3) – arid steppes; (4) – srid steppes and forests of low mountains.

Yellow and white-orange color territories cover semi-deserts zones. Semi-Deserts are the intermediate zone between the steppe and deserts. The climate is dry and hot in summer, cold in winter: (5) – dry steppes; (6) – desolate steppes.

Deserts. They occupy a wide strip from 500 to 700 km, stretching from the Caspian Sea to the foothills. They are: (7) – northern deserts; (8) – middle deserts; (9) – southern deserts.

In the mountainous regions of Kazakhstan, the change of natural zones is determined by the change in altitude: (10) – desert basins. Upland plains and foothills: (11) – steppe foothills; (12) – desert of the north Tianshan type; (13) – desert of the central Asian type.

Mountains: (14) – Tarbagatai-Sauro-Altai belt types; (15) – Dzungaro-North Tien Shan belt types; (16) – Karatai-Western Tien Shan belt types. High-altitude zones influence the development of nature. The change in altitude leads to alternation of natural zones and changes in vegetation and climate [10].

The study of desertification of the lands of Kazakhstan is conducted to study the causes and extent of this process, as well as to prepare measures for its prevention and management. The study process is based on data from East Kazakhstan, which is one of the regions of the country with the most affluent and rich in water resources in the region of the Republic of Kazakhstan, where desertification is beginning, and special attention is being paid to this issue [11].

Desertification is a serious problem in Kazakhstan, as most of the country is in a semi-desert and desert zone. Sources of desertification in Kazakhstan include unstable land use, irregular use of agricultural land, climate change and insufficient conservation.

The problem of desertification of lands in the Caspian region West Kazakhstan is one of the most pressing problems of Ecology and agriculture in the region. In many areas of the region, soil cover and access to plant nutrients are deteriorating due to land cover destruction and soil erosion. The Caspian region is one of the most dynamic regions on the planet. Its condition is greatly influenced by a combination of natural and anthropogenic factors.

Desertification in Atyrau and Mangystau regions is an urgent problem faced by Kazakhstan, requiring an integrated approach and long-term solutions. Effective management of water resources, the introduction of sustainable agricultural practices and the conservation of natural ecosystems will help mitigate the effects of this process and ensure the sustainable development of the region (Figure 3).

The interrelation of the desertification process in the Caspian region and East Kazakhstan is a complex ecological process that can be considered in the context of common climatic, hydrological and anthropogenic factors affecting both regions. Despite the difference in geographical location (the Caspian region is in the west of Kazakhstan, and East Kazakhstan is in the east of the country), there are several key factors of interconnection between these regions, including through climate change, water resources, and the impact of human activity.

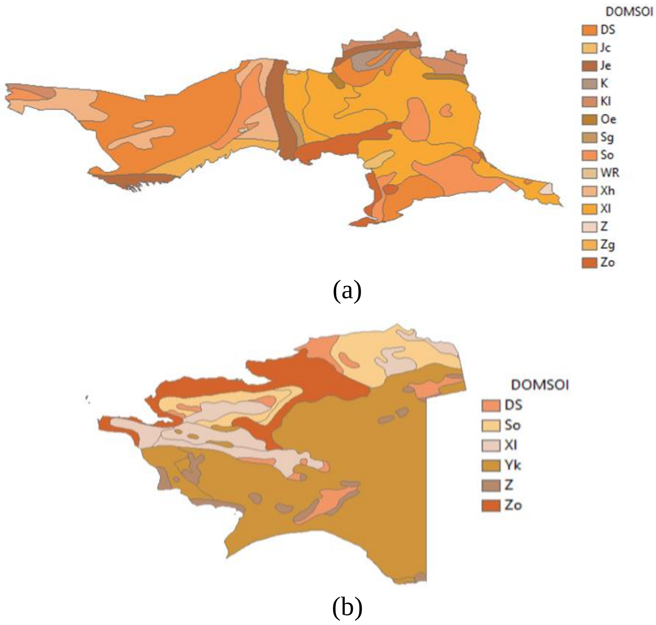

Figure 3. Soil type structure of Atyrau and Mangystau regions: (a) – tyrau region consists: Ds – Podzoluvi soils; Jc – Calcaric Fluvisols; Je – Eutric Fluvisols; K – Kastaznozems; KI – Luvic Kastanozems; Oe – Eutric Histosols; Sg – Gleyic Solonetz; So – Orthic Solonetz; WR – Planosols; Xh – Haplic Xerosols; XI – Luvic Xerosols; Z – Solonchaks; Zg – Gleyic Solonchaks; Zo – Orthic Solonchaks; Yk – Calcic Yermosols; Z – Solonchaks [12]

Although East Kazakhstan is generally less dependent on rivers, current water supply problems and declining water resources in the Caspian region (including due to changes in the Caspian Sea level) may affect overall approaches to the use of water resources in Kazakhstan. A decrease in water resources in one part of the country may increase competition for water and worsen problems in other regions.

Increased soil salinity, erosion, and deterioration of water quality are common problems both in the Caspian region and in some areas of Eastern Kazakhstan. Both regions are experiencing changes in vegetation and wildlife due to climate change and economic activity. The impact of ecosystem changes in one region may have an indirect impact on ecosystems in another region if there are natural links between them, such as animal migration routes or water flows.

The process of desertification in the Caspian region and Eastern Kazakhstan is closely linked through climate change, water resources and anthropogenic factors. Although each of these regions has its own characteristics, common problems such as land degradation, water stress, and ecosystem degradation require comprehensive solutions and coordinated efforts at the national level to mitigate them and prevent further environmental degradation [13].

2. Materials and methods

Desertification is the degradation of land in arid, semi— arid and dry sub-humid areas caused by climate change and anthropogenic activities. Remote sensing plays a key role in identifying, monitoring, and predicting this process. Monitoring of desertification by remote sensing of the Earth in the East Kazakhstan region is an important component of the management of Natural Resources and environmental protection in this region. Remote sensing is a method that uses satellite data to study and analyze changes in the Earth's surface.

In recent decades, climate change has increasingly affected ecosystems and agriculture around the world. The vulnerable ecosystem of East Kazakhstan, faced with the problem of desertification, requires special care. Global warming, changes in precipitation and other aspects of climate change have a serious impact on this region, leading to irreversible consequences for nature and humans. In this article, we will consider the impact of climate change over decades from 2000s to 2020s on the desertification of Eastern Kazakhstan and possible ways to solve this problem.

East Kazakhstan region located in the eastern part of the country. It occupies an area of 97800 sq kilometers on the soils of mountainous areas and areas with sandy and undeveloped soil. Geographical coordinates of researched region at 48°52'54.98" between 48°31'44.43" north latitude and 82°51'56.43" east longitude between 83°31 '46.61" [14].

In this research paper, special attention should be paid to the soil structure of the region under study, because the soil composition and soil structure have a significant impact on the processes of desertification. Soil degradation leads to a decrease in its productivity, deterioration of the water balance and, ultimately, to the expansion of desert areas.

The soil structure of East Kazakhstan is a way of organizing and combining soil particles (sand, silt, and clay) into aggregates of various shapes and sizes. It affects water permeability, aeration, fertility and soil resistance to erosion and it is shown in Figure 4.

Soils with a low humus content (less than 1%) are less resistant to erosion, as organic matter plays an important role in retaining moisture and nutrients. Salt marshes (Solonchaks) and saline soils: Salinization of the soil reduces its fertility and prevents vegetation growth, which accelerates the process of desertification. In arid regions, improper irrigation and evaporation lead to the accumulation of salt on the soil surface. This phenomenon can be seen under the Zg indicator (Gleylic solonchak).

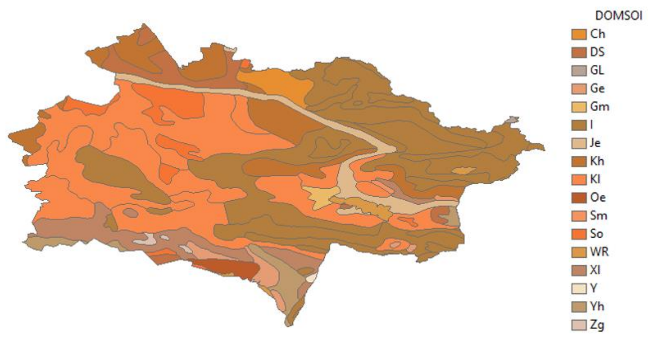

Figure 4. Soil type structure of East Kazakhstan: Ch – Haplic Chernozems; Ds – Podzoluvi sols; Gl – Glaciers; Ge – Eutric Gleysols; Gm – Mollic Gleysols; I – Lithosols; Je – Eutric Fluvisols; Kh – Haplic Kastanozems; KI – Luvic Kastanozems; Oe – Eutric Histosols; Sm – Mollic Solonetz; So – Orthic Solonetz; WR – Planosols; XI – Luvic Xerosols; Y – Yermosols; Yh – Haplic Yermosols; Zg – Gleyic Solonchaks

The East Kazakhstan region has a sharply continental climate with large differences in seasonal and daily temperatures. Summers are hot and moderately dry, and winters are cold and snowy. The average temperature of the winter months, from -12°C to -15°C, in the foothills of Altai -9°C to -11°C. However, with the attack of arctic air masses, the temperature can drop to -42°C. The average maximum temperature in July is from +25°C to +30°C. The maximum summer temperature can reach the +45°C mark. The average annual level of precipitation is from 300 to 600 mm, in the mountains-about 900 mm, in some places up to 1500 mm.

The climate of the region is sharply continental, with a large daily and annual amplitude of air temperature. The average temperature in January is -17°C, July +21°C, precipitation covers 300 mm per year. The average annual wind speed is 2.3 m/s, the average annual air humidity is 66% [15].

There are two main reasons why the phenomenon of desertification occurs. They are natural and anthropogenic. As a natural factor, the indicator of seasonal drought and the amount of precipitation is less than normal. And the anthropogenic factor, that is, the reason that arose from the activities of mankind, is the misuse of land plots within the framework of economic activity agriculture. Overgrowth and improper distribution of pastures and land resources, uncontrolled use of land for growing crops, and soil contamination with toxic substances.

The methodology for studying the phenomenon of desertification of the lands of East Kazakhstan will consist of the following indicators. Indicators of climatic characteristics of Kazakhstan (Statistical information) and state of land cover of the territory of Kazakhstan (Vegetation conditions and migration of sand dunes).

The average and maximum decennial height of snow cover in winter (Tables 1, columns 1 and 2) are calculated based on daily monitoring of the height of snow cover installed in an open area within the locality. According to these data, the average decade of snow cover was determined. From them, the maximum values were selected for each winter, according to which the average values of the largest and maximum values for the control period of at least 40 years were found. The maximum daily height (Table 1, column 3) is determined as the largest of the values of the maximum height of snow cover for the year, obtained because of field surveys of snow cover, which are carried out on the last day of each decade. Snow shooting data is an average of 100 measurements on a route of one to two kilometers.

Table 1. Snow precipitation indicator, 2020s [16]

City/town/place	Snow cover, cm			Duration of the onset of stable snow cover, days
	Average for the largest decade of winter	Maximum of the largest decade	Maximum daily amount of winter on the last day of the decade	
East Kazakhstan				
Zaysan	26.2	73.0	69.0	136.0
Katon-Karagay	26.9	89.0	48.0	160.0
Ust-Kamenogorsk	57.4	104.0	-	147.0
Shemonaikha	49	83	85	151

Duration of permanent snow cover (Table 1, Column 4). Defined as the average of the annual periods of stable snow cover. The period of formation of snow cover is determined between the date of formation of permanent snow cover, when the visible area of the meteorological station is covered with more than 60% snow, and the date of disappearance of permanent cover, when the degree of environmental cover is less than 60%. In addition, snow cover is considered stable if it is maintained for at least 30 days in a row with breaks of no more than three days.

The least precipitation in East Kazakhstan falls in September. The average for this month is 29.5 mm. At the same time, most precipitation is observed in November. The level and amount of precipitation affects the vegetation of area. Visual information can be seen in Figure 5.

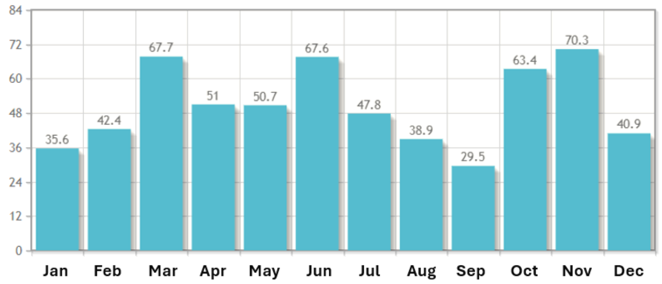

Figure 5. Average amount of precipitation in East Kazakhstan, 2020s

As a factor contributing to climatic indicators, we can use humidity and temperature indicators of the region between certain periods of time. Humidity is the concentration of water vapor in the air. Humidity changes depending on the temperature and pressure in the controlled system. The same amount of water vapor leads to an increase in the relative humidity of cold air compared to warm air.

Air temperature is one of the thermodynamic parameters of the state of the atmosphere. Air temperature is an indicator of a quantity that indicates the degree of its heating. Air temperature is one of the most variable indicators of the state of the atmosphere.

Remote sensing of the earth is a set of technologies that allow obtaining, processing and interpreting information about objects on the earth's surface without physical contact. The specific goals of a scientific study should include the following points: Study and analysis of the dynamics of changes in vegetation and soil cover in the East Kazakhstan region based on the analysis of remote sensing data over the past decades, assessment of the impact of natural and anthropogenic factors on the desertification process in this region, determination of optimal remote sensing parameters for effective desertification control, development of recommendations and strategies for combating desertification in this region based on the results of research and analysis of remote sensing data [17].

To study climate indicators in the region, control work can be carried out using indicators for several years free of charge through the POWER Data Access Viewer platform. In order to study climate indicators in the region, control work can be carried out using indicators for several years free of charge through the POWER Data Access Viewer platform. Power Data Access Viewer is a web—based GIS tool that allows you to see and explore various variables related to renewable energy sources anywhere around the world. The tool is provided as part of NASA's World Energy Resources Forecast (POWER) project. Using Power Data Access Viewer provides access to daily averaged data for specific date ranges and parameters for a single location, view interactive charts and data tables, download various tabular and geospatial file formats, access climate datasets for the entire globe and generate custom climatological reports and single point data [18]. The results of the research on the project are provided in the form of interactive maps, through applications and data services that describe meteorological conditions, solar radiation and other information, and show how these resources can change over time.

Spatial analysis makes it easier to answer many questions, including those related to renewable energy sources. Under GIS, NASA's solar and meteorological data can be placed on a single smart card along with socio-economic data, energy network data and other infrastructure. Thus, modern GIS software helps to bring clarity to the complex tasks of renewable energy, helping to understand the huge volumes and variety of data, showing an accurate picture of current conditions and providing users with the opportunity to model and simulate strategies [19]. Since the POWER Project was launched 20 years ago, in 2002, with the aim of making surface energy measurements available, it has seen a huge increase in the amount of data it collects and the set of answers it can offer, as well as the communities it serves.

As people around the planet explore this area more closely and invest in capturing solar and wind energy, they will study and apply Earth observation materials made by NASA from space. These NASA observations are free and accessible to everyone, they help us better understand how the complex systems of our planet work. After all, we are all astronauts on a small spaceship called Earth [20].

POWER Regional Data Access Viewer platform https://power.larc.nasa.gov/data-access-viewer/ temperature and humidity indicators in the territory of the East Kazakhstan region are monitored and analyzed. With a primary data library, you can download and edit the average air temperature and air humidity data for each month for 12 months of each year on Microsoft Excel.

According to the data downloaded through the POWER Data Access Viewer platform, average air temperature indicators were available. The lowest air temperature in the 20-year period between 2000s and 2020s is -14°C, recorded in 2000s in the Altai District of the East Kazakhstan region. The highest temperature in 2012 in Urdzhar District of East Kazakhstan region was recorded at +36°C. The area that showed the highest air humidity in East Kazakhstan region between 2000s and 2020s is Glubokovsky, in 2000s. The lowest air humidity in Ayagoz district in 2020s.

One of the methods of studying desertification through climate research is the analysis of long-term climate data, such as data on temperature, precipitation, humidity and other parameters. By analyzing such data, scientists can identify climate change trends in a particular area and determine whether desertification is occurring there. Another method of studying desertification through climate research is the modeling of climatic conditions using special computer programs. Using such models, scientists can assess the impact of various factors, such as greenhouse gas emissions, land-use changes, etc., on the desertification process. Also, special research expeditions to deserted and desolate areas are conducted to study desertification with the help of climate research. As part of such expeditions, scientists collect data on climatic conditions, soil composition, vegetation and other parameters, which help them better understand the processes of desertification and develop measures to prevent it.

Thus, methods of studying desertification through climate research allow scientists to obtain valuable data on climatic conditions in desertification areas and develop effective strategies to combat this global problem phenomenon.

3. Results and discussion

The processing of remote sensing of the Earth has recently been increasingly closely integrated with Geographic Information Systems (GIS). ArcGIS package provides a wide range of tools for working with raster data, which makes it possible to process remote sensing and use GIS analytical functions.

The Data Access Viewer platform provides access to climate data obtained through Earth remote sensing. In this research work, the necessary parameters, such as weather stations or geographical areas, were selected using the platform, and the corresponding climate indicators from 2000s, 2010s and 2020s of East Kazakhstan were obtained. The platform's interface allowed us to visualize data and export it for further analysis. To obtain climate data through Data Access Viewer, the parameters of interest were set, such as time range (2000s, 2010s and 2020s), geographical location (East Kazakhstan), and data type (Temperature, humidity). After that, the platform provided access to the relevant data sets, which can be viewed directly on the website or downloaded for further processing.

To obtain climate data through the Data Access Viewer, users need to specify parameters such as the time range, geographic location, and data type. After that, the platform provides access to the corresponding datasets, which can be viewed directly on the website or downloaded for further processing. The obtained climate data of East Kazakhstan for 2000s, 2010s and 2020s from Power NASA Data can be seen in Figure 6.

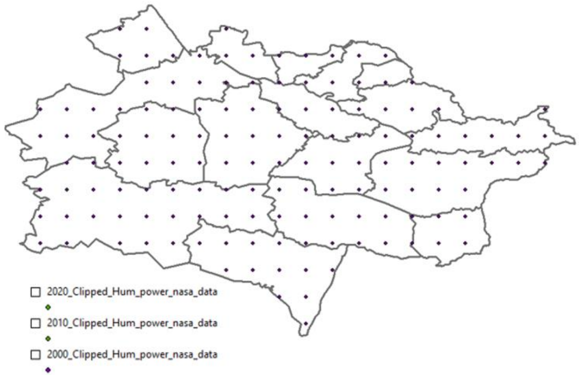

Figure 6. The obtained climatic data of East Kazakhstan for 2000, 2010 and 2020 from the Power NASA Data

According to obtained data from Power NASA Data, the average annual temperature for period 2000-2024, across East Kazakhstan was + 4.37°C, which is 1.73°C higher than the climate norm for period 1991-2000 [21]. In East Kazakhstan, temperature in three difference decades showed these numbers: the first decade from 2000 to 2009 is 4.71°C, the second decade from 2010 to 2019 is 3.56°C, and the third period from 2020 to 2024 is 4.85°C. Average temperature data for East Kazakhstan showed in Table 2.

As a digital method, thematic maps have been prepared for visual display of temperature and humidity indicators. Figure 7 below is a map showing the average air average temperature of the East Kazakhstan region for two decades 2000s, 2010s and 2020s.

Table 2. Average temperature (°C) indicator for decades 2000s, 2010s and 2020 [21]

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
2000-2009	-11.8	-8.9	-7	5.7	15.3	20.6	22.6	18.8	12.2	5.1	-4.9	-11	4.71
2010-2019	-13.7	-9.8	-6.2	5.1	14.1	18.2	19.8	16.9	10.8	4.5	-5.7	-12.3	3.56
2020-2024	-14.8	-11.3	-8.5	6.3	16.1	21.2	23.4	19.5	13.6	6.2	-4.4	-9.8	4.85

Table 3. Average air temperature (°C) value indicators from 1 to 9 for decades 2000s, 2010s and 2020

Period	1	2	3	4	5	6	7	8	9
2000s	-12	-7	-4	0	+5	+10	+17	+22	+25
2010s	-10	-5	-2	0	+3	+7	+13	+19	+23
2020-2024	-12	-7	-3	0	+4	+ 9	+16	+21	+27

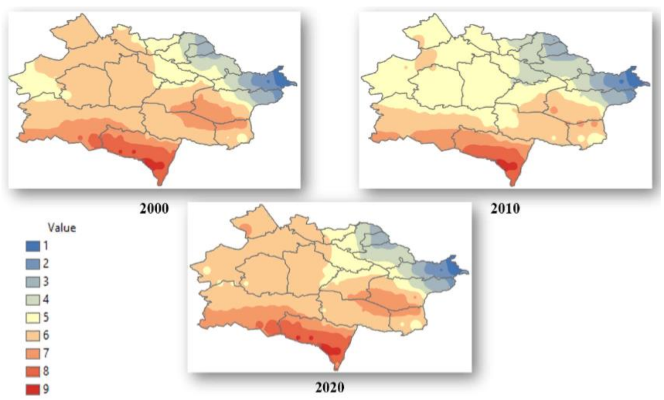

Figure 7. Map of the two-decade average temperature indicator of the East Kazakhstan

We got access to the data formed by the physical structure of the region, the terrain and the location of hydrographic objects. From the English «Value» - The Value Indicator is divided into 9 categories.

The average air temperature from 1 to 4 in the blue color is low, usually these values indicated from negative to positive Celsius (°C) and indicators from 6 to 9 characterize these regions as high and showed positive Celsius (°C). The value of 5 characterizes the relatively average value and equals to 0°C.

Figure 8 below is a Thematic Map showing the average humidity of the East Kazakhstan region for two decades 2000s, 2010s and period 2020s. Label «Value» - The Value Indicator consists of 9 categories. In this method, Blue was used as a «working color». The thickening of the blue color and their increase in values from 1 to 9 characterize an increase in the average air humidity indicator. As you move from the Altai and Saur-Tarbagatai mountains to the Balkhash-Alakol lowlands in the south-west of the region, the humidity indicator decreases.

According to thematic maps, there is a logical relationship between the average humidity and air temperature. In the territories of Gorno-Altai, Katon-Karagai and Glubokovsky, which have hydrographic resources, temperature indicators are low, and humidity is high.

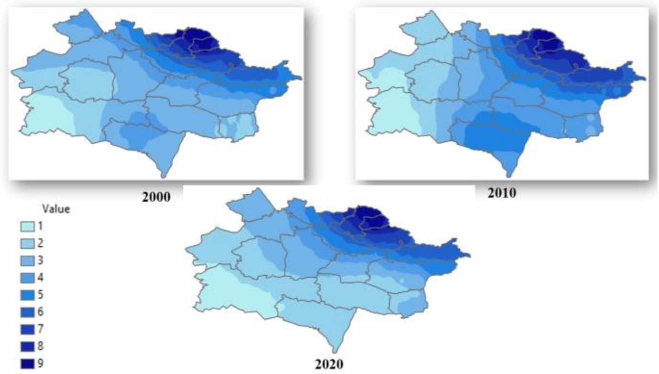

Figure 8. Map of the average humidity indicator of the East Kazakhstan for two decades

Unlike the temperature, which usually varies significantly between day and night, the dew point tends to change more slowly, so although the temperature may decrease at night, a wet day usually gives way to a wet night. The perceived humidity level in East Kazakhstan, measured as the percentage of time during which the level of humidity comfort is characterized as damp, stuffy or heavy, does not change significantly throughout the year, always remaining within 46% and 77%.

You can build a visual model of the humidity indicator using the ArcScene application of the ArcGIS software. In general, the studied goal and the 3D model on the target will help to correctly analyze the result visually. The higher the humidity index, the less likely the soil will degrade and the area will become desaturated. East Kazakhstan region according to the humidity indicator 2000s,2010s, and 2020s the 3D model is shown in Figure 9.

Figure 9. 3D model of humidity in East Kazakhstan

Depending on the operating architecture, humidity values occupy a place between categories 1 and 9. As the values increase, one can observe a change in the model. The primary data obtained during processing must undergo the process of «reclassify», that is, reclassification or reclassification.

Low levels of precipitation and high evaporation of humidity lead to water scarcity and increased desertification processes. As a result, insufficient water resources negatively affect the survival of plants on earth and the soil loses its stability by degrading and turning into sand.

According to the above data, an increase in air temperature in the summer season from +35 to +43°C leads to drought, evaporating water from the soil. The drying of the soil, in turn, leads to a decrease in fertility and the growth of desert areas.

The East Kazakhstan region is in the central part of Kazakhstan and is one of the driest and hottest regions in the country. The influence of temperature and humidity indicators plays an important role in the desertification process in this area.

High temperatures are one of the main factors affecting the desertification of the East Kazakhstan region. Summer temperatures in the area can reach 40-45 degrees Celsius, and this strongly affects the evaporation of water from the soil, contributing to dryness and drought. Desiccation of the soil, in turn, leads to a decrease in fertility and the growth of desert areas.

Humidity is another important indicator affecting desertification. The East Kazakhstan region is characterized by low humidity, especially air humidity. Low precipitation and high evaporation of moisture lead to water scarcity and increased desertification processes. As a result, in the absence of sufficient water, plants cannot survive and the soil loses its stability, becoming sandy.

The combination of high temperature and low humidity affects the formation of sand dunes (dunes), which are moved by the wind. This gives the phenomenon of desertification an additional boost because moving sand dunes makes it difficult for plants to grow and reduces soil fertility. Information about the migration or displacement of sand dunes will be described in the next chapter.

Thus, climatic indicators high temperature and low humidity are one of the main causes of desertification in the East Kazakhstan region. This causes a decrease in soil fertility, an increase in desert areas (dune) and their migration. All these points have a negative impact on the socio-economic and environmental spheres of the region, such as ecosystems and agricultural activities.

4. Conclusions

The study of desertification of the lands of the West and East Kazakhstan region by the remote sensing method is a scientific study that has significant scientific novelty and practical value.

In research case it is important to able to properly clarify difference between «Desert» and «Desertification». Desert is a stable ecosystem, especially 40% territory of Kazakhstan, and desertification is a process that can affect even areas that were once green or fertile. Process of desertification clearly identified in the West Kazakhstan. There are several reasons for occurring desertification process.

Studies have revealed that parameters such as the soil structure of the area, the level of sensitivity of the soil cover plays an important role in the process of degradation and the occurrence of desertification. The sensitivity of the soil of the studied area depends on its structure. A comparative analysis was made for two different areas of Caspian Sea region West and mountain East Kazakhstan, in individual areas there are types of soils that are susceptible to structural degradation. Soil types as: Zg (Gleyic Solonchaks), XI (Luvic Xerosols), So (Orthic Solonetz), WR (Planosols) and KI (Luvic Kastanozems) are found both in the West and in the East of Kazakhstan. According to the logical structure of the work, it can be recorded that the phenomenon of soil degradation occurred precisely in these areas.

The climatic indicators of the studied territories are another important parameter for identifying any process to logically substantiate whether there have been changes on the surface of the land cover. Climate data includes the average annual air temperature, humidity, and precipitation over the past 24 years from 2000 to 2024. By monitoring statistical data and fixing numbers using remote sensing and GIS, it will help to identify a pattern and get the desired result. It is clearly known that amount of precipitation in Western part of country is lower than in Eastern Kazakhstan. The average annual air temperature (+4.4°C) in Eastern Kazakhstan is lower than in the Western part of the country (+10.6°C). The lack of precipitation with 186 mm per year and high temperatures in Western Kazakhstan leads at best to drought, and at worst to desertification. Meanwhile, the amount of precipitation equals 416 mm per year in East Kazakhstan. Humidity can somehow offset the difference between the two regions. Humidity in the Caspian region makes the air «softer» with 64% due to hydrography. The humidity index of Eastern Kazakhstan is 77%, as well as the height of the terrain from west to east, is increasing, as can be seen in Figure 9. The absence of mountains can also indirectly affect the occurrence of desertification.

Remote sensing (remote sensing of the earth) is a method based on the use of special equipment and technologies that allow you to obtain information about the state and properties of the earth's surface by analyzing optical and infrared radiation received by satellites or aircraft. The use of the remote sensing method in the study of desertification of the lands and find differences between West and East Kazakhstan region makes it possible to observe, analyze and evaluate changes in the natural environment in large areas with high spatial resolution. This approach makes it possible to more accurately determine the boundaries and extent of desertification, as well as identify the factors and causes of this process.

The scientific novelty of this study lies in the use of modern remote sensing methods and technologies to identify areas of desertification, analyze and assess its causes and consequences. Moreover, this study can provide new data and knowledge about the factors contributing to desertification in this area, as well as suggest effective measures and strategies to prevent and eliminate desertification. The study of land desertification by the remote sensing method of the West and East Kazakhstan region can be of great practical importance for the development of environmentally sustainable land restoration strategies and plans, as well as for taking measures to protect the environment and preserve biological diversity.

Thus, the study of desertification of the lands of the West and East Kazakhstan region by the remote sensing method is a significant scientific and applied work that can be of great practical importance and contribute to the development of effective measures to prevent and eliminate desertification.

Author contributions

Conceptualization: M.E.A., Y.Z.; Data curation: M.E.A., S.V.T.; Formal analysis: M.E.A., Y.Z., T.B.N.; Funding acquisition: Y.Z., S.V.T.; Investigation: M.E.A., Y.Z.; Methodology: Y.Z., M.E.A.; Project administration: Y.Z., S.V.T.; Resources: M.E.A., Y.Z.; Software: M.E.A., T.B.N.; Supervision: Y.Z., T.B.N.; Validation: Y.Z., M.E.A.; Visualization: M.E.A., T.B.N.; Writing – original draft: M.E.A., Y.Z.; Writing – review & editing: Y.Z., S.V.T. All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan under the framework of the program (Grant No.BR24993218).

Acknowledgements

The authors would like to express their sincere gratitude to the editor and the two anonymous reviewers for their constructive comments and valuable suggestions, which significantly contributed to the improvement of the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

References

[1] Jiang, L., Bao, A., Jiapaer, G., Guo, H., Zheng, G., Gafforov, K., Kurban, A. & De Maeyer, P. (2019). Monitoring land sensitivity to desertification in Central Asia: Convergence or divergence. *Science of the Total Environment, (658), 669-683.* https://doi.org/10.1016/j.scitotenv.2018.12.152

[2] Shao, H., Liu, M., Shao, Q., Sun, X., Wu, J., Xiang, Z. & Yang, W. (2014). Research on eco-environmental vulnerability evaluation of the anning River Basin in the upper reaches of the Yangtze river. *Environmental Earth Sciences, 72(5), 1555-1568.* https://doi.org/10.1007/s12665-014-3060-9

[3] Government website. (2024). About Kazakhstan. Administrative and territorial structure. *Retrieved from*: https://www.gov.kz/article/19305?lang=en

[4] Assanova, M.A. (2015). Public policy and model of sustainable development in the re-public of Kazakhstan. *Asian Social Science, 11(6), 237-243*. https://doi.org/10.5539/ass.v11n6p237

[5] Saigal Kazakhstan. (2015). Issues and approaches to Combat Desertification 2005-2015. *Retrieved from*: https://www.unccd.int/sites/default/files/naps/kazakstan-eng2005.pdf

[6] Baitulin, I.O. (2001). National Strategy and Action Plan to Combat Desertification in Kazakhstan, Sustainable Land Use in Deserts. *Springer, Berlin, Heidelberg*. https://doi.org/10.1007/978-3-642-59560-8_47

[7] Symeonakis, E., Karathanasis, N., Koukoulas, S. & Panagopoulos, G. (2016). Monitoring sensitivity to land degradation and desertification with the environmentally sensitive area index: the case of Lesvos Island. *Island Degrad. Dev., 27(6), 1562-1573.* https://doi.org/10.1002/ldr.2285

[8] Veron, S.R., Paruelo, J.M. & Oesterheld, M. (2006). Assessing desertification. *Journal of Arid Environments, 66(4), 751-763.* https://doi.org/10.1016/j.jaridenv.2006.01.021

[9] Liu, J., Wang, Y., Peng, J., Braimoh, A.K. & Yin, H. (2013). Assessing vulnerability to drought based on exposure, sensitivity and adaptive capacity: a case study in middle Inner Mongolia of China. *Chinese Geographical Science, 23 (1), 13-25.* https://doi.org/10.1007/s11769-012-0583-4

[10] Popov, M.G. (2011). Vegetation of Kazakhstan. Part 2. *Retrieved from*: https://otherreferats.allbest.ru/geography/00008737_0.html

[11] Amirkhanov, M.E. & Zhakypbek, Y. (2023). Remote sensing monitoring of desertification in the Kurchum district of east Kazakhstan region. *International journal Young Scientist, 1.1 (448.1), 13–17*

[12] Saparov, A.S. (2013). Soil Research in Kazakhstan. Annual report. *Retrieved from*: https://www.fao.org/fileadmin/user_upload/GSP/docs/eurasian_workshop/Soils_of_Russiaba.pdf
[13] Zhumabayev, E.E. (2015). Strategic measures to combat desertification in the Republic of Kazakhstan until 2025. *Retrieved from*: https://ecogosfond.kz/wp-content/uploads/2018/06/opustinivanie.pdf
[14] Mamyrkhanova, M. (2022). How the East Kazakhstan region will be divided. *Retrieved from*: https://ru.sputnik.kz/20240117/rf-i-kazakhstan-dogovorilis-ob-uvelichenii-obema-tranzita-nefti-v-knr-do-10-mln-tonn-v-god-41642222.html
[15] Oskemen Annual Weather Averages. (2017). Monthly Average High and Low Temperature. Average Precipitation and Rainfall days. *Retrieved from*: https://www.worldweatheronline.com/Oskemen-weather-averages/East-Kazakhstan/KZ.aspx
[16] Government website. (2024). Committee for construction and housing and communal services of the Ministry of investment and development of the Republic of Kazakhstan. Construction climatology of the Republic of Kazakhstan. *Retrieved from*: https://www.gov.kz/memleket/entities/kds?lang=en
[17] Robinove, C.J., Chavez, P.S., Gehring, D. & Holmgren, R. (2021). Arid land monitoring using Landsat albedo difference images. *Remote Sensing of Environment, (11), 133-156.* https://doi.org/10.1016/0034-4257(81)90014-6
[18] Sun, Q.Q., Zhang, P. Sun, D.F. Liu, A.X. & Dai, J.W. (2018). Desert vegetation-habitat complexes mapping using Gaofen-1 WFV (wide field of view) time series images in Minqin County. China. *International Journal of Applied Earth Observation and Geoinformation, (73), 522–534.* https://doi.org/10.1016/j.jag.2018.07.021
[19] Amirkhanov, M., Zhakypbek, Y., Aben, A. & Mussakhan, N. (2023). Monitoring of glaciation and melting in the east Kazakhstan region. Almaty. *Mining journal of Kazakhstan, (11),* 27-30.
[20] Ehleringer, J.R. (2021). Leaf absorptances of Mohave and Sonoran Desert plants. *Oecologia, (49), 366-370.* https://doi.org/10.1007/BF00347600
[21] Republican State Enterprise Kazhydromet. (2023). An overview of the climate features in Kazakhstan. *Retrieved from*: https://www.kazhydromet.kz/uploads/calendar/192/year_file/6646ff553af2710-05-2024_obzor-osobennostey-klimata_kazahstan-za-2023.pdf

Батыс және Шығыс Қазақстан жерлерінің шөлейттену жағдайын салыстырмалы түрде талдау

М.Е. Амирханов, Ы. Жақыпбек*, С.В. Турсбеков, Т.Б. Нурпеисова
Satbayev University, Алматы, Қазақстан
**Корреспонденция үшін автор: y.zhakypbek@satbayev.university*

Андатпа. Зерттеу бір-бірінен өзгеше, бірақ кейбір жағдайларда ұқсас екі Батыс және Шығыс Қазақстанның аймағына талдау және салыстыру жүргізіледі. Климаттық деректердің өзгеруінің, топырақ құрылымының және оның өзгеру сезімталдығының 2000, 2010 және 2020-2024 жылдардағы Қазақстандағы шөлейттенуге әсері Батыс және Шығыс Қазақстан мысалында сипатталған. Автор екі аймақтың топырақ құрылымында деградацияға бейімделген: Zg, XI, So, WR және KI типтері кездесетіні тіркелді. Климаттық параметрлер, оның ішінде, аймақтың температурасы 3.6-4.9°C аралығында өзгергені белгілі болды, ылғалдылық 64%-77% шегінде болды және әртүрлі уақыт кезеңдеріндегі жауын-шашын мөлшерін салыстыра келгенде 416 мм-ден 605 мм-ге дейін өзгергені анықталды. Қашықтықтан зондтау деректерін пайдалана отырып, автор табиғи ортадағы өзгерістерді талдап, бақылау процесінде визуализациялар мен 3D модельдеуді жасады. Осылайша, қолда бар ғылыми-зерттеу жұмыстарының жиынтығы, статистикалық мәліметтер және өзіндік тәжірибе ұсынылды, өйткені жұмыс барысында шөлейттену бойынша ғылыми зерттеулердің нәтижелері ұсынылды. Зерттеу нәтижелері Қазақстанда жерді шөлейттенудің жеделдетілген процесі жүріп жатқанын көрсетті.
Негізгі сөздер: *шөлейттену, климат, температура, ылғалдылық, жауын-шашын, қашықтықтан зондтау, мониторинг.*

Сравнительный анализ состояния опустынивания земель Западного и Восточного Казахстана

М.Е. Амирханов, Ы. Жақыпбек*, С.В. Турсбеков, Т.Б. Нурпеисова
Satbayev University, Алматы, Казахстан
**Автор для корреспонденции: y.zhakypbek@satbayev.university*

Аннотация. В исследовании проводится анализ и сравнение двух совершенно разных, но в некоторых случаях схожих регионов Западного и Восточного Казахстана. На примере Западного и Восточного Казахстана описано влияние изменений климатических данных, структуры почвы и ее чувствительности на процесс опустынивания в Казахстане за десятилетия 2000-х, 2010-х годов и с 2020 по 2024 год. Автор сравнил и обнаружил, что типы почв: Zg, XI, So, WR и KI встречаются как на Западе, так и на Востоке Казахстана, подверженных деградации почвенной структуры. Климатические параметры, такие как температура воздуха в данной местности, фиксированно колеблются в пределах 3.6-4.9°C, влажность существенно меняется, все время в пределах 64%-77%, а количество осадков в разные периоды времени менялось от 416 мм до 605 мм. Используя данные дистанционного зондирования, автор проанализировал изменения в природной среде, создал визуализации и 3D-моделирование в процессе мониторинга. Таким образом, был представлен набор существующих исследовательских работ, статистическая информация и собственный опыт, поскольку в ходе работы были представлены результаты научных исследований по опустыниванию. Результаты исследования показали, что в Казахстане наблюдается ускоренный процесс опустынивания земель.

Ключевые слова: *опустынивание, климат, температура, влажность, осадки, дистанционное зондирование, мониторинг.*

Publisher's note

All claims expressed in this manuscript are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.