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# ASSESSMENT OF FOREST FIRES FACTORS IN EASTERN KAZAKHSTAN OVER THE LAST 20 YEARS (2003 - 2023) USING GIS TECHNOLOGIES

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**Abstract:** In this article, a study was conducted to analyze the factors leading to the occurrence of one of the natural disasters - fires on the territory of Eastern Kazakhstan. This work examined the consequences of forest fires that occurred before 2022 and analyzed changes in the state of forest cover in recent years using satellite images. The article also describes the methodology and application of geographic information technologies for assessing the potential damage caused by fires based on data from space. This technology provides a quick assessment of possible damage from forest and steppe fires, which can be supplemented with data from the area. Based on space monitoring data, areas affected by fires are identified, and a rapid assessment of such areas is carried out using information from the MODIS system, after which it is recommended to supplement it with more detailed medium-resolution data, such as Landsat images. In addition, the article determined the structure of forest cover, and also identified factors influencing the occurrence of fire conditions in the territory of Eastern Kazakhstan. As a result of the study, a set of proposals was developed to assess the level of damage caused by forest fires and measures to prevent such fires.

**Key words:** fire, forest fires, natural disasters, imbalance of ecosystems, anthropogenic factors, remote sensing methods, space photography, space monitoring, GIS technologies

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## INTRODUCTION

The East Kazakhstan region extends north from 48˚ to 51˚ north latitude and east from 77˚ to 87˚ east longitude, bounded on the west by 76˚ 50" east longitude and on the east by 87˚ 20" east longitude. This area is located southwest of the Altai Mountain range, known as the Kazakh Altai, and is bounded by the Kalba and Sauyr-Tarbagatai ranges, as well as the Zaysan basin (Figure 1). The total area of the region is 97.8 thousand square kilometers (Yegorina, 2000). The territory of Eastern Kazakhstan contains 40% of the total reserves of wood resources of the main tree species, which play an important role in the formation of forest cover in the country. Forest areas in the East Kazakhstan region, in particular in the eastern part of the region, include dark coniferous taiga forests and pine forests of the Kazakh Altai and Saur (Zhensikbayeva, 2018).

Forest fires are accidental fires that occur within forest cover. They cause the destruction of trees and shrubs present in the forest and can lead to a decrease in the protective and other beneficial properties of the forest, destruction of wildlife, as well as infrastructure, and in some cases, populated areas. In addition, forest fires pose a serious threat to the lives of people and farm animals. Classification of fires. Classification of forest fires is based on various characteristics. Depending on the type of fire and the structure of the forest area, forest fires are divided into lower, upper and soil. According to the degree of burning intensity, forest fires are divided into weak, medium and strong. The intensity of combustion depends on the presence of combustible materials, the slope of the terrain, time of day and wind strength (Blinov, 2016).

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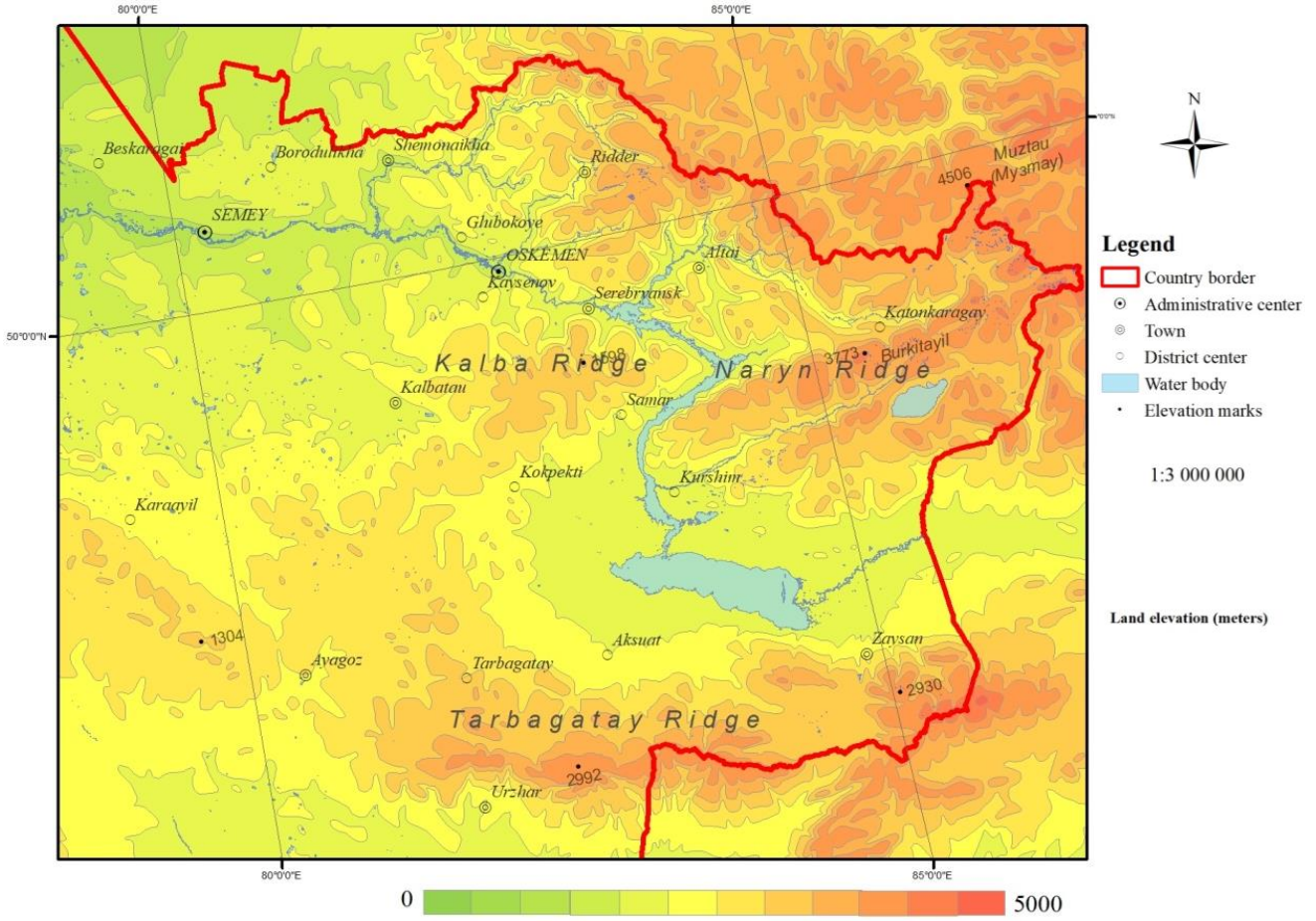



Figure 1. Hypsometric map of East Kazakhstan Region (National Atlas of the Republic of Kazakhstan, 2010)

Taking into account the speed of fire propagation, low and upper fires are divided into permanent and rapidly spreading. The speed of propagation of a weak lower fire does not exceed 1 meter per minute, and a strong one is more than 3 meters per minute. High fires have a spreading rate of up to 3 meters per minute at low intensity, up to 100 meters per minute at medium intensity and above 100 meters per minute at high intensity. The height of the fire also varies: a weak lower fire reaches a height of up to 0.5 meters, an average - 1.5 meters, a strong - more than 1.5 meters (Table 1). Soil (underground) fires are characterized by burning depth, which is no more than 25 cm for weak, 25-50 cm for medium and more than 50 cm for strong (Blinov, 2016). The main factors influencing the occurrence of forest fires. The main factors influencing the occurrence of forest fires include the frequency of rainfall, the amount of precipitation and wind patterns. Fire danger depends on the amount, nature and condition of combustible materials, forest cover and weather conditions such as precipitation and wind. Weather is the most variable factor, and fire danger increases as air temperatures rise and humidity decreases. Temperature and relative humidity vary both within a day and at different times of the year, depending on geographic location and altitude (Krepsha, 2014).

## MATERIALS AND RESEARCH METHOD

Table 1. Classification of forest fires according to combustion indicators (Vlasova, 2014)

| Indicator of forest burnability (ha) | Fire hazard level |
|---|---|
| less than 300 | I – safety |
| 301 – 1000 | II – lower degree of danger |
| 1001 – 4000 | III – medium degree of danger |
| 4001 – 100000 | IV – high danger |
| more than 100000 | V – very high danger |

Forest fires, as one of the natural disasters, often cause imbalance in ecosystems and damage local structures. Recent studies indicate an increase in the number of forest fires around the world due to climate change. At the present stage, the work on the early identification of fire conditions is very relevant. In this field, scientists using the latest technologies are trying to identify various natural disasters, natural conditions of the forest. An example of this is the presentation in the works of E.V. Arkhipov, S.M. Zikriarova, I.A. Snytin, D.M. Syzdykov, P.K. Yants, S.J. Gadal, S.A. Ivanova of geoinformation systems and ways to effectively determine the state of the forest using remote sensing devices. Models for the prevention of emergencies using geoinformation systems have been created by E. Chuvieko and A. Jain. The need to create a geographic information system (GIS) for space-based fire monitoring of forests in the vast territories of our country and the constant lack of funds for the protection of sparsely populated remote forest areas is obvious. The use of space monitoring makes it possible to reduce the cost of detecting forest fires and automate the process of detecting forest fires. The data processing scheme consists of three main stages (Figure 2). At the first stage (input data), the polygon shape file is loaded into the GIS and added to the fire observation shape file. The forest fire observations shape contains all observations of forest fires since

the beginning of the current season and is the basis for constructing a database and analyzing the forest fire situation. The forest fire observation table stores the date and time of forest fire observation, satellite, area, administrative affiliation, the nearest populated area and its coordinates, the distance and azimuth of the direction to it from the geometric center of forest fire observation, the sign of belonging to a forest zone and the contour area (Pavlichenko et al., 2009).

At the second stage, newly discovered fires are analyzed. The main purpose of the analysis is to find fires that have been ongoing since the last observation and index all fires found. Fire indexing consists of spatially combining all observations of one fire as a separate polygon. The spatial combination of all observations of one fire has the meaning of the burning left by the fire, and will be further referred to as the fire trail.

The third stage consists of a number of auxiliary calculations (Pavlichenko et al., 2009):

1. determination of the territorial affiliation of fire traces to regions, subjects, states;
2. search for the nearest populated areas and calculate the distance and azimuth of the direction from the populated area to forest fires;
3. calculation of areas of fire traces in projective units;
4. setting a sign of a forest fire. This geographic information system for forest fire monitoring allows for rapid spatial analysis of forest fires. An increase in cases of forest fires was noticed in Kazakhstan in 2019-2020. This raises the question of how dangerous forest fires are and how they may be related to various climatic, abiotic and anthropogenic factors, as well as the possibility of predicting their occurrence in order to take preventive measures (Bogdanov et al., 2018). To date, as of January 1, 2022, the total area of the state forest fund is 30,552.5 thousand hectares and occupies 11.2% of the territory of the republic (Figure 3). Forests cover 13,635.3 thousand hectares, which is 44.6% of the total area of the forest fund. The area of the private forest fund is 1,017 hectares, and there is no forest cover on this territory. The level of forest cover in the republic is 5.0%. Most of the state forest fund, namely 74.9%, is managed by the government of the regions, and 24.4% is managed by the Committee (Vaganov, 2018). The total area of Republic Kazakhstan forest owners under the jurisdiction of the Committee is 7450.9 thousand hectares, and of this area 7335.9 thousand hectares are specially protected natural areas that have the status of a legal entity (Figure 4). These include 10 state natural reserves, 14 state national natural parks and 7 state natural reserves (Svarichevskaya, 1965). The forest area of the East Kazakhstan region is 3,843 thousand hectares, of which more than 2 million hectares are covered with forest.

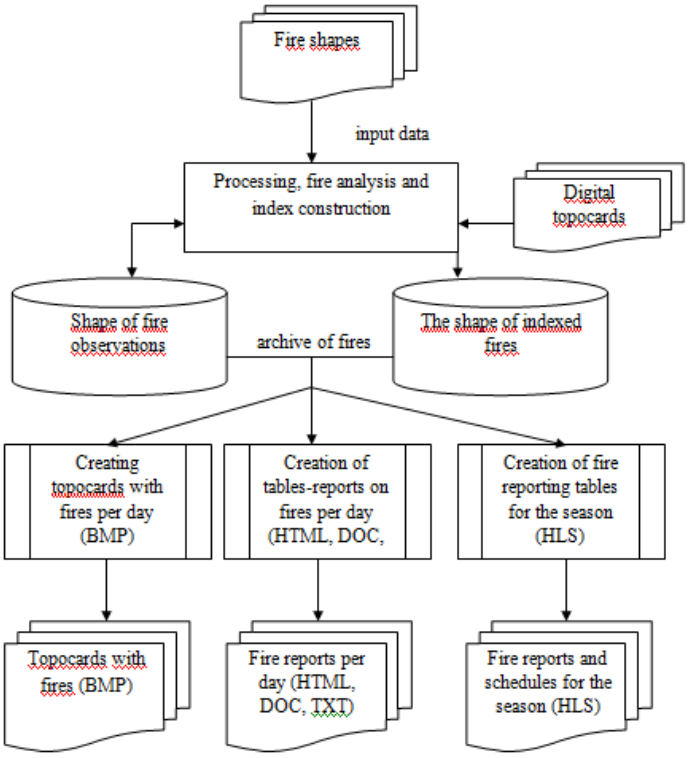
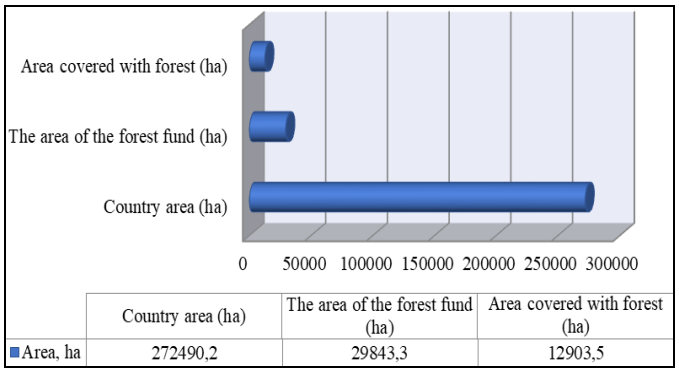



Figure 2. Scheme for processing data on forest fires in the ArcGis (Pavlichenko et al., 2009)




| | Country area (ha) | The area of the forest fund (ha) | Area covered with forest (ha) |
|---|---|---|---|
| Area, ha | 272490,2 | 29843,3 | 12903,5 |

Figure 3. Forest Fund of the Republic of Kazakhstan in the period 2023 (Information on the availability of land and its distribution by category, land owners, land users and lands in the East Kazakhstan region as of 2022, 2023)

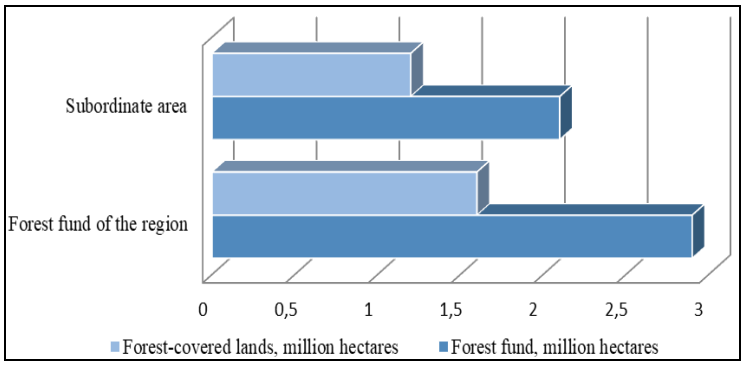



Figure 4. Forest Fund of the East Kazakhstan Region in the period 2023 (Information on the availability of land and its distribution by category, land owners, land users and lands in the East Kazakhstan region as of 2022, 2023)

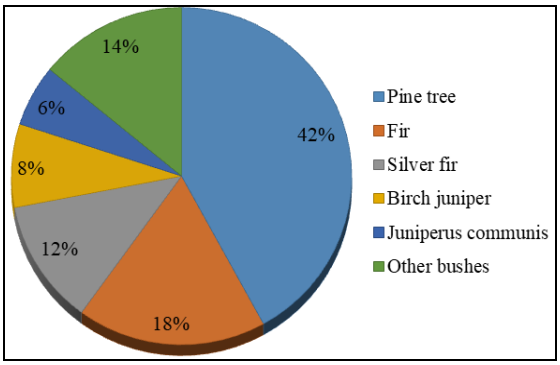



Figure 5. Types of forest species in the East Kazakhstan region (Baimaganbetov et al., 2020)

It is remarkable that more than half of the forest resources of the entire country are concentrated in this region of Eastern Kazakhstan. The forest cover level of this area is 16.5%. The main tree species that predominate in this area are pine, spruce, fir, cedar and larch, as well as aspen, birch and poplar (Zhensikbayeva, 2018). Forest areas in Eastern Kazakhstan are located mainly on the ridges of the Altai Mountains. Mainly coniferous forests are common here. In the lower parts of the forest zone there are deciduous and mixed forests. In the north, the altitudinal forest belt extends from 800 to 1700 meters, and in the south it reaches 2300 meters. These forests include trees such as pine, birch, aspen, poplar, cedar, spruce, fir, larch, as well as various types of shrubs. The species composition of forests is presented in the Figure 5 (Baimaganbetov et al., 2020).

The main timber reserves are concentrated in seven forestry enterprises, namely Altaisky, Riddersky, Verkhneubinsky, Malubinsky, Pikhtovsky, Cheremshansky and Ust-Kamenogorsky forestries, and amount to 96.6 million cubic meters, which is 84% of the total reserves (Shishikin et al., 2013). On the territory of the state forest fund, logging is carried out, beekeeping and deer breeding are being developed, areas are provided for health and recreational purposes, as well as haymaking and grazing, and medicinal raw materials are collected (Information on the availability of land and its distribution by category, land owners, land users and lands in the East Kazakhstan region as of 2022, 2023).

In 2020, a comprehensive plan for forest reproduction and increasing the volume of afforestation in the East Kazakhstan region for the period from 2021 to 2025 was developed and approved by the mayor of the city as part of the implementation of the Address of the President of the Republic of Kazakhstan dated September 1, 2020. The plan calls for 15,000 hectares of forest to be planted using individual seedlings over five years, for a total of 76 million seedlings (Information on the availability of land and its distribution by category, land owners, land users and lands in the East Kazakhstan region as of 2022, 2023).

1) 2021 - 513 hectares (177.5 million tenge); 2) 2022 - 600 hectares (789.8 million tenge);

3) 2023 - 1537 hectares (1133.6 million tenge); 4) 2024 - 5650 hectares (1032.9 million tenge);

5) 2025 - 6700 hectares (583.2 million tenge). Total - 15 thousand hectares (3.7 billion tenge).

The planned activities for 2021-2022 have been completed in full. In 2023, 7.8 million are planned to be planted on 1,537 hectares with the planting of individual seedlings. The material and technical base of state forestry institutions has been significantly strengthened and positive results have been achieved in preserving forests from fires.

**RESEARCH RESULTS**

On the total area of the forest fund of Eastern Kazakhstan, there are 13 municipal state forestry institutions and 4 specially protected natural areas - “Markakol” and “Western Altai”, the State National Natural Park “Katon-Karagay” and “Alakol”.

Table 2. Forest fires in the East Kazakhstan region for 2019-2023 (Information on the availability of land and its distribution by category, land owners, land users and lands in the East Kazakhstan region as of 2022, 2023) Note: On June 8, 2022, the East Kazakhstan region was divided into two - Abay with the regional center in Semey, and, in fact, East Kazakhstan region, where Oskemen remained the main city

| Region | Year | Number of fires | Amount of damage (thousand tenge) | Death of people | Injured people |
|---|---|---|---|---|---|
| East Kazakhstan region (including Abay region) | 2019 | 1755 | 165082 | 37 | 54 |
| | 2020 | 2037 | 2066421 | 46 | 46 |
| | 2021 | 1480 | 537069 | 47 | 51 |
| East Kazakhstan region | 2022 | 401 | 77965 | 18 | 13 |
| | 2023 | 339 | 60518 | 23 | 15 |

Table 2 contains statistics on forest fires in the East Kazakhstan region for the period from 2019 to 2023. Let's analyze the main indicators: **1.** Number of fires: - In 2019, 1,755 forest fires were registered; - In 2020, the number of fires increased to 2,037; - In 2021, the number of fires decreased to 1,480; - In 2022 there were only 401 fires; - In 2023, the number of fires also decreased to 339. **2.** Amount of damage (thousand tenge): - In 2019, damage from forest fires amounted to 165,082 thousand tenge; - In 2020, the damage increased significantly and reached 2,066,421 thousand tenge.

Forest fires can occur for various reasons, both natural and man-made. Natural factors include lightning, volcanic eruptions, sparks from falling rocks and spontaneous combustion. These phenomena are caused by high temperatures, low humidity and the presence of flammable materials. On the other hand, man-made causes include man-made ignition sources such as cigarettes, electrical sparks and any other sources that can start a fire due to human carelessness in coming into contact with flammable materials in the forest (Table 3). “In 2022, out of 801 cases of forest fires, 444 cases or 55% occurred from lightning strikes, 127 cases or 15% arose as a result of steppe fires moving onto state forest lands (due to the fault of the population 12, forest users - 1, other organizations and enterprises - 9), from unknown causes, 208 cases or 26% were recorded, and these figures are repeated annually with minor adjustments” (Velichko, 2023).

1-Moss-lichen, grass-moss-lichen, 2- short-grass crooked forests and deciduous woodlands; 3- Kobresia smirnovii, K.myosuroides, medium grass meadows; 4 -pine and birch-pine forests, lichen, moss, grass cover; 5 -fir and small-leaved-fir forests with large-grass moss cover; 6 -deciduous and small-leaved-larch forests, moss and birch-moss communities; 7-small-leaved aspen and birch forests with large grass communities; 8 -Shrub thickets combined with meadow and richly mixed-grass steppes; 9 -Larch and herbaceous communities on the northern slopes combined with meadow steppes and shrubs on the southern slopes; 10-Wormwood-feathergrass in combination with brittlegrass; 11- Stipa sereptana, Artemisia gracilescens, Allium polyrhizum; 12-sand-feather grass and shrub communities; 13-Stipa capiilata, Artemisa frigid, Caragana pumila, Clestogenes squarrosa, Potentilla acaulis; 14- Festuca valesiaca, Stipa kirghisorum, Stipa lessingiana, Stipa capillata, Spiraea hypericifolia, Caragana frutex, Caragana pumila; 14b- shrub-wormwood-turfgrass; 15 - arable land on the site of dry fescue steppes; 16- Wormwood-fescue; 17- Shrub - forbs - red feather grass; 18- Shrub-forb-red-feather, petrophytic-forb and shrub-fescue communities; 19 - Fescue-feather grass; 20 - Festuca valesiaca, Stipa

capillata, Stipa pennata, Artemisia marchalliana, Spirea hypericifolia, Lonicera microphylla; 21 -Artemisia sublessingiana, Stipa sereptana, Allium polyrzhum, Anabasis salsa; 22-Artemisa sublessingiana, Stipa sareptana, Nanophyton erinaceum, Parmelia vagans; 23-Artemisia xanthochroa, Artemisia santolina, Agropyron fragile, Calligonum rubicundum, Calligonum crispum; 24 - Shrublands, halophytic meadows and reed beds; 25-Calamagrostis epigeios, Xanthium strumarium, Trifolium, Plantago major, Potentilla anserina, Elaeagnus oxycarpa; 26 - aspen - birch - willow thickets, meadows and grass swamps; 27- кeed, halophyte meadows and communities. The occurrence and spread of fires in the East Kazakhstan region are highly dependent on the topography and altitudinal zone in which the vegetation cover is located.

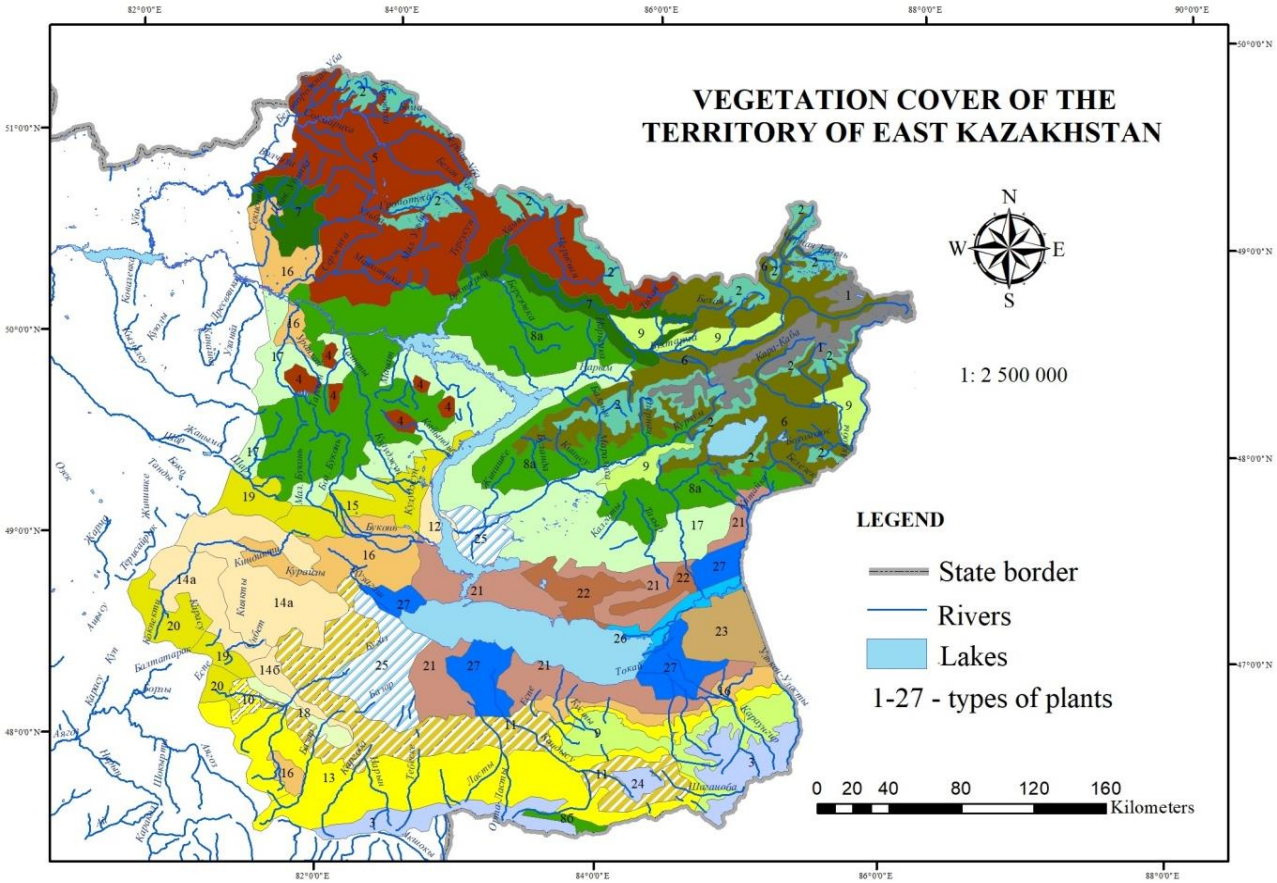



Figure 6. Vegetation map of the East Kazakhstan region (National Atlas of the Republic of Kazakhstan, 2010)

Table 3. Number of fires in Kazakhstan for 2020-2023 (Velichko, 2023)

| Forest fires | | Steppe fires | |
|---|---|---|---|
| 2020 | 701 | 2020 | 130 |
| 2021 | 749 | 2021 | 115 |
| 2022 | 706 | 2022 | 74 |

Table 4. Number of fires in Kazakhstan for 2020-2023 (during August) (Velichko, 2023)

| August | | | |
|---|---|---|---|
| Forest fires | | Steppe fires | |
| 2020 | 125 | 2020 | 33 |
| 2021 | 137 | 2021 | 39 |
| 2022 | 122 | 2022 | 13 |

Table 5. Number of fires in Kazakhstan for 2020-2023 (during August) (Official statistical accounting of fires and their consequences in Kazakhstan, 2019-2023)

| September | | | |
|---|---|---|---|
| Forest fires | | Steppe fires | |
| 2020 | 39 | 2020 | 16 |
| 2021 | 87 | 2021 | 31 |
| 2022 | 47 | 2022 | 23 |

In mountain forests, natural fires begin after snow melts on the southern slopes, which occurs at different times: in the mountain ranges - in April, in the middle mountains - at the end of May, and in the upper zone - only in June and sometimes even in early July. Due to the climatic conditions of the region, fast-growing grass begins to limit the spread of fires (Figure 6). After the snow melts in late June and mid-July, the fire threat decreases significantly. According to Kazhydromet forecasts, in the upcoming fire danger period the average temperature will be +30ºC. Dryness and lack of precipitation are expected in the southern, eastern and western parts of the republic, while temperatures can reach +40ºC. All this will significantly increase the risk of forest fires. Due to the climatic conditions of the region, fast-growing grass begins to limit the spread of fires (Table 4). After the snow melts in late June and mid-July, the fire threat decreases significantly. (Shishikin et al., 2013). The growing season of the grass begins on the southern slopes and in light coniferous forests on the eastern and western exposures, and ends in dark coniferous forests on the northern slopes. In autumn, herbaceous plants gradually lose moisture and complete their life cycle, but by the end of autumn, when frost sets in, they dry out completely (Table 5). During periods of drought, fires can occur and spread throughout the entire mountain system, regardless of slopes and vegetation conditions (Arkhipov, 2017). In spring and autumn, when fires occur mainly in pine-birch and deciduous forests, and in summer during a period of prolonged drought - in all other types of forests. Under normal weather conditions, the fire spreads along bodies of water in the south and west. However, if the ridges and hills are higher than 500 meters, then the fire can engulf valleys, basins and lower slopes. During a period of prolonged drought in the spring, fires can spread to the eastern and some northern slopes (Arkhipov, 2017).

The intensity of lightning activity, that is, the duration of thunderstorms and the number of days with lightning, is closely related to the physical and geographical location of the region. In addition, the terrain greatly influences lightning activity. On mountain slopes, where humid winds act, the greatest number of lightning events is observed. This is because dynamic turbulence increases and updrafts create conditions for the formation of strong convective currents, which leads to the formation of clouds and, consequently, lightning. However, an increase in the number of thunderstorms in the mountains is observed only up to a certain altitude (800/1000 meters). Regarding the consequences of fires, persistent and intense lowland fires negatively affect the growth and health of pine forests. The impact depends on the age of the forest stand and the intensity of fires. A study conducted in the Katon-Karagai State National Natural Park showed that in all burnt areas the tree stand is generally preserved, but the condition of the wood can be assessed as unsatisfactory.

The number of healthy trees leaves much to be desired, and most forest areas have been damaged and destroyed. Already in the first year after the fire, it became obvious that the fire had caused serious damage to the trees. In 2018, in the new burned area, the proportion of destroyed and drying trees exceeded 93% (Baimaganbetov et al., 2020).

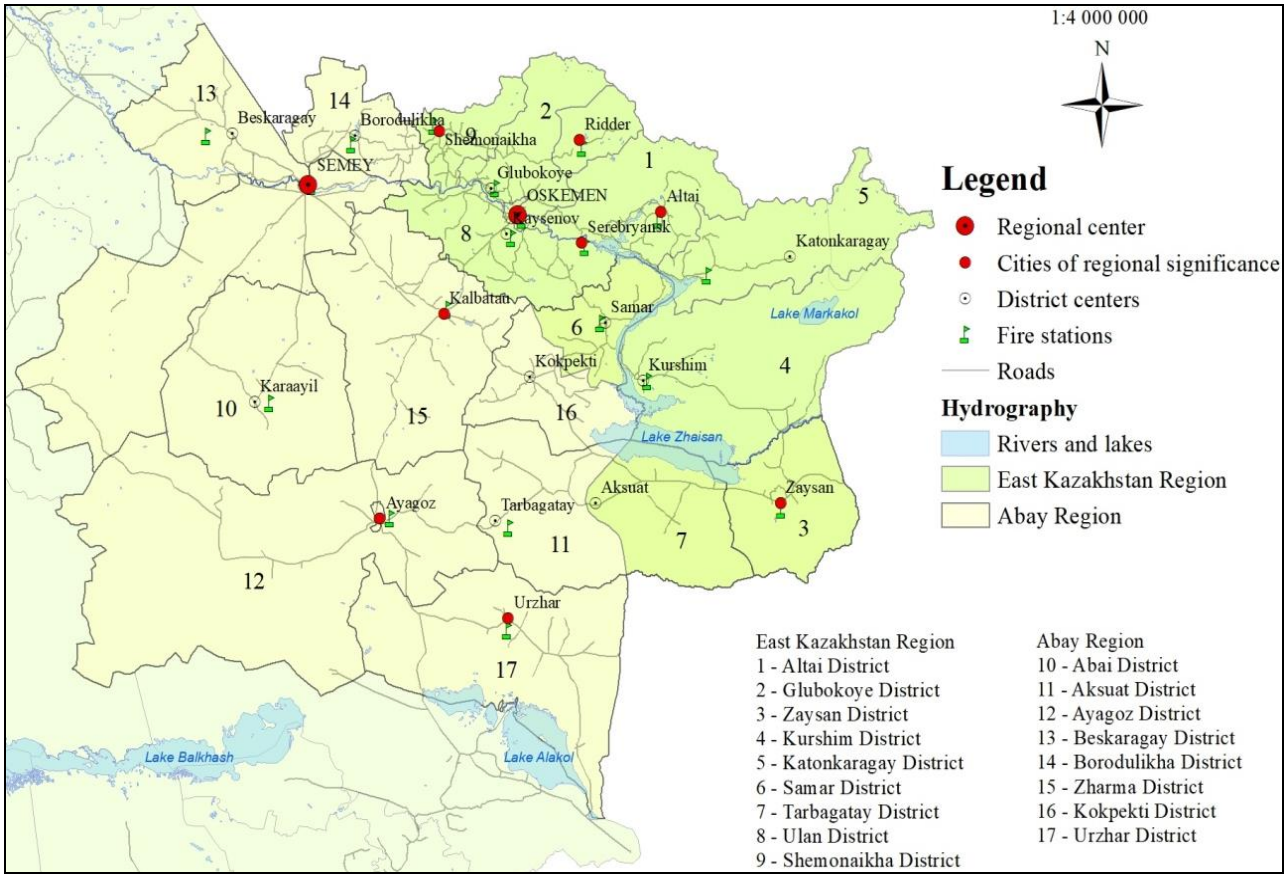



Figure 7. Fire stations on the territory of East Kazakhstan (National Atlas of the Republic of Kazakhstan, 2010)

According to the indicators of fire incidents and depending on the flammability index, all forest management in the East Kazakhstan region were conditionally divided into three groups. The highest level of fire danger (group I) was recorded in "Asubulak forestry" with a combustion index of 229.6 units, which indicates a high fire danger (Figure 7). The region is primarily planted with pine trees and is prone to wildfires. Over the past 15 years, 6,781.2 hectares of fires have occurred on the territory of this forestry, of which 2,848.7 hectares are in forested areas. The causes of fires are mainly related to anthropogenic activities (46.5%) and lightning strikes (53.5%) (Loupian et al., 2017). Most of the fire situation was included in group II of communal government agency "Zaysan forestry" (93.17) and communal government agency "Narym forestry" (69.09). These regions are characterized by flatter terrain, but there are still cases when forest fires spread to the territory of the forest fund. Particular attention should be paid to preventing transboundary fires in the Zaisan forestry communal government agency and conducting educational activities, since the main causes of fires here are closely related to human activity.

Group III includes communal government agency "Kurchum forestry" (25.68), communal government agency "Ridder forestry" (15.21), communal government agency "Samar forestry" (7.6) and communal government agency "Oskemen forestry" (2.08). Despite the low burning index values, fires occur in these areas, affecting large areas. For example, in 2011, at the Ridder forestry communal government agency, an overhead fire destroyed about 300 hectares of valuable pine forest in two hours. The main cause of forest fires in these areas is human activity, which accounts for 99.16% of all cases. It should be noted that in communal government agency "Ridder forestry" with such a number of fires, forest protection acts very quickly, and the average area of one fire during the study period is 6.2 hectares (Chlachula, 2019).

On the territory of the Samar forestry communal government agency, the main type of forest tree is pine, which contributes to the transformation of this zone into an area with a high risk of forest fires. This circumstance significantly

increases the risk of fires in this area. According to data for the last 15 years, the conditions conducive to the occurrence of fires in this territory are caused by 57.8% anthropogenic factors and 42.2% by natural causes (Meshkov et al., 2009).

This year marks the highest number of forest fires registered in the East Kazakhstan region, reaching 314 cases. The second largest number of fires is Pavlodar region with 141 incidents. Zhambyl, West Kazakhstan and Turkestan regions found themselves faced with a significant increase in the number of forest fires, with only 2 cases in each of them. It should be noted that in 2022, the only region where no forest fires were registered was the Mangistau region (Table 6).

As for steppe fires, this year the largest number of incidents was recorded in the Karaganda region - 34 cases. It is followed by the West Kazakhstan region with 23 cases and the Kostanay region with 19 cases. A smaller number of steppe fires were registered in the Zhambyl and Akmola regions, where two cases were recorded, as well as in the Atyrau region, where only one steppe fire was registered. It should be recalled that this year there was one of the major forest fires in the Kostanay region, which began on September 2 and required eight days to completely extinguish it. As a result of this fire, 43 thousand hectares of forest were destroyed and damaged, as well as more than 90 residential buildings in two settlements. A total of 12 people were injured, burned or poisoned in the fire, and another person was found dead in his home, buried under rubble. When analyzing the causes of forest fires in the Republic of Kazakhstan, it should be noted that the main factor causing fires is the careless handling of fire by local residents and vacationers when igniting forest fires. Throughout the Republic, 82% of all forest fires are caused by direct or indirect human impact, while natural factors (thunderstorms) are responsible for only 18% of forest fires. Only in the ribbon forests of the Irtysh region the share of forest fires caused by thunderstorms is 50-65% (Arkhipov and Arkhipov, 2014). To locate forest fires for rapid response, data obtained from remote sensing satellites are used, which create images in the infrared spectrum with a spatial resolution of 250 to 1000 meters. These data make it possible to quickly determine the coordinates of fires (thermal anomalies) and predict the spread of forest fires, including the use of meteorological information. To perform tasks that require regular and operational space surveys, it is recommended to use aerial photography to create detailed large-scale maps in small areas in areas of intensive forest management. This has advantages, especially when monitoring forests located in remote and inaccessible areas, as well as when monitoring fire conditions, fire sites and illegal logging in protected areas.

Table 6. Number of forest and steppe fires in Kazakhstan for 2022 (Velichko, 2023)

| Regions | Forest fires | Steppe fires |
|---|---|---|
| East Kazakhstan | 314 | 8 |
| Pavlodar | 141 | |
| Akmola | 55 | 2 |
| Karagandy | 55 | 34 |
| Almaty | 42 | |
| Kostanay | 36 | 19 |
| North Kazakhstan | 30 | |
| Kyzylorda | 13 | |
| Aktobe | 10 | 8 |
| Atyrau | 5 | 1 |
| Zhambyl | 2 | 2 |
| West Kazakhstan | 2 | 23 |
| Turkestan | 1 | |

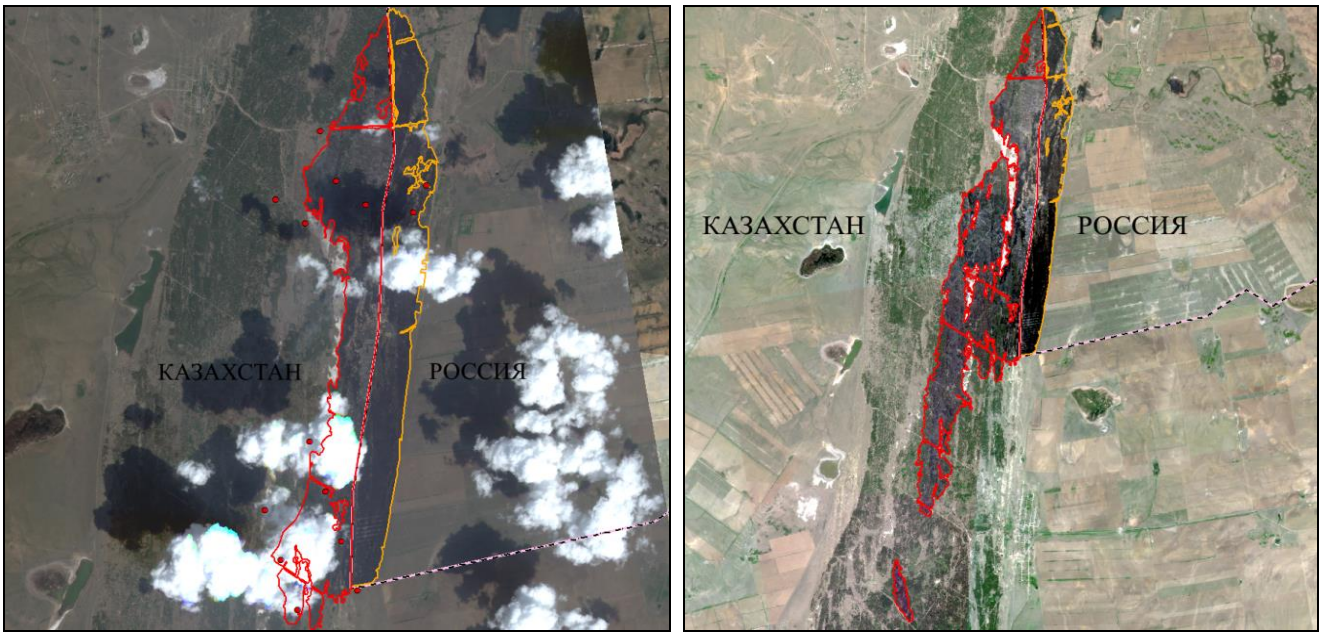



Figure 8. World View 2 image (fragment) with overlay of taxation map and burnt areas, obtained from Landsat and World View 2 data of the territory of the Semipalatinsk reserve for the period from 05.22.22 to 05.25.22 (https://forestopen.gharysh.kz/)

The Figure 8 shows the initial sources of fire in the Semipalatinsk reserve. It is important to ensure that rescuers are promptly informed about the occurrence and spread of forest fires. To do this, in most cases, a web interface is used, containing a graphical representation of the locations of forest fires over the last 24 hours, as well as an indication of geographic coordinates, date and time of fire detection, probability of detection, fire classification and other related information. Thermal channels of satellite images are used to detect forest fires (Figure 9).

There are two main types of fire detection algorithms: marginal and contextual. Marginal algorithms are based on identifying an abnormally high temperature above a certain point that exceeds the norm for the Earth's surface. In

contrast, contextual algorithms analyze the temperature of neighboring pixels, allowing temperature fluctuations to be detected in the context of surrounding pixels at lower temperatures (Arkhipkin et al., 2014).

Figure 9. Photos from fire scenes in the East Kazakhstan region: a - Fire in the forests of the city of Ridder, https://www.nur.kz/, 05.11.2021, Ridder, East Kazakhstan region; b - Fire in the Semey Ormany reserve, https://baigenews.kz/, 08.04.2023, Abay Region; c - Fire on the territory of the Kulunjunsky State Nature Reserve, https://orda.kz, 05.02.2022, East Kazakhstan region; d - Fires in the East Kazakhstan region, inbusiness.kz, 05.16.2023, East Kazakhstan region

High-resolution analysis of the following parameters is performed using remote sensing data:

- Detailed study of fire spread;
- Assessment of the total area covered by fire extinguishing in certain segments of the territory;
- Assessment of economic losses;
- Planning activities to prevent forest fires;
- Identification of hotbeds of burning peat bogs and other objects.

Satellite data is essential for assessing the spread and detection of wildfires, as well as for analyzing smoke clouds and fire risk. The ability to quickly detect fires in small areas, especially in conditions of increased fire danger, depends on the speed of detection. Therefore, the most suitable requirements for operational monitoring of forest and soil fires are those of satellites with high radiometric resolution and high image frequency, such as the NOAA and EOS series. Satellites with high spatial resolution must be used to monitor the consequences of fires.

## CONCLUSION

Despite the low level of forest cover, forest fires cause serious damage to the forest fund of the Republic of Kazakhstan. In addition to natural factors, the level of fires in forests is influenced by the economic situation in the country and the effectiveness of measures to protect forests from fires.

From 2000 to 2022, the year 2022 was characterized by a high degree of danger from fires. While the high number of fires and area burned in 2010 can be explained by drought, the excessively high level of fires in 2021 and 2022 may be due to insufficient government attention to protecting forests from fires.

To minimize damage from forest fires, it is necessary to develop a comprehensive system for protecting forests from fires, taking into account the natural conditions and characteristics of the forest fund in each region of the republic.

In order to reduce the risk of fires, the following measures are proposed:

- Creation of a lightning rod service in the territories of communal government agency "Asubulak forestry" and communal government agency "Samar forestry", since cases of fires in pine forests due to lightning discharges are more common here;
- Taking urgent measures to normalize the sanitary situation in the spruce plantations of the dark taiga, including sanitary pruning and debris removal;

- Application of satellite images and monitoring through special platforms for rapid detection and control of fires.

To make a decision in the management of forest protection activities, a comprehensive assessment of the emergency situation is necessary, which is achieved by including all stages of the information and software complex to increase the percentage of reliability when checking it on the ground. Practice has shown that the most important block is considered to be the use of auxiliary information, including custom information, higher-resolution images (Landsat), taxational maps of vegetation and soils, conducting field research, climatic characteristics.

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