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RATIONAL USE OF AGRICULTURAL LAND OF THE WEST KAZAKHSTAN REGION IN THE CONTEXT OF CLIMATE CHANGE

All over the world, agriculture will have to adapt to new climatic conditions. Experts from the International Food Organization have concluded that after 2030, crop yields will decrease in many regions of the world due to climate change.

For agriculture, the greatest danger is posed by such manifestations of climate change as rising temperatures, changing precipitation patterns, sea level rise (for coastal lowlands) and frequent droughts and floods, especially in areas prone to natural disasters. These changes are affecting agriculture, and the problem of ensuring food security is becoming more acute.

This article discusses the problem of rational use of agricultural land in the Western region of Kazakhstan in the context of climate change. The main focus is on the need to adapt agriculture to new climatic conditions and the efficient use of available land resources. The paper presents the key aspects of this problem, analyzes possible solutions and offers recommendations for the sustainable development of agriculture in the region.

Key words: agricultural lands, Western Kazakhstan, climate change, rational use, adaptation, sustainable development.

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Климаттың өзгеру жағдайында Батыс Қазақстан аймағының ауыл шаруашылық жерлерін ұтымды пайдалану

Ауыл шаруашылығы – экономиканың климаттың өзгеруіне неғұрлым сезімтал секторларының бірі, өйткені ауыл шаруашылығы өндірісі едәуір дәрежеде ауа райы жағдайларына, әсіресе жылу мен жауын-шашынға тәуелді.

Халықаралық азық-түлік ұйымының сарапшылары 2030 жылдан кейін планетаның көптеген аймақтарында климаттың өзгеруіне байланысты дақылдардың өнімділігі төмендейді деген қорытындыға келді.

Ауыл шаруашылығы үшін ең үлкен қауіп – температураның жоғарылауы, жауын-шашынның таралу режимінің өзгеруі, теңіз деңгейінің көтерілуі (жағалаудағы ойпаттар үшін) және жиі құрғақшылық пен су тасқыны сияқты климаттың өзгеруінің көріністері, әсіресе апаттарға бейім аймақтарда. Бұл өзгерістер ауыл шаруашылығына әсер етеді, азық-түлік қауіпсіздігі мәселесі барған сайын өткір бола түсуде.

Бұл мақалада климаттың өзгеруі жағдайында Қазақстанның батыс өңіріндегі ауыл шаруашылығы мақсатындағы жерлерінің қазіргі жағдайына, ауыл шаруашылығы саласында, атап айтқанда, өсімдік шаруашылығы салаларында пайдалану ерекшеліктеріне талдау жасалынды, сондай-ақ оларды ұтымды пайдалану мәселелері қарастырылады. Негізгі назар ауыл шаруашылығын жаңа климаттық жағдайларға бейімдеу және қолда бар жер ресурстарын тиімді пайдалану қажеттілігіне аударылады. Жұмыста осы мәселенің негізгі аспектілері ұсынылған, ықтимал шешімдер талданады және аймақтағы ауыл шаруашылығының тұрақты дамуы үшін ұсыныстар айтылады.

Түйін сөздер: ауыл шаруашылығы мақсатындағы жерлер, Батыс Қазақстан, климаттың өзгеруі, ұтымды пайдалану, адаптация, тұрақты даму.

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Рациональное использование сельскохозяйственных земель Западного Казахстана в условиях изменения климата

Сельское хозяйство – один из наиболее чувствительных к изменению климата секторов экономики, поскольку сельскохозяйственное производство в значительной степени зависит от погодных условий, особенно от жары и осадков.

Эксперты Международной продовольственной организации пришли к выводу, что после 2030 года во многих регионах планеты урожайность сельскохозяйственных культур будет снижаться из-за изменений климата.

Для сельского хозяйства наибольшую опасность представляют такие проявления изменения климата, как повышение температуры, изменение режима распределения осадков, подъём уровня моря (для прибрежных низменностей) и частые засухи и наводнения, особенно в областях, предрасположенных к стихийным бедствиям. Эти изменения влияют на сельское хозяйство, всё более острой становится проблема обеспечения продовольственной безопасности.

В данной статье проанализировано современное состояние земель сельскохозяйственного назначения в западном регионе Казахстана в условиях изменения климата, особенности использования их в сельскохозяйственной сфере, в частности, в растениеводческих отраслях, а также рассматриваются вопросы их рационального использования. Основной акцент делается на необходимости адаптации сельского хозяйства к новым климатическим условиям и эффективному использованию доступных земельных ресурсов. В работе представлены ключевые аспекты данной проблемы, анализируются возможные решения и предлагаются рекомендации для устойчивого развития сельского хозяйства в регионе.

Ключевые слова: сельскохозяйственные земли, Западный Казахстан, изменение климата, рациональное использование, адаптация, устойчивое развитие.

Introduction

Arid and semi-arid regions are defined by unfavourable environmental conditions, including low and erratic precipitation, high wind speeds, intense solar radiation, and high evapotranspiration potential for much of the year (Modarres and da Silva 2007). These regions cover approximately 41% of the Earth's land surface and are home to over one-third of the world's population (Golla 2021). Livestock production in arid and semi-arid regions is highly susceptible to temperature increases and rainfall decreases (Rojas-Downing et al. 2017; Balamurugan et al. 2018). The optimal temperature range for livestock is between 10-30°C, with feed intake decreasing by 3-5% for every degree increase in temperature. Conversely, lower temperatures would increase feed requirements by up to 59%. Furthermore, climate change scenarios are expected to have a significant impact on livestock production, particularly through drought and heat stress (Habeeb, Gad, and Atta 2018). Climate variability can impact the occurrence and transmission of various diseases in livestock. For instance, increased rainfall can lead to Rift Valley Fever (RVF), while increased temperatures can cause tick-borne diseases (TBDs) to become epidemics among sheep, goats, cattle, and camels (Bett, Lindahl, and Delia, 2019). Rising temperatures and water shortages can affect different livestock breeds in different ways.

In arid regions of Asia, extreme variability in rainfall and drought stress have resulted in severe feed shortages (Arunrat, Pumijumnong, and Hatano 2018).

Central Asia is classified as drought-prone and is one of the most vulnerable areas to moisture deficit in the world (Dubovyk et al. 2019; Guo 2018). Based on the findings of foreign scientists, rising temperatures, decreasing precipitation, and increasing evaporation in Central Asia (Lioubimtseva and Henebry 2009; Yin et al. 2016) heighten the vulnerability of ecosystems to droughts due to limited water resources, low adaptive capacity, and a growing population (Zheleznova et al. 2022).

The rate of increase in air temperature in Kazakhstan, located in the northern part of Central Asia, has been somewhat faster in recent decades compared to other regions of the world located in the same latitudinal zone. Based on measurements from 110 meteorological stations for the period from 1950 to 2020, it reached 0.31 °C (Karatayev et al.

2022; Zheleznova et al. 2022). In Kazakhstan, the air temperature has notably increased in the last two decades, while there has been no significant trend in precipitation (Li et al. 2017).

The most widespread phenomena in Kazakhstan, in terms of frequency and impact on the environment, population, and economy of the region, are atmospheric droughts (Zheleznova et al. 2022). In recent decades, their study has received special attention due to their high social and economic consequences for the region. Droughts have occurred throughout the country with varying frequency and intensity, with the highest frequency during the growing season. Dubovyk et al. (2019) reported that Kazakhstan experienced drought every year between 2000 and 2016.

An increase in the frequency of droughts in Kazakhstan may have several negative consequences, such as soil degradation, reduced or complete loss of crop yields, and an increased risk of forest fires. It is important to note that the drought in 2021 in the southern and southwestern regions of Kazakhstan caused significant damage to the country's agricultural sector. According to official data from the Ministry of Agriculture, 1,714 heads of livestock died due to drought in the Mangistau and Kyzylorda regions in 2021.

Agriculture is a significant contributor to Kazakhstan's economy, accounting for 10 to 38 percent of GDP and employing 18 to 65 percent of the population. Adapting to and mitigating drought can help reduce the negative impacts of climate change. Greenhouse gas emissions are expected to continue increasing over the next 30 years, and mitigation efforts will not be universally effective. Adapting to complex natural conditions should be a crucial policy step towards addressing climate change (Bolatova, Abulkhairova, and Kulshigashova 2022).

Considering the aforementioned issues, the article's main objective is to examine the rational use of agricultural land in the West Kazakhstan region in light of climate change. This will be achieved through the analysis of long-term climatic and statistical data on land resources, as well as the use of satellite images.

Materials and methods

This study focuses on the Western region of Kazakhstan, which includes the Aktobe, Atyrau, West Kazakhstan, and Mangistau regions (see Figure 1).

The study area extends from 41°N to 51°N, which significantly influences the thermal regime. It extends from 45°27′E to 56°E in the west to east direction. The region is far from oceanic waters, which affects its climatic features.

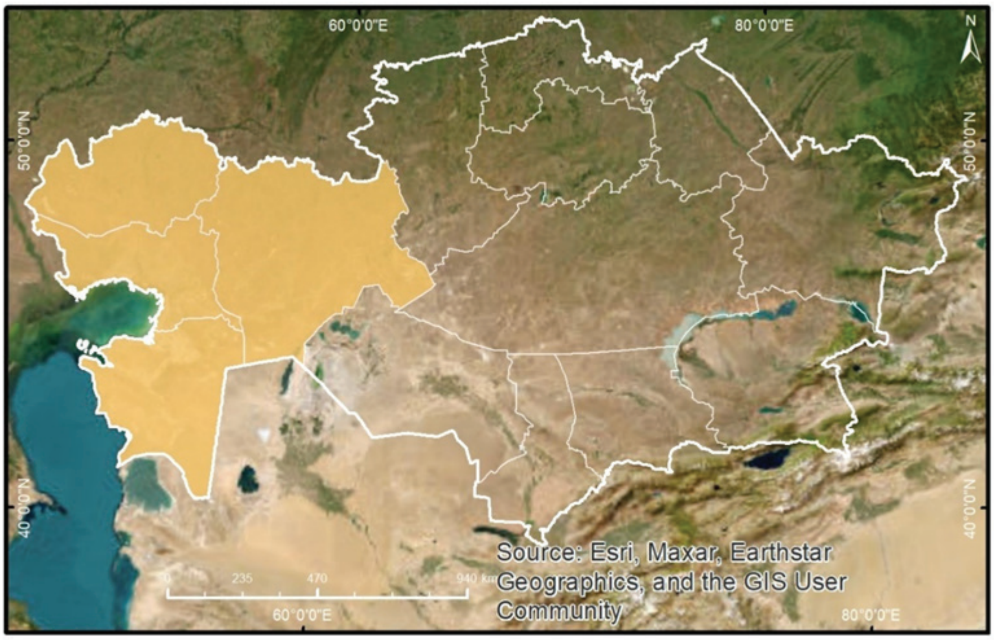


Figure 1 – Object of the study

It comprises three natural landscape zones: 1) the southern subzone of tipchak-covy steppes, which is a steppe; 2) a semi-desert zone; and 3) a desert that is subdivided into two subzones, northern and southern.

The study area exhibits heterogeneous climatic conditions due to its significant extension from north to south. The average January air temperature increases from -15°C in the north to -2°C in the south. Similarly, the July isotherms follow the same pattern, with temperatures rising from north to south, from +22°C to +27°C in the northern half of the region. The precipitation levels exhibit a consistent decrease from north to south, ranging from 350 mm to 150 mm. An isohyet of 150 mm almost follows the meridian, dividing the Mangistau region into a relatively wet western area and a dry eastern area.

The major waterways are situated in the northern section of the study area, with the Ural River being the largest. In the southern half of the study region, there is no surface runoff, except for dry channels on the slopes of Karatau and Aktau, as well as some chinks associated with spring snowmelt and rare rainfall.

Soil formation processes in the region follow zonal regularities. The northern steppe region of the territory is part of the subzone of southern low humus chernozems. The humus content in the upper horizon averages about 5%. Southward, the chernozems give way to dark chestnut soils, with the upper horizon containing 3-4% humus. Various types of soils, including typical, carbonate, saline, and carbonate-saline varieties, are present. Further south, these soils are replaced by light chestnut soils. All of these soils are solonetzified and occur in complex with solonets. The desert zone is characterised by brown soils, while grey-brown soils prevail in Ustyurt. Meadow soils are widespread in the river valleys, which are valuable fodder lands. A significant portion of the region under study is occupied by solonchaks and soras, which are types of saline soils. Additionally, a significant part of the region is occupied by sandy massifs.

The northern narrow steppe strip of the region has been almost completely ploughed, previously this area was a typechak cotyledonous steppe. Tree and shrub vegetation is only present in the river valleys, including alder, willow, rosehip, and tamarix. To the south, the vegetation changes to semi-desert wormwood-grass vegetation. On saline lands, vegetation is represented by halophytes. Meadow vegetation is widespread in river valleys.

The text concludes with a mention of the initial materials and methods of research. The study is based on the system method, which allows for a comprehensive and comparative analysis of measures to improve and maintain soil fertility and land resource utilization (Bertalanfi 1969). The article employs traditional and modern research methods, including comparative, historical, statistical, and cartographic methods, as well as remote sensing data and GIS products.

Background information was collected mainly from foreign and domestic literature sources. All collected factual materials related to the study area were analysed. Secondly, specific information on qualitative conditions and hydrological features of soils of the territory was obtained from the data of local executive bodies and land relations management bodies. In the description of climatic conditions in the study area, data on average annual air temperature and precipitation obtained from meteorological stations in Uralsk, Aktobe, Shalkar, Atyrau, Kulsary, Aktau and Beineu for the period from 2002 to 2022 were used.

Information on the use of agricultural land was obtained from reports of the Department of Agriculture of the regions, statistical summaries of the Committee on Statistics of the Republic and consolidated analytical reports of the Committee on Land Resources Management.

This study used NASA MODIS/Terra 16-day L3 Global 250 m SIN Grid V005 (MOD13Q1) surface reflectance data between 2002 and 2022 for the growing season.

The MODIS data was reformatted from a sinusoidal projection to Mercator Universal Transverse Coordinate Systems and then distributed across the study area. EVI and NDVI were subsequently calculated using the following equations:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$ or NDVI = (B5-B4) / (B5+B4) (Kriegler 1969)

$$EVI = 2.5 * \frac{(NIR - Red)}{(NIR + 6 * Red - 7.5 * Blue + 1)}$$ or EVI = 2.5* (B5-B4) / (B5+6*B4-7.5*B2+1) (Liu and Huete 1995)

Where MODIS bands 1, 2, and 3 correspond to red (620-670 nm), near-infrared (841-876 nm), and blue (459-479 nm), respectively.

Results and discussion

The study focuses on the West Kazakhstan region, which covers 736.2 thousand km2 (27% of Kazakhstan's total area) (Figure 2). It comprises the administrative districts of Aktobe, Atyrau, West Kazakhstan, and Mangistau regions.

As of 1 November 2022, the agricultural land area in Western Kazakhstan was 27.27 million has, accounting for 23.5% of the country's total agricultural land area. The Aktobe region accounts for the largest share of this area, with 13.1 million has (48.4%), followed by the Atyrau region with 3.2 million has (11.7%), the West Kazakhstan region with 7.9 million has (28.9%), and the Mangistau region with 3 million has (11%).

The majority of the agricultural land in the West Kazakhstan region is comprised of pastures. In West Kazakhstan, pastures make up 92.5% of agricultural land, while arable land accounts for only 2.2%, hayfields for 2.9%, fallow land for 2.3%, and perennial plantations for approximately 0.1%.

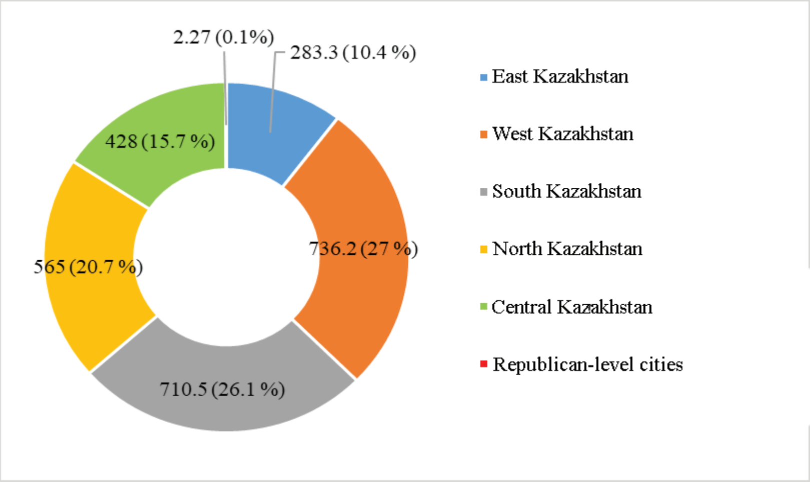


Figure 2 – Regional division of the territory of Kazakhstan, km^2 (%).

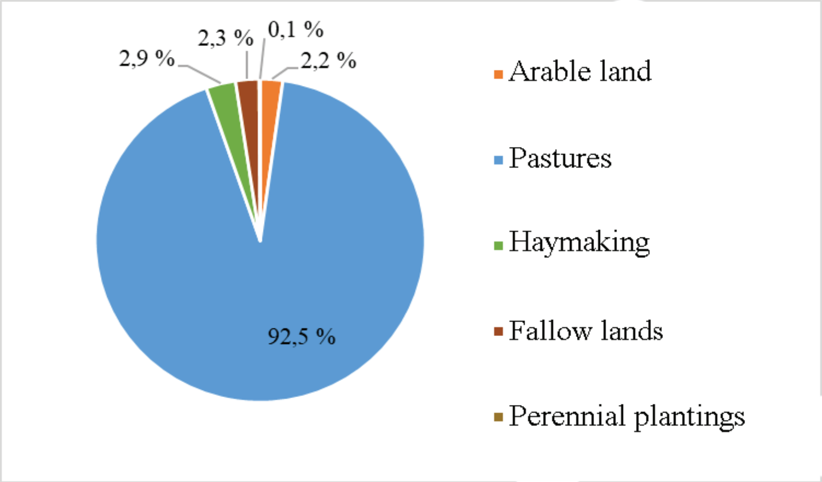


Figure 3 – Structure of agricultural land in the Western region, %

The Aktobe region boasts the largest massif of agricultural land in the region, accounting for almost 43% of all agricultural land in West Kazakhstan. The two largest arrays of arable land are found in Aktobe (749.5 thousand ha) and West Kazakhstan (623.3 thousand ha), which together make up 99.26% of the region's arable land. Additionally, the largest hayfields and fallow lands are concentrated in these two regions (Table 1).

Table 1 – Area of agricultural land by oblasts of the Western region as of 1 November 2022, thousand ha

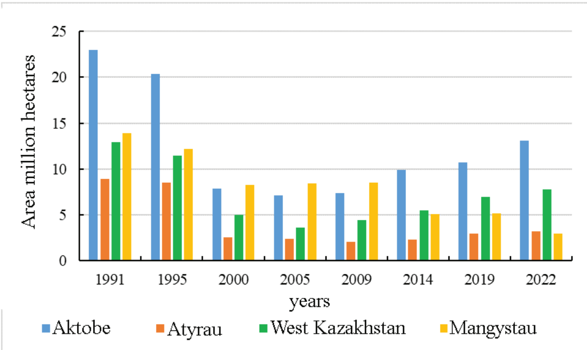
Name of the regions	Total farmland	including					
		Arable land		Perennial plantings	Fallow	Haymaking	Pastures
		total	irrigated				
Aktobe	26 970,2	749,5	12,3	1,6	453,0	464,6	25 301,5
Atyrau	9 767,2	9,3	9,1	0,8	11,3	132,9	9 612,9
West Kazakhstan	13 888,9	623,3	27,4	2,7	964,3	1 235,6	11 063,0
Mangystau	12 634,5	0,8	0,8	0,5	0,3	0,3	12 632,3
Total	63 260,8	1 382,9	49,6	5,6	1428,9	1 833,4	58 609,7

Between 1991 and 2005, the area of agricultural land in the region decreased by 37.2 million ha due to the reform of agricultural enterprises. However, since then, the area of land in this category has increased annually, with a total increase of 5.6 million has from 2005 to 2022 (Figure 4 a,c). The development of reserve land (Figure 4 b,d) has led to the increase in agricultural land since 2005. Furthermore, due to the efforts of the Agribusiness Development Programme 2017-2021, the agricultural land area in the western region has expanded by 2.6 million ha since 2017 (refer to Figure 4 c,d). According to the Republic of Kazakhstan Bureau of National Statistics (2022) , the area of sown grain crops increased from 634.7 thousand ha to 845 thousand ha, while the sown areas of potatoes, melons, and vegetable crops increased from 26 thousand ha to 48.3 thousand ha. Additionally, the sown areas of oilseeds increased from 72.6 thousand ha to 274.3 thousand ha, and the sown areas of fodder crops increased from 377.8 thousand ha to 443.3 thousand ha. In recent years, the region has seen a significant increase in arable land. However, there has been a decrease in gross yield and productivity of agricultural crops. The following section describes the changes in agricultural land.

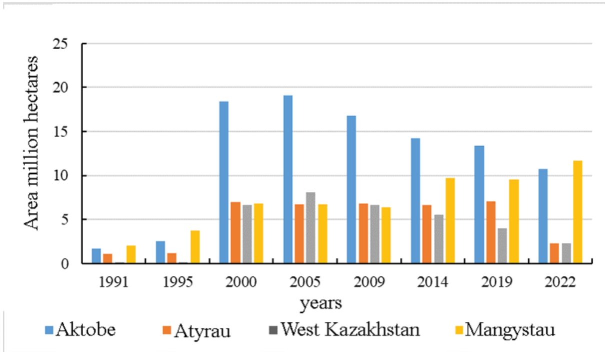
Between 1991 and 2022, the arable land in the region decreased from 4,171.3 thousand has to 1,382.9 thousand has, a reduction of 2,788.4 thousand has over the last 30 years. The area of arable land in the region experienced a significant decline in 2000 and 2014 (see Figure 5a) (Report 2023; Kazakhstan 2021, 2015, 2009; 2005; 2002)). The primary cause of this decline is the drought trend in the area. Dubovyk et al. (2019) found that between 2000 and 2014, over 50% of the country's territory experienced varying degrees of drought, with the most widespread droughts occurring in 2012 and 2014. Bolatova et al. (2022) also reported that the severe drought in 2021 resulted in significant economic losses and changes in cropped areas. As a result of agro-industrial complex development programmes, the total area of arable land in the region increased from 2014 to 2022 to 4.3 million has, despite some of the arable land being designated as fallow land during this period (Figure 5b).

In 2022, the total area of hayfields in the region was 1,833.4 thousand ha, with the majority located in West Kazakhstan Oblast (1,245.1 thousand ha) (Figure 5d). West Kazakhstan Oblast accounts for 67.4% of hayfields in the region and 24.2% of the total area of hayfields in Kazakhstan, according to the Summary analytical report on the state and use of land (2023).

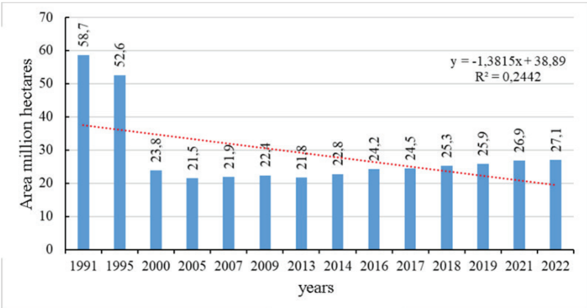
Additionally, the area of pasture land in the region has decreased in recent years. Between 2017 and 2022, the pasture area in the region decreased by 47.9 thousand has (Figure 5c). This reduction is attributed to the allocation of some pastures for the construction of non-agricultural facilities and their conversion into other lands, including arable land.



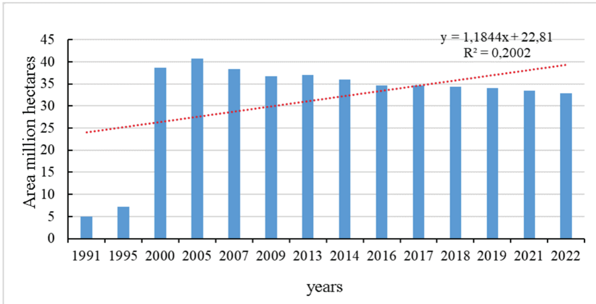
a) Dynamics of agricultural land area by region for 1991-2022, Mha



b) Dynamics of the reserve land area by region for 1991-2022, Mha

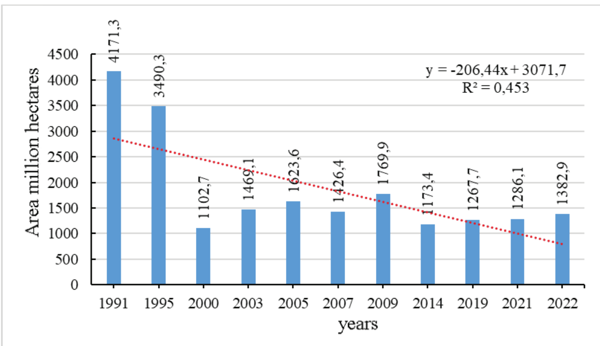


c) Dynamics of agricultural land area in the region for 1991-2022, Mha

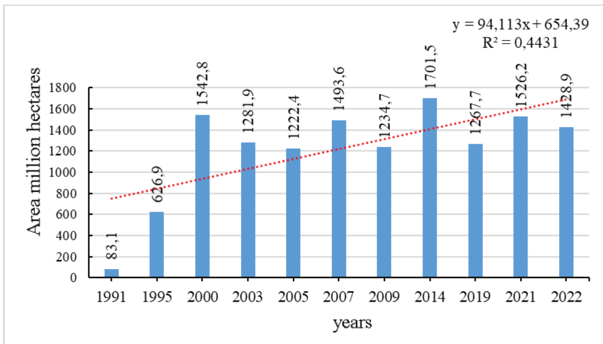


d) Dynamics of the reserve land area in the region for 1991-2022, Mha

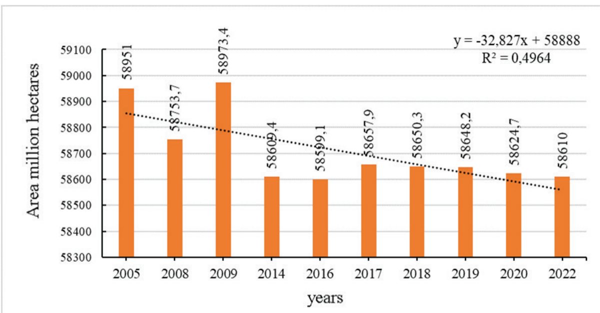
Figure 4 – Dynamics of the area of agricultural and reserve lands in Western Kazakhstan (1991-2022), million ha



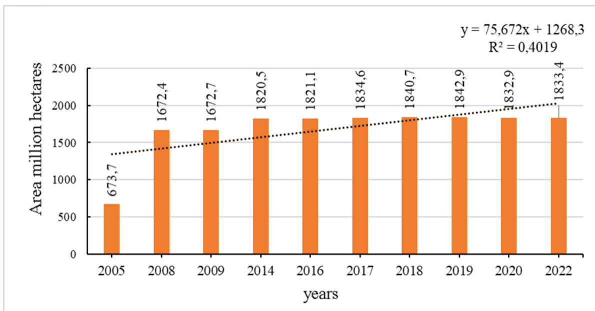
a) Dynamics of arable land area in the region for 1991-2022 thousand hectares



b) Dynamics of the fallow lands area in the region for 1991 – 2022 thousand hectares



c) Dynamics of the area of pastures in the region for 2005-2022, million hectares



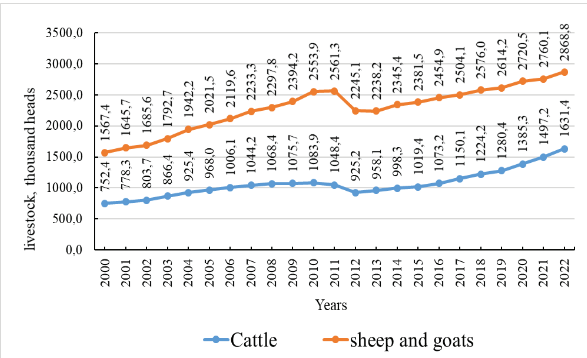
d) Dynamics of the area of hayfields in the region for 2005-2022, million hectares

Figure 5 – Structure of agricultural land in the region (1991-2022)

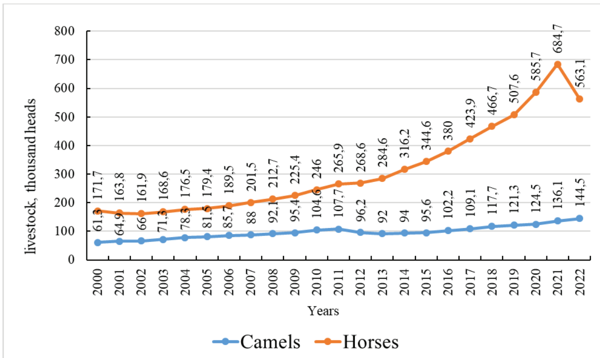
Agriculture is a crucial sector for the economy of the West Kazakhstan region. The living standards of the population, provision of the region with basic foodstuffs of own production, and the activity of processing enterprises and other related branches of agriculture depend on its condition and development. Livestock is the primary branch of agricultural production in most of the region, serving as the basis for economic development, income, and employment in rural areas. In 2022, the region's gross agricultural output totalled 919,921.5 million tenge, accounting for 9.7% of the country's total output. Livestock production accounted for 58% (533,432.1 million tenge) of this output, while crop production accounted for 42% (386,489.4 million tenge).

The analysis of the state and development of agriculture over the past 22 years indicates positive changes in agricultural production since 2000, which can be attributed to state support of the agricultural sector. In 2014, the total sown area in crop production increased by 209.5 thousand has compared to 2022 (see Figure 5a). The Republic of Kazakhstan Bureau of National Statistics reported an increase in the area under cereal crops from 634,700 ha to 845,000 ha, potato, melon and vegetable crops from 26,000 ha to 48,300 ha, oilseed crops from 72,600 ha to 274,300 ha, and fodder crops from 377,800 ha to 443,300 ha between 2017 and 2022. However, despite the significant increase in arable land, there has been a trend of decreasing gross yield and productivity of agricultural crops in recent years. In 2017, the region harvested a total of 850.2 thousand tonnes of cereals and leguminous crops. However, by 2021, this figure had decreased by half, resulting in a total harvest of 418.3 thousand tonnes. Additionally, the yield of grain and leguminous crops in the region was 12.3 centners per 1 ha in 2017, but this decreased to 5.8 centners per 1 ha in 2021.

Although the livestock industry in the region has grown in recent years, the pasture area – which is the main source of fodder for livestock – decreased by 47.9 thousand hectares in 2017-2022 (Figure 5c). This reduction has led to a violation of the maximum permissible load on the total area of pastures in the region. According to the National Bureau of Statistics of the RK, the number of horses, cattle, sheep, and goats in the region more than doubled between 2000 and 2022. According to the Republic of Kazakhstan Bureau of National Statistics (2022) the number of cattle in the region increased from 752.4 thousand to 1631.4 thousand heads between 2000 and 2022. Similarly, the number of camels increased from 61.3 thousand to 144.5 thousand heads, and the number of small cattle increased from 1567.4 thousand to 2868.8 thousand heads (Figure 6 a,b). Additionally, the number of horses in the region increased almost fourfold from 171,700 to 684,700 head between 2000 and 2021. However, the number of horses in the region decreased by 121.6 thousand head to 563.1 thousand head in 2022.



a) Livestock of cattle, sheep and goats by region, thousand heads



b) Number of camels and horses by region, thousand heads

Figure 6 – Population data by livestock sector in the region

Despite the fact that the West Kazakhstan region is well provided with pasture land in comparison with other regions of the country, most of the pasture land in the territory is located within the reserve areas. In 2022, Aktobe Oblast will have 25,301.5 thousand hectares of pasture land, including 13,393.8 thousand hectares of agricultural land, 8,030.1 thousand hectares of reserve land and 3,877.6 thousand hectares of residential land (Figure 7) (Report 2023).

In the Atyrau region, over 60% of the 9,612.9 thousand hectares of pasture lands are within reserve lands, which amounts to 5,775.9 thousand hectares. Similarly, in the Mangistau oblast, over 70% of the 12,362.6 thousand hectares of pasture lands are within reserve lands, which amounts to 8,667.6 thousand hectares (see Figure 7). As shown in Figure 8, public farms own the majority of livestock and poultry in the area, and therefore, they use pasture lands near the settlements.

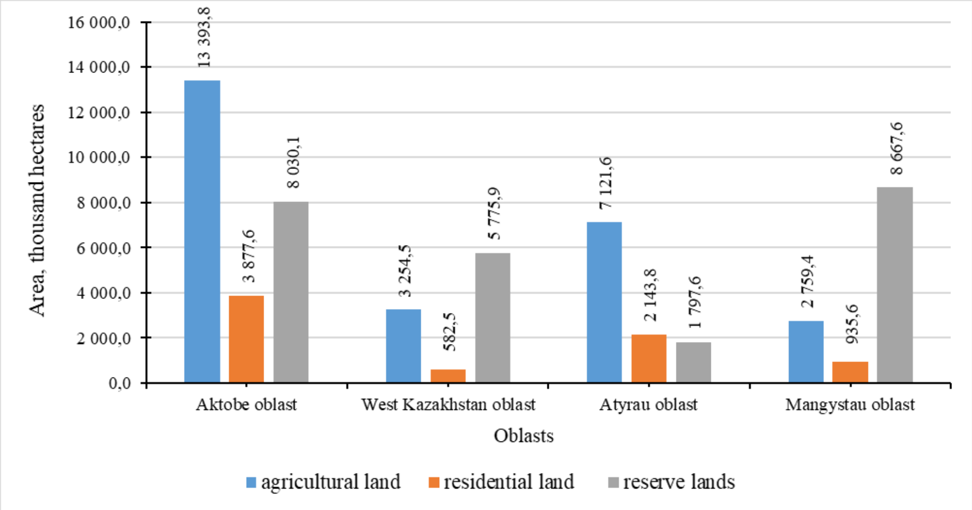


Figure 7 – Structure of pasture lands, thousand ha

According to the Republic of Kazakhstan Bureau of National Statistics (2022), Figure 8 illustrates that the public owns 44.1% of cattle, 46.9% of small cattle, 22.1% of horses, and 40% of camels in the area. Additionally, Figure 7 shows that the area of pastures near settlements in Atyrau oblast is 582.2 thousand ha, while in Mangistau oblast, it is only 935.6 thousand ha.

Overgrazing on pastures near the settlement leads to the violation of normative load, resulting in accelerated degradation processes.

According to the legislation of the Minister of Agriculture of the Republic of Kazakhstan from 14 April 2015 № 3-3/332, which approves the maximum permissible norm of load on the total area of pastures, there is a deficit of 1,264.3 thousand hectares of pasture lands for public farming in Atyrau region and 1,021.2 thousand hectares in Mangistau region as of 2022. As of 2022, there are 155.3 thousand heads of livestock in the households of the population of Mangistau region, in accordance with the legislation of the Ministry of Agriculture of the Republic of Kazakhstan (No. 3-3/332, dated 14 April 2015). The norm in Mangistau region is 12.6 hectares per head, and the area of pasture lands on the lands of settlements in the region is 935.6 thousand hectares.

Agriculture is well developed in the region despite the challenging agro-climatic conditions. Spring wheat is grown and cattle are raised in the northern part of the region, while farming is limited in the southern regions due to water scarcity, making livestock breeding a more favourable option. West Kazakhstan and Aktobe oblasts lead in almost all types of livestock production in the region (Figure 9 a,b,c), while only Mangistau and Atyrau oblasts dominate in camel farming (Figure 9 d).

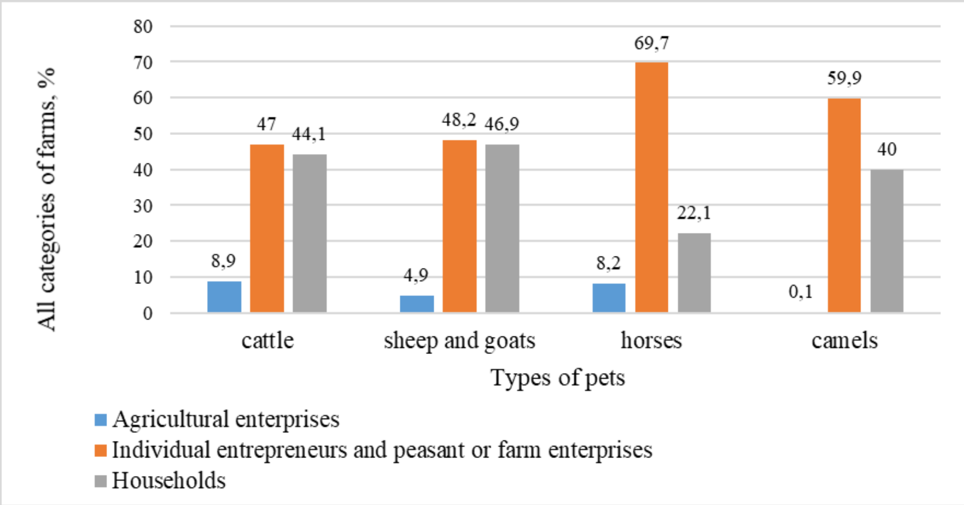


Figure 8 – Livestock in all categories of farms

Cattle breeding is a dominant industry in the region, with beef cattle comprising over 80% of the total livestock. The remaining animals are raised for dairy, meat, and dairy-meat purposes (Traisov and Bozymova, 2004). The region ranks third in terms of cattle population, following the southern and northern regions, and accounts for 18.3% (1,631,400 head) of the total cattle population in the republic. The region ranks third in terms of cattle population, following the southern and northern regions, and accounts for 18.3% (1,631,400 head) of the total cattle population in the republic. The region mainly develops the Kazakh white-headed breed among the beef breeds, while Simmental, black-mottled, and red-steppe breeds represent the dairy cattle.

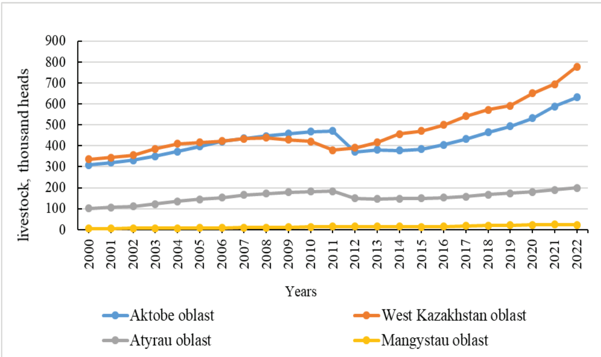
In 2022, the number of cattle in Aktobe region was 632.3 thousand, 777.5 thousand in West Kazakhstan region, 198.8 thousand in Atyrau region, and 22.8 thousand in Mangistau region. It should be noted that the number of cattle in Aktobe, West Kazakhstan, and Atyrau regions has doubled from 2000 to 2022, while in Mangistau region it has quadrupled. The number of cattle in Mangistau region increased from 5.5 thousand heads in 2000 to 22.8 thousand heads in 2022. However, in comparison to 2021, it decreased by 1.0 thousand heads (Figure 9a). The main reason for this decrease is the death of 1,714 cattle due to drought in Mangistau Oblast in 2021.

The main industry in the region is sheep breeding. Approximately 60% of the livestock consists of sheep of meat-shearing breed, while the remaining 40% are sheep of meat-wool breeds (Traisov 2004). The West Kazakhstan region is the second-largest producer of small ruminants in the country, after the South Kazakhstan region, accounting for 16.2% of the total. In 2022, the Aktobe region had a total of 1,312,000 small ruminants, while the West Kazakhstan region had 1,306,600, the Atyrau region had 597,000, and the Mangistau region had 332,900.

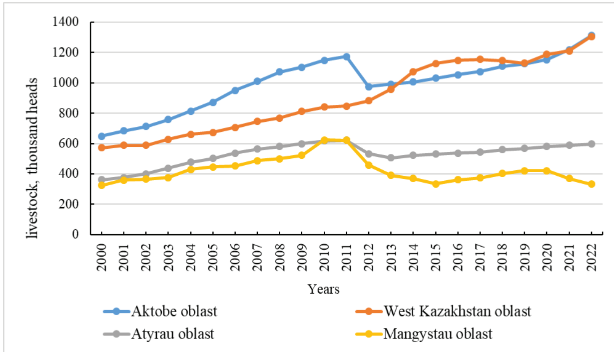
Horse and camel breeding are traditional sectors in the region. In 2022, the number of camels in the region was 144.5 thousand, which is 2.5 times more than in 2002. The West Kazakhstan region ranks first in the country for the number of camels, accounting for 56%. The Mangistau region accounts for 60% of the camels in the region.

Analyses of livestock population trends in the region indicate that the sharpest declines in all livestock species occurred in 2012, 2014, and 2021. The 2021 drought had a significant impact on horse production, among other factors. In 2021, the region had 684,700 horses. In 2022, the number decreased by 121,600 to 563,100. Agricultural drought is characterized by reduced soil moisture, which causes plant stress, reduced productivity, and yield. The onset of agricultural drought may differ significantly from that of meteorological drought, depending on the available moisture reserves in the soil before the start of the dry period.

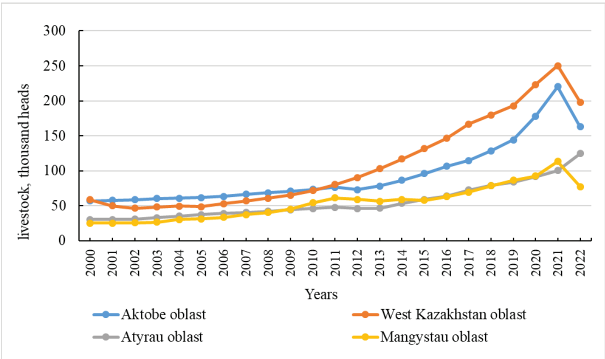
In order to mitigate the effects of drought, it is necessary to detect drought in a timely manner, to monitor its development and to assess the damage in a timely manner. To solve these tasks of drought monitoring over large areas in an operational mode requires the use of not only traditional ground-based but also space-based observations.



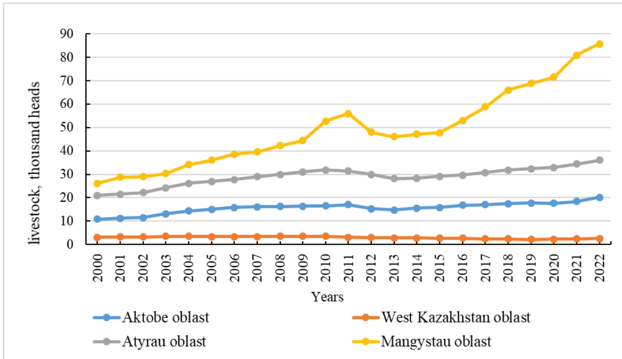
a) Number of cattle, thousand heads



b) Number of sheep and goats, thousand heads



c) Number of horses, thousand heads



d) Number of camels, thousand heads

Figure 9 – Dynamics of livestock population by oblast

Traditional methods of detecting drought and assessing its parameters use ground-based meteorological observations (precipitation, soil and air surface temperature, soil and air humidity). Different indices have been proposed for different natural conditions to assess the intensity of drought Space-based monitoring of agricultural drought has been addressed by researchers in several countries around the world. They have proposed many methods based on indices, which are fractional-linear combinations of spectral channels in the visible, near-infrared and thermal spectral bands. They allow differences in reflectance (usually in the red and near-infrared bands) of vegetation under normal and stressed conditions to be taken into account. Earth remote sensing (ERS) data track crop health in terms of projected land cover and the temperature regime of an area. Signs of drought from remote sensing data are identified using the Normalised Difference Vegetation Index (NDVI) and the brightness temperature of the underlying surface, as well as various combinations of these parameters. To check the suitability of the indices used in the study area, it is desirable to compare them with actual data on the hydrothermal regime of the study period and crop yields.

Normalised Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) as the main vegetation indices for the West Kazakhstan region are calculated on the basis of MODIS data (MOD13Q1) for the spring and autumn seasons of 2002, 2012 and 2022 (Figure 10). At the present stage (to date) for the assessment of vegetation is widely used index (NDVI) is the primary analytical product of remote sensing, which alleviates the complexity of multispectral sections. In the presented work, the quantitative indices of NDVI sections per study area have the following subdivisions 0 to 0.15 – very low, 0.15-0.2 – low, 0.2-0.4 – medium; 0.4-0.5 – high and above 0.5 – very high density indices (Table 2 and Figure 10).

Figure 8 shows significant changes in the vegetation cover of Western Kazakhstan between 2002 and 2022, based on the results of MODIS data analysis (Kudaibergenov et al. 2023).

The study results on vegetation cover density in Western Kazakhstan indicate changes in land area across different classes. The area of land in the very low (0-0.15) and low (0.15-0.2) classes increased, while the area in the medium (0.2-0.4), high (0.4-0.5), and very high (>0.5) classes decreased (refer to Table 2). For instance, in 2002, the area of land classified as very low class (0-0.15) was 0.78 million ha, which increased sharply to 19.21 million ha in 2022, an increase of 18.43 million ha or 2643%. Similarly, the area of land classified as low class (0.15-0.2) was 14.05 million ha in 2002, which increased to 17.48 million ha in 2022, an increase of 3.43 million ha or 124.4%.

Table 2 – Dynamics of changes in vegetation cover indicators (NDVI) of the West Kazakhstan region for 2002, 2012 and 2022

NDVI Classes	NDVI 2002		NDVI 2012		NDVI 2022		Changes in the period from 2002 to 2012		Average rate of change		Changes in the period from 2012 to 2022		Average rate of change	
	area		area		area		area		area		area		area	
	million ha	%	million ha	%	million ha	%	million ha	%	million ha /year	%	million ha	%	million ha /year	%
Very low (0-0.15)	0.78	1.0	12,9	17.7	19.21	26.4	+12.12	+1554	+1.21	+155.4	+6.31	+48.9	+0.63	+4.5
Low (0.15-0.2)	14.05	19.3	28,16	38.7	17.48	24	+14.11	+100.4	+1.41	+10.04	-10.68	-37.9	-1.06	-3.79
Average (relatively good indicator.) (0.2-0.4)	24.13	33.2	21,1	29	15.72	21.6	-3.03	-12.5	-0.30	-1,25	-5.38	-25.5	-0.53	-2.55
High (good indicator) (0.4-0.5)	20.54	28.3	8,32	11.4	12.38	17	-12.22	-59.5	-1.22	-5.95	+4.06	+55.3	+0.40	+5.53
Very high (>0.5)	13.27	18.2	2,29	3.2	7.98	11	-10.98	-87.2	-1.09	-8.72	+5.69	+248.4	+0.57	+24.8
Total	**72,77**	**100**	**72,77**	**100**	**72,77**	**100**	-	-	-	-	-	-	-	-

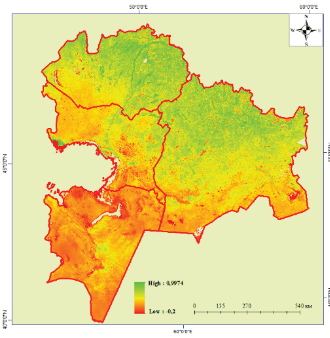
There has been a decrease in area for land classified as medium, high, and very high. Specifically, the area of land classified as medium class (0.2-0.4) decreased from 24.13 million ha in 2002 to 15.72 million ha in 2022, a decrease of 8.41 million ha. Similarly, the area of land classified as high class (0.4-0.5) decreased from 20.54 million ha in 2002 to 12 million ha in 2022. In 2022, the area of land classified as very high class (>0.5) decreased by 5.29 million ha to 7.98 million ha, compared to 13.27 million ha in 2002 (a decrease of 8.16 million ha) (Table 2 and Figure 10).

During the study period of 2002, 2012, and 2022, the lowest vegetation values were observed in 2012. The land area of the highest vegetation class (0.4-0.5) in the study area was only 8.32 million ha in 2012, but increased by 4.06 million ha to 12.38 million ha in 2022. Additionally, the area of the very high land cover class (>0.5) was only 3.2 million ha in 2012, but increased by 5.69 million ha to 7.98 million ha in 2022 (Table 2 and Figures 9) (Kudaibergenov et al. 2023).

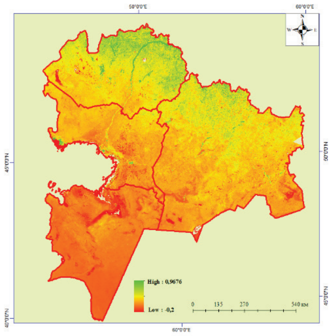
During the analysis of the dynamics of vegetation cover change in the West Kazakhstan region based on remote sensing data, the data of average annual air temperature and precipitation obtained from meteorological stations in Uralsk, Aktobe, Shalkar, Atyrau, Kulsary, Aktau, and Beineu for the period from 2002 to 2022 were used to correlate the obtained data. The average annual air temperature in West Kazakhstan Oblast for the same period was also considered. Data from meteorological stations in Atyrau, Kulsary, Aktau, and Beineu show an increase of 1.5°C, while data from Ural, Aktobe, and Shalkar meteorological stations show an increase of 0.4°C (Kazhydromet 2022).

The highest annual average temperature was recorded in 2007-2008, 2010, 2014-2015, and 2021, according to all meteorological stations in the study area. These findings are consistent with the studies conducted by Dubovyk et al. (2019) and Zheleznova et al. (2022).

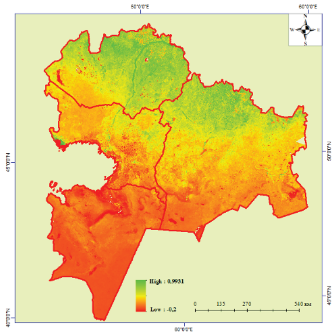
When analysing vegetation cover indicators in the West Kazakhstan region for 2002, 2012 and 2022 based on MODIS data, it was found that the lowest indicator was recorded in 2012. This was due to a sharp increase in the average annual air temperature in the region, as reported by meteorological stations in Atyrau, Kulsary, Aktau and Beineu, which began in 2011 (refer to Figure 11a).



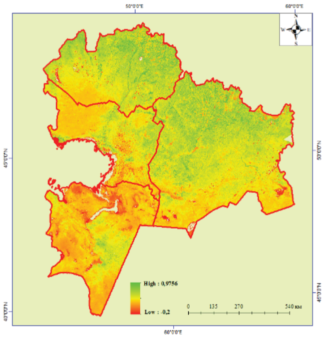
2002 (NDVI)



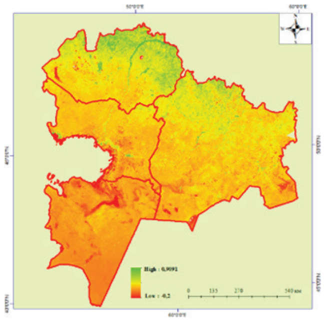
2012 (NDVI)



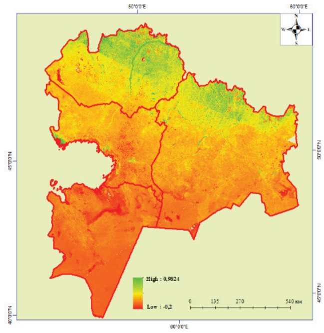
2022 (NDVI)



2002 (EVI)



2012 (EVI)

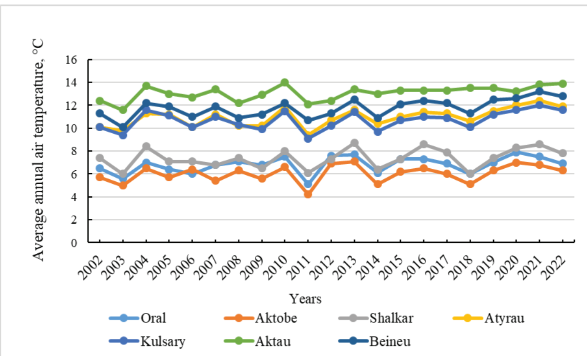


2022 (EVI)

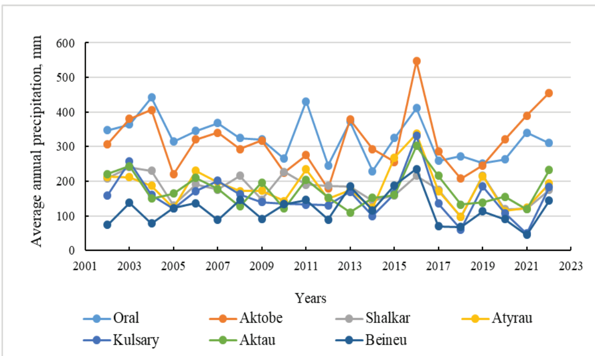
Figure 10 – NDVI and EVI indices of the West Kazakhstan region for 2002, 2012 and 2022 based on MODIS data

The deterioration of vegetation indicators in the region from 2002 to 2012 may have been influenced by the decrease in average annual precipitation. The average annual precipitation uniformly decreased from 2002 to 2011 at all meteorological stations in the Western region (Uralsk, Aktobe, Shalkar, Atyrau, Kulsary, Aktau), except for the Beineu meteorological station (Kazhydromet 2022). From 2013 to 2016, the average annual precipitation increased again (Figure 11b). As illustrated in Figure 9, the improved vegetation in the West Kazakhstan region in 2022 may be attributed to the increased precipitation in the area compared to 2012.

Based on data from all weather stations in the study area, the years 2008, 2010, 2014, 2018, and 2021 had the lowest average annual precipitation recorded (Kazhydromet 2022).



a) Indicators of the average annual air temperature in the West Kazakhstan region for 2002-2022, °C



b) Average annual precipitation for 2002-2022 in the West Kazakhstan region, mm

Figure 11 – Climatic data from meteorological stations of the West Kazakhstan region (2002-2022)

The monitoring methodology used has the disadvantage of not allowing a direct assessment of drought damage for each individual field. This is due to the insufficient spatial resolution of the MODIS satellite data used for this purpose. In our opinion, LANDSAT images are the most promising tool for direct drought damage assessments from available remote sensing data. They have a higher spatial resolution, although significantly lower image repeatability.

Conclusion

The region's susceptibility to climate-induced droughts is determined by its geographical location, which significantly affects sustainable development and living conditions. Climate change causes land degradation in all ecosystems of the region, resulting in decreased land productivity, crop yields, and livestock productivity. The current conditions have rendered traditional land use patterns unsustainable, resulting in a decline in the population's income and living standards.

When analysing climatic data from local meteorological stations in the region, it has been observed that the average annual temperature has increased since the 2000s, while conversely, the average annual temperature has decreased. Remote sensing data analysis indicates a significant decrease in the region's vegetation cover indicators from the 2000s to the 2022s. As a result, the total volume and yield of crops in the region have declined. In 2017, 850.2 thousand tonnes of grain and leguminous crops were harvested in the region, but by 2021, this had decreased by half to 418.3 thousand tonnes. In 2017, the yield of grain and leguminous crops in the region was 12.3 centners per 1 hectare. However, in 2021, it decreased to 5.8 centners per 1 hectare. Despite this, there was significant growth in agriculture, including livestock farming. Between 2000 and 2022, the number of cattle in the region increased from 752,400 to 1,631,400 heads, camels from 61,300 to 144,500 heads, and small cattle from 1,567,400 to 2,868,800 heads.

To ensure rational land use in the region under changing climate conditions, it is essential to develop science-based land management methods using remote sensing techniques. Additionally, it is crucial to implement sustainable land use models in combination with adaptation technologies, with social and institutional support from government structures.

Acknowledgement

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