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SPATIAL ANALYSIS AND MAPPING OF POTENTIAL WILDFIRES FROM LANDSAT SATELLITE DATA

ABSTRACT

In 2023 there was a severe forest fire on the territory of the Semipalatinsk Forest. More than 60 thousand ha were burned. This resulted in high environmental costs, destroying trees, real estate, recreational and even human lives. One of the most pressing issues was the determination of the origin and spread of forest fires. In such cases, remote sensing data is a spatial and temporal measure to obtain fast and accurate data to prevent the further spread of the fire and to neutralize this natural disaster. Using such geospatial information, it is possible to prioritize preventive measures to reduce the risk of forest fires and identify mitigating factors to increase the likelihood of immediate fire suppression in threatened areas. This work proposes to assess the fire potential and to determine the hazard potential. This is done by analyzing and mapping the area of the fire that has occurred. The mapping of the fire potential was approached from a remote sensing point of view by estimating and mapping the total vegetation cover using Landsat-8–9 OLI/TIRS DATA and the geographic information systems QGIS, SAGAGIS. A morphometric, spatial analysis of conditions was also conducted, taking into account many factors affecting fire potential-land exposure, aspect, wind direction, fire statistics, population density, climatic characteristics, etc. As a result, an attempt was made to create indices RBR, RdNBR, dNDVI, dGNDI, GEMI and BAI, which could be the basis for the determination of fire potential. These indices are based on the type of tree, the vegetation and the topographic features. These characteristics make it possible, after the classification of the Landsat images, to evaluate the reliability of the information obtained by determining the area of the fire through the Object Based Image Analysis segmentation method and by assessing the accuracy of the detected data. The index values identified were consistent with reliable information for identifying fire locations and monitoring estimated fire risk. They could be used to map fire potential from regional to local scales.

KEYWORDS: forest fire, remote sensing, landsat, SAGAGIS, QGIS, object based classification

INTRODUCTION

In the steppes of the Republic of Kazakhstan, despite the vastness of the country, there are not many forested areas. The main reason for this is the fact that most of the territory is located in arid, semiarid and desert areas. The area of forests and bushes on the territory of the Republic is 23.6 million ha. It's only 4.6 % of the total area of Kazakhstan. And the actual forest area amounts to 1.2 %, or 11.5 million ha. The studied forest reserve is the State Forest Natural Reserve "Semey ormany". It is located in the territory of the Abay region, bordering with the Eastern Kazakhstan region, with the total area of 654 179.8 ha.

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The effects of global warming in recent years, a decrease in the amount of precipitation, an increase in summer travelers in the forest area, and fire protection of the forest fund in these regions require increased security measures. Therefore, especially in mountainous forest areas with complex terrain that makes it difficult for the forest fire monitoring service to control[1], it is necessary to introduce a new monitoring method, such as the use of remote sensing data [*Yankovich* et al., 2019].

Using modern remote sensing materials for this purpose can completely solve the problem that was difficult to solve before. Because it has become clear that remote sensing is an effective approach to controlling deforestation globally, nationally, and regionally. However, due to problems related to cloud cover of satellite imagery, spatial and temporal resolution of seasonal and remote sensing observations, monitoring forest degradation and recovery using remote sensing remains one of the most pressing issues [*Mitchell* et al., 2017]. Earth remote sensing data "ERSD" are presented in studies on flooding and its consequences for coastal forests, the method of multidimensional analysis for the identification of a flood-prone area and the development of protective structures [*Apshikur* et al., 2023].

The effect of the above-mentioned deficiencies in the control of forest fires is not so high, since forest fires are mainly seasonal, i. e. in the hot periods of the year, several years of seasonal remote sensing surveys are required, and statistics are monitored based on these materials. The use of multi-year remote sensing data in statistical data, both on the topic of monitoring the condition of agricultural land and on the topic of using remote sensing data with the use of intelligent GIS, is somewhat more fully expressed in studies [*Rakhymberdina* et al., 2022].

Currently, publicly available ERSD materials are sufficient for full-scale monitoring of natural emergencies such as forest fires, floods and surface avalanches, and droughts. Emergency monitoring, which is the subject of the study, makes it possible to reduce the high costs of material and human resources in traditional control [*Rakhymberdina* et al., 2022].

Currently there are a large number of software complexes that analyze remote sensing materials on various thematic maps, one of which is the need to prepare a satellite for processing materials and create thematic maps for studying the growth rate of forest clumps, the process of destruction, etc., and examples of the preparation of some maps there are studies [*Toguzova* et al., 2022]. And the use of a satellite for forest fire forecasting "Landsat, Sentinel-2", taking images in a software environment is clearly described in the guide to examples of using SAGA GIS and ways to obtain the necessary data[2].

Methods of image classification and fire index are often used to determine temporary changes in forest areas and to analyze the degree of fire effects. The study of daily changes in the course of fire using satellite images has been studied in some works [*Ongeri*, *Kenduiywo*, 2020]. In studies on this topic, index indicators are used that give the image a change in the earth's surface, such as the vegetation cover index "VI", the normalized vegetation difference index "NDVI", and the total normalized vegetation difference index "TNDVI", etc. [*Sadenova* et al., 2022]. Given the differences in these metrics, they have been used in studies of the effects of differences in carbon dioxide emissions, biomass loss and ash formation on the environment, and the effects of green cover as a result of anthropogenic activities on the microbial community structure in river bed sediments [*Muter* et al., 2024]. These limits are used to determine the intensity of the fire and the resulting damage to the ground cover, as well as the contamination of groundwater with wastewater.

In the direction of our research direct, the following research work has been developed. This thesis is a work to determine the applied normalized combustion coefficient "NBR" and

[1] Web resource: https://www.oopt.kz/categories/view/semey_ormany/ (accessed 20.04.2024)

[2] Web resource: https://sagatutorials.wordpress.com/mapping-fires-from-satellite-imagery/ (accessed 20.04.2024)

NDVI indices on Landsat satellite images to analyze three different fires that occurred in the Casorla, Nerva and Anzalcollar regions of southern Spain in 1995 and 2001. The fact that the NIR and SWIR ranges are preferred and are the most suitable bands for revealing fire characteristics studies for forest fire control using NBR and dNBR indices with the use of Landsat-7 and MODIS satellite images have been studied quite extensively [*Vlassova* et al., 2014]. However, it can be seen from some studies that the NDVI index is a determinant indicator of various topics on Earth [*Kulenova* et al., 2022]. In these studies, Landsat-8 and Sentinel-2 indices were compared and their relationship with field indices was examined. Among the indices, dNBR showed the highest correlation with segmentation-based analysis comparing Landsat-8 data with other survey data [*Laurin* et al., 2018]. Using Landsat-8 and Sentinel-2, a number of scientists have conducted studies of the severity of fire damage using three dNBR, dBNR, RdNBR relative, and RBR relative fire coefficients [*Allen*, *Sorbel*, 2008]. They applied reflective, thermal, and mixed measurements to the images and concluded that Sentinel-2 provided slightly better results, while NBR-based measurements provided a higher correlation for analyzing burn severity at the site, on the plants, and in the soil.

A number of studies cite data from Landsat-8–9 OLI/TIRS and Sentinel-2 and other satellites to identify factors of forest fire occurrence and the use of indices that determine the relationship of urban forests in urbanization in regulating the atmosphere of the environment [*Abedzhanova* et al., 2023]. This, in turn, indicates a large-scale level of use of remote sensing data.

The object studied in this article, based on the image classification method, has also been used in various studies for the identification of areas damaged by forest fires [*Mitri*, *Gitas*, 2006]. The basis of the said study, to identify the areas affected by the fire, used high-resolution data and concluded that the density of the pixels mainly affected the accuracy, which consisted in determining a total of 87 % and a kappa factor of 0.74. Studies that determined a kappa coefficient of about 0.86 using bitmaps were performed by [*Polychronaki*, *Gitas*, 2012]. It also used high-resolution images to assess the severity of the burn. To do this, they used GeoEye imagery and found an accuracy of about 72 % and 82 % for two sets of data, respectively [*Dragozi* et al., 2015].

Based on the analysis of scientific works, in this study we used the indicators of Landsat-8 images to determine the burned area in a homogeneous area covered by forests and agriculture with a predominance of conifers. The purpose of the study is to determine the index suitable for determining the area of the fire and mapping its severity. In this study, we conducted a study to identify the burned area and analyze the severity of the burn, covering an area of about 60 thous. ha, in addition to analyzing the satellite data, determining the indices related to the monitoring of forest fires dNBR, RBR, RdNBR, dNDVI, dGNDVI, BAI and GEMI, in order to identify the consequences of forest fires, the course of occurrence, influencing factors.

Data obtained as a result of the study were compared with the data of the State Forest Nature Reserve “Semipalatinsk ormany” and an accuracy analysis was carried out.

The practical significance of this study is that it is an attempt to use the capabilities of methods for using remote sensing and GIS technology for monitoring the said industry and to propose an appropriate methodology for mapping fire potential, in addition, model maps based on GIS obtained as a result of the study, can provide directional assistance to fire managers in.

RESEARCH MATERIALS AND METHODS

Study Area

Research area the state forest nature reserves “Semey ormany” are part of the Beskaragay, Borodulikha districts of the Abay region — Beskaragay, Borodulikha, Zharminsky, Urdzharsky, Abay, Ayagoz, Tarbagatay districts and the Beskaragay, Borodulikha districts of the forest reserve with the total area of 654 179.8 ha, located on the territory of the city of Semey (Fig. 1).

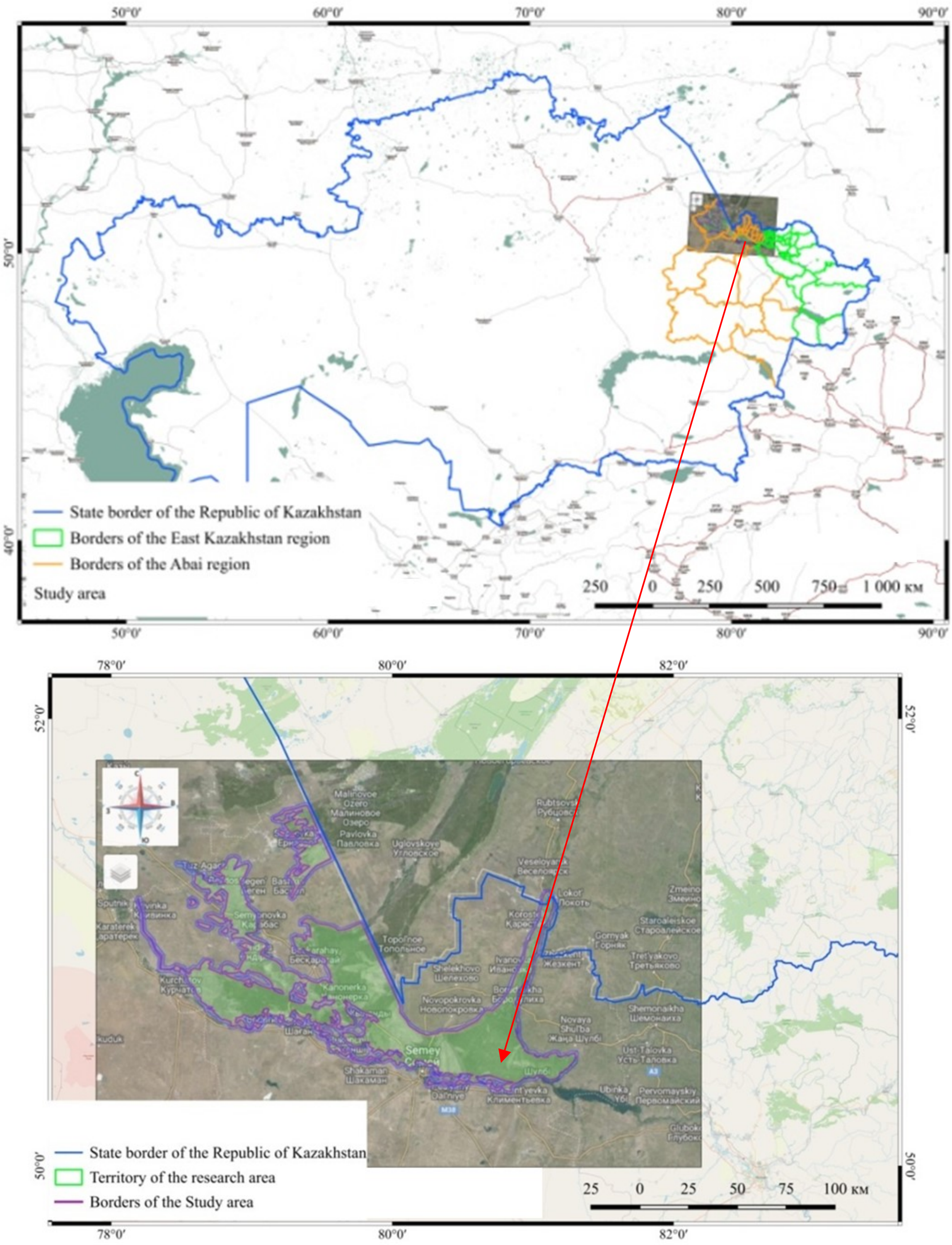


Fig. 1. Geographical location of the Semipalatinsk Forest Reserve

Geographically, the territory of the reserve is located in the Irtysh plain, Kokpekty-Shar low hills and Chingiztau mountains. Forest strips are located in the northwestern part of the East Kazakhstan Region[1]. The territories of Begen, Borodulikha, Bukebay, Dolon “without floodplain forests”, Zhana semey Kanonersky, Morozov, Novoshulba, Semipalatinsk “without floodplain

[1] Web resource: https://www.oopt.kz/categories/view/semey_ormany/ (accessed 20.04.2024)

forests” branches belong to the steppes latitude-geographical zone, the territory of Zharminsky branch — to the desert latitude-geographical zone. According to the botanical and geographical classification, the territory occupied by the forest strips along the Irtysh belongs to the Eurasian steppe region, the Trans-Volga-Kazakhstan province, the East Kazakhstan steppe subprovince, the dry fescue-grass steppe zone on chestnut soils. The studies of the soil layer of the territory on the subject of vegetation have been carried out intensively by the local scientists in the last few years [*Rakhymberdina* et al., 2021].

The flora of higher plants in the pine forest strips along the Irtysh is represented by a total of 201 genera, of which 61 are represented by 344 species. The basis of flora is angiosperms — 340 species, including: dicotyledons — 80.59 % “274 species”, monocotyledons — 19.41 % “66 species”. The most important forest forming species are pine “*Pinus sylvestris*”, birch “*Betula pendula*” and aspen “*Populus tremula*”.

In the conditions of Semey forest, forest areas with strong winds in the region, in addition to preventing sand avalanches and playing a protective role of structures, roads, etc., deciduous forests in the floodplain at the mouth of the Irtysh, in addition to the function of water regulation, contribute to increasing the productivity of agricultural crops, hay, pastures.

The fire in the research area occurred on June 8, 2023 and was completely extinguished on July 13 of the same year. According to the Ministry of Ecology[1], the damage caused by the fire is estimated at 165 billion tenge, of which about 30 billion tenge are direct damages, the rest are losses due to the loss of useful properties of the forest. After the fire, it was reported in the media that the government was going to allocate more than 1.2 billion tenge to the Ministry of Ecology to prevent forest fires and deal with the consequences of the fire.

Research data

A satellite image used in this study is medium resolution Landsat-8–9 OLI/TIRS Collection 2 Level 2 satellite data. The Landsat-8–9 Level 2 collection includes both Landsat-8 and the recently launched Landsat-9 satellites “provided by NASA/USGS”, which provide seasonal continental coverage. Landsat-8–9 Level 2 provides global information on surface reflection and surface temperature. Level 2 scientific products are created from the initial Level 2 Batch 1 data, which meets the solar elevation limit of <76° and contains the ancillary inputs necessary to create a scientific product. The resulting images provide spectral and spatial information for emergency services to create maps of the subject of interest (Table 1).

Table 1. Landsat-8 OLI & TIRS Sensors

Landsat-8–9 OLI/TIRS	Description	Wavelength (min-max)	Resolution (m)
Band 1	Coastal/Aerosol	0.433 to 0.453 μm	30
Band 2	Visible blue	0.450 to 0.515 μm	30
Band 3	Visible green	0.525 to 0.600 μm	30
Band 4	Visible red	0.630 to 0.680 μm	30
Band 5	Near-infrared	0.845 to 0.885 μm	30
Band 6	Short wavelength infrared	1.57 to 1.65 μm	30
Band 7	Short wavelength infrared	2.11 to 2.29 μm	60
Band 8	Panchromatic	0.50 to 0.68 μm	15
Band 9	Cirrus	1.36 to 1.38 μm	30
Band 10	Long wavelength infrared	10.60 to 11.19 μm	100
Band 11	Long wavelength infrared	11.50 to 12.51 μm	100

[1] Web resource: https://24.kz/ru/news/incidents/item/622385-ushcherb-ot-pozhara-v-semej-ormany/ (accessed 20.04.2024)

Landsat-8–9 OLI/TIRS imagery from May 12, 2022, satellite imagery from June 15, 2023, during the fire, and post-fire imagery from September 27 of this year were used to analyze the pre-fire conditions of the study area.

Research methods

In this study, the state of the forest reserve territory before the fire, during the fire and after the fire is discussed on the basis of the remote sensing data. The forest reserve territory is located in the territory of the State Forest Nature Reserve "Semey ormany" Abay Region — Beskaragaysky, Borodulikha districts, where forests and agricultural land are most frequently found. The study was conducted with indices obtained from processing satellite images of Landsat-8–9 OLI/TIRS, object-based classification techniques, combustion zone and combustion intensity, and the differences in the definition of the combustion zone were compared using the corresponding plug-ins of the geoinformation systems QGIS and SAGAGIS in the publicly available, and the identification of some factors of preliminary monitoring of forest fires was analyzed.

RESEARCH RESULTS AND DISCUSSION

Classification of research area

After downloading the Landsat-8–9 OLI/TIRS satellite images with the required time periods, Band B4, B5, and B10 are uploaded to the SAGA GIS software for the object-based classification method of the burned area and classified by color (Fig. 2).

Since the study area was chosen as a wooded area, the bands were displayed in the order of 7,6,4 of the combination. This combination gives an image close to natural colors, but at the same time allows us to analyze the state of the atmosphere and smoke (Fig. 2, inside the red circle).

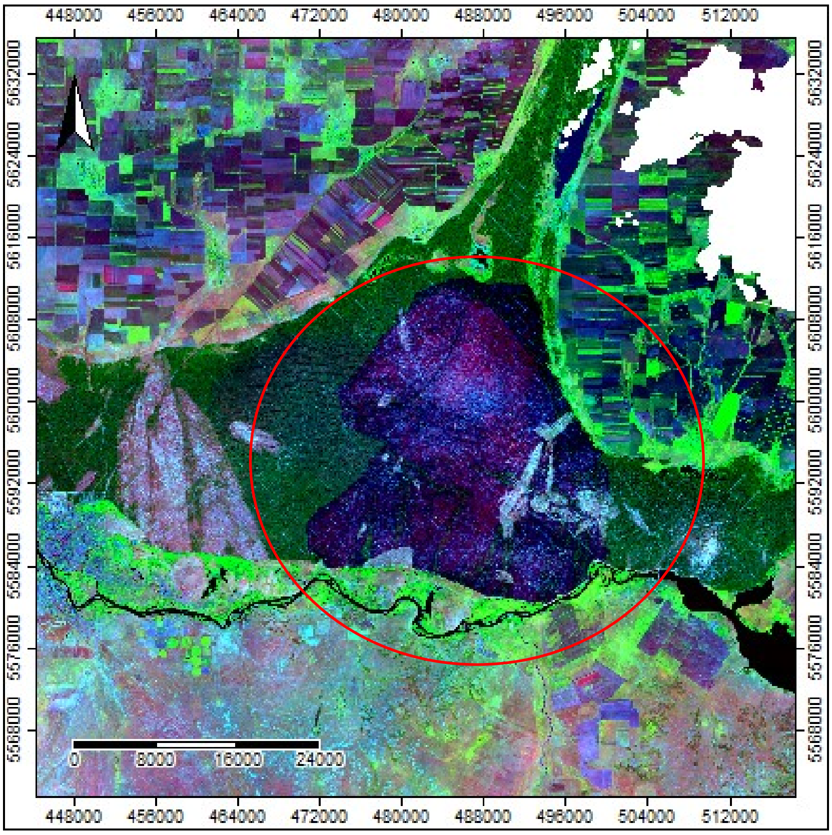


Fig 2. Classification of the burned area by color

According to the resulting map, plants appear in dark and light shades of green, urbanized areas appear in white, green-blue and red, soil, sand and minerals can have very different colors. The complete absorption of mid-infrared radiation by water, snow and ice allows you to see the coastline very clearly and emphasize water features in the image. Hot spots "such as burnt wood ash" appear red or yellow.

One advantage of using this combination of bands is that it is the most rationally selected combination for fire control.

Object-Based Classification

Using satellite imagery Landsat-8–9 OLI/TIRS C2 L2, a pre-fire, during fire and post-fire mapping of the research area is determined by object-based classification analysis of bands combinations (Fig. 3).

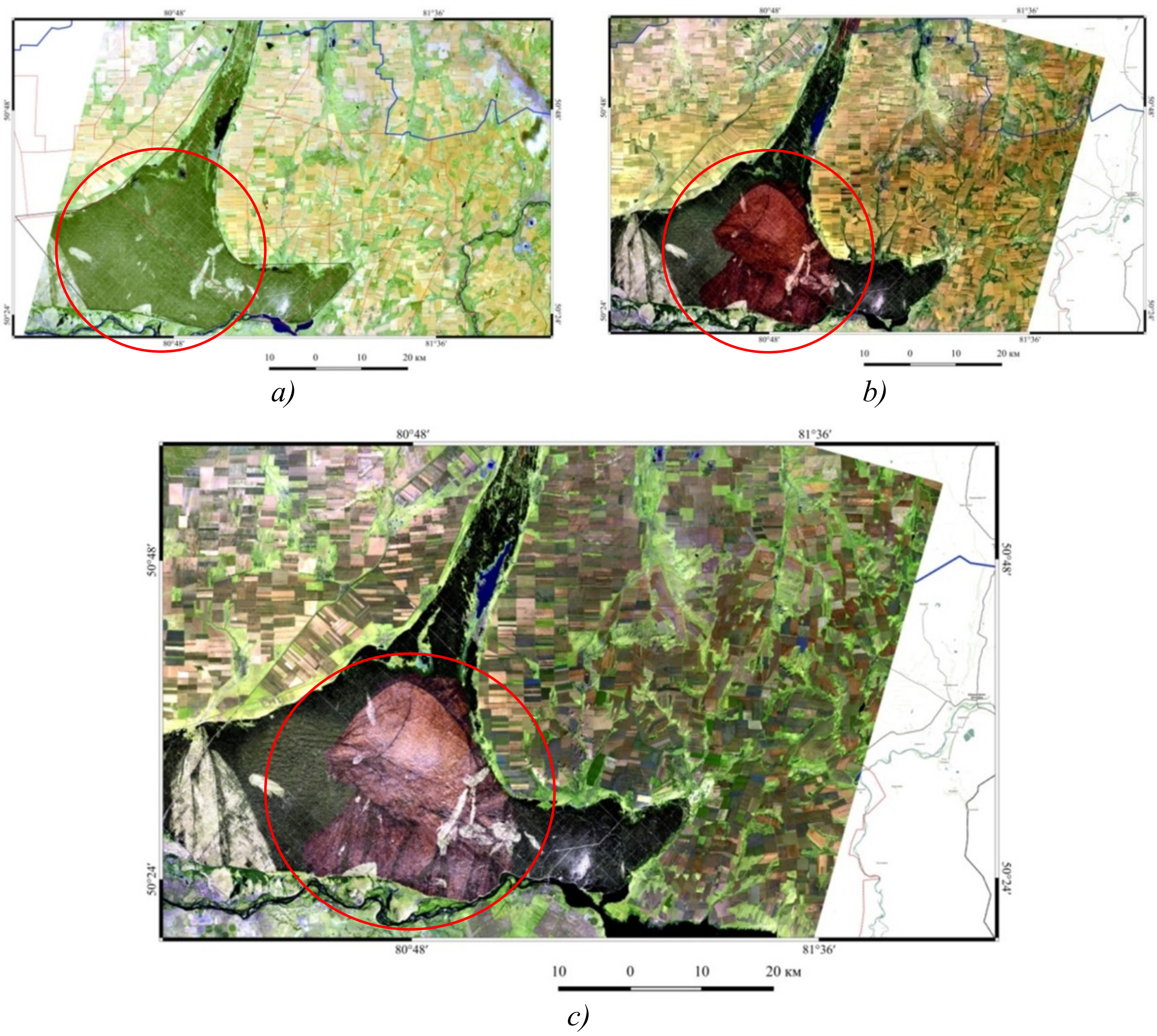


Fig. 3. Analysis of the study area in the combination of bands 7,6,4, Landsat-8–9 OLI/TIRS C2/L2: a) before the fire 2022.05.12; b) burning period 06.15.2023; c) after the fire 2023.09.29

From the results of the combination of bands, it can be seen that the condition of the territory before the fire (Fig. 3a), most of it is green-covered, during the fire (Fig. 3b) — brownish-pink, and more than two months after the fire-ash color of the bareland of the territory (Fig. 3c).

When using a combined composition containing 10 bands of the selected Landsat-8–9 OLI/TIRS, the burned areas are usually clearly visible, as shown in Fig. 2. On the Landsat-8 satellite, band 10 and 11 are bands that detect heat in the Long Wavelength IR[1]. Unlike weather stations that monitor air temperature, these Landsat-8 bands show the heat level of the ground surface, which is usually hotter than the air. However, their measurements are not as accurate (the resolution of the images is 100 meters per pixel). Although these shortcomings do not provide detailed information for some studies, conditional color imagery can provide additional information for determining the fire hazard of large areas. Therefore, bands 10,5,4 are the best choice for fire risk monitoring.

Burned areas are often black in color and absorb and release large amounts of thermal energy. The SAGA-GIS program can be used to quickly and easily map burned areas from Landsat imagery using object-based image analysis techniques. The first step is to use the multi-resolution segmentation method.

The result of segmentation depends on the scale, shape and compactness parameters controlled by the user [*Yankovich*, *Yankovich*, 2020]. The scale parameter, which controls the size of the segment, determines the maximum uniformity. The value of the selected Scale parameter directly affects the separation of the image by determining the size of objects in the image. Although the shape setting adjusts the color weight, compactness determines how dense the pixels are for the object being compared to the circle [*Liang* et al., 2023]. For observable image classification, an integrated nearest neighbor classification method based on a fuzzy rule is used (Fig. 4).

As part of this study, during the determination of areas by segmentation method divided classes (Table 2), more than 200 thous. ha of land were exposed to fire hazard. According to the Committee on Forestry and Wildlife of the Ministry of Agriculture of the Republic of Kazakhstan[2], 60 thous. ha of forest and agricultural land were affected by the fire. The advantage of this method is to determine the extent of fire accidents in the main forest clusters by comparing the analyzed class area from satellite images with local forest maps. The method shown here allows you to quickly assess the fire area over large areas and is best suited for mapping specific fires or their control areas.

The object-based classification method can be a rational method for evaluating the organization of measures for timely monitoring and prevention of fire hazards in forest and agricultural territories by area of territories and class numbers.

Methods for classifying objects with Landsat-8–9 OLI/TIRS satellite image indices determine the combustion zone and combustion intensity and compare differences in the definition of the combustion zone (Table 3). In the study, it is proposed to construct the dNBR, RBR, RdNBR, dNDVI, dGNDI, GEMI and BAI indices of plants using an arithmetic combination of channels [*Kurnaz* et al., 2006].

The Normalized Burn Coefficient “NBR” index is one of the most actively used indices in fire management studies conducted by remote sensing studies of the Earth (Fig. 5). The NBR index is by taking a ratio of two bands dropping the values between −1 to 1. As vegetation reduction occurs in the post-fire process, near-infrared reflectance is significantly reduced. Healthy plants usually give higher values, while bare ground or recently burned areas give lower index values.

Differentiated normalized fire rate “dNBR”, using the NBR difference calculated from images before and after the fire occurred, determines the area of burned areas [*Brandon* et al.,

[1] Web resource: https://eos.com/ru/blog/kombinatsii-kanalov-landsat-8/ (accessed 20.05.2024)
[2] Web resource: https://ru.wikipedia.org/wiki/Semey ormany/ (accessed 20.04.2024)

2022]. In the NBR index before the fire, the green colors (Fig. 5a) after the fire (Fig. 5b) changed to orange. It can be understood that the fire occurred in areas of the dNBR index (Fig. 6), indicated by positive values from −0.59 to 0.39, while areas with negative values were not affected by the fire.

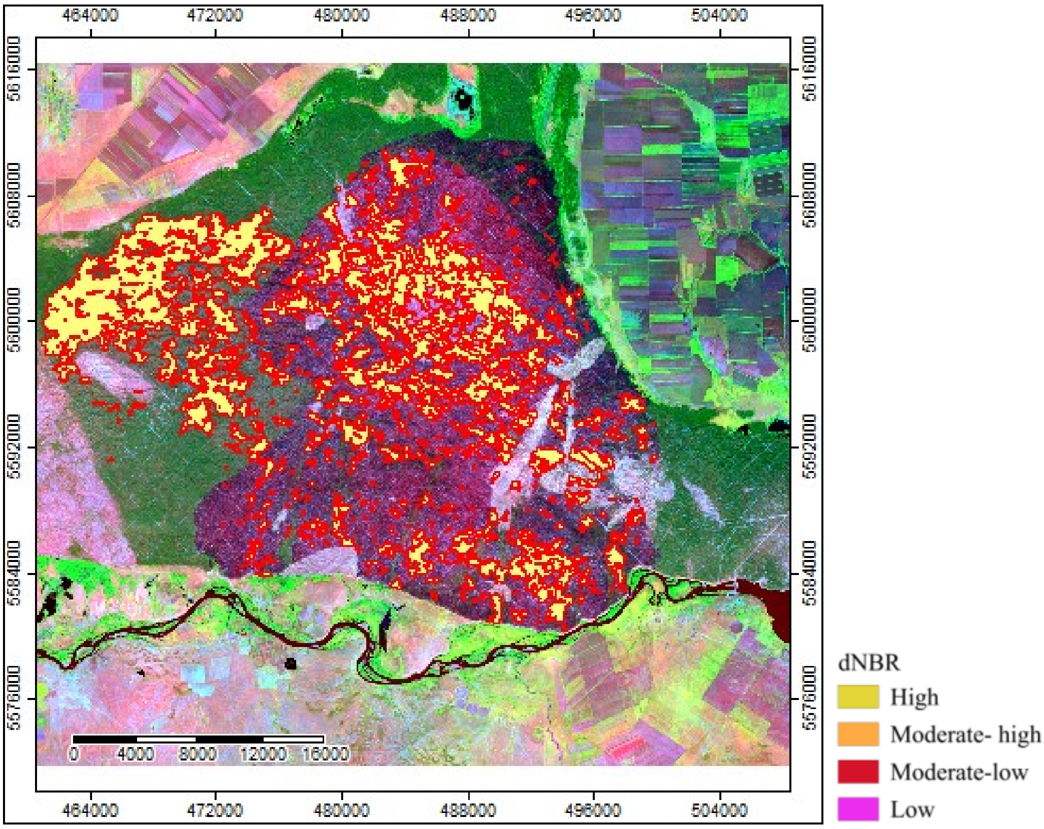


Fig. 4. Fire spread rate by segmentation method Object Based Image analysis (OBIA)

Table 2. Forest fire areas obtained from indices and OBIA

No.	CLUSTER	PERIMETER (m)	AREA (Ha)
1	0	1 665 120,000 000	13636,2600
2	1	1 499 760,000 000	18727,8300
3	10	860 520,000 000	6458,8500
4	11	1 178 880,000 000	9251,1000
5	12	586 320,000 000	5050,0800
6	13	881 400,000 000	8282,1600
7	14	503 520,000 000	3727,1700
8	15	512 040,000 000	3703,2300
9	16	397 680,000 000	5881,5000
10	17	698 520,000 000	5246,2800
11	18	260 040,000 000	1220,6700
12	19	947 700,000 000	13910,3100
13	2	2 053 500,000 000	19888,6500

No.	CLUSTER	PERIMETER (m)	AREA (Ha)
14	20	960 960,000 000	7017,3900
15	21	1 498 320,000 000	12768,3000
16	22	635 280,000 000	7624,0800
17	23	1 015 260,000 000	9409,1400
18	24	320 040,000 000	3082,6800
19	3	912 360,000 000	6505,1100
20	4	1 243 440,000 000	12477,7800
21	5	1 289 580,000 000	14902,5600
22	6	1 429 140,000 000	15514,0200
23	7	96 180,000 000	633,6000
24	8	305 280,000 000	1889,8200
25	9	848 460,000 000	7460,1900

Table 3. A ratio between bands of fire risk assessment indicators determined from Landsat-8–9 OLI/TIRS images

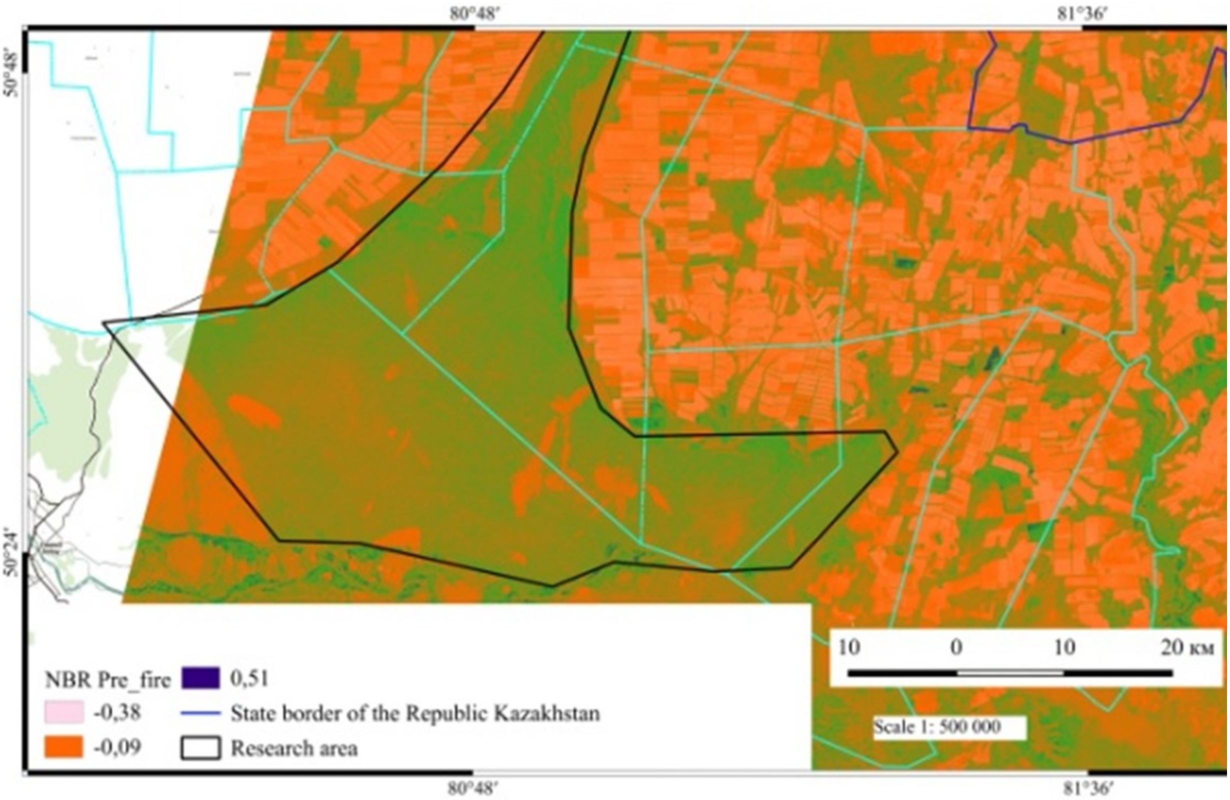
Indices	Landsat-8–9
NBR	B5 − B7 / B5 + B7
NDVI	B5 − B4 / B5 + B4
dNDVI	$NDVI_{pre\text{-}fire} - NDVI_{post\text{-}fire}$
GNDVI	B5 − B3 / B5 + B3
dGNDVI	$GNDVI_{pre\text{-}fire} - GNDVI_{post\text{-}fire}$
dNBR	$NBR_{pre\text{-}fire} - NBR_{post\text{-}fire}$
RdNBR	$dNBR / \sqrt{(NBR_{pre\text{-}fire} / 1000)}$
RBR	$dNBR / NBR_{pre\text{-}fire} + 1.001$
BAI	$1 / (0.1 - B4)^2 + (0.06 - B5)^2$
GEMI	$\gamma \cdot (1 - 0.25 \cdot \gamma) - B4 - 0.0.125 / 1 - B4$ $\gamma = 2 \cdot (B5^2 - B4^2) + 1.5 \cdot B5 + 0.5 \cdot B4 / B5 + B4 + 0.5$

The location of post-fire burns is observed in all identified indices, although the dNBR index cited in the study showed better results for fire risk analysis than other indices compared.

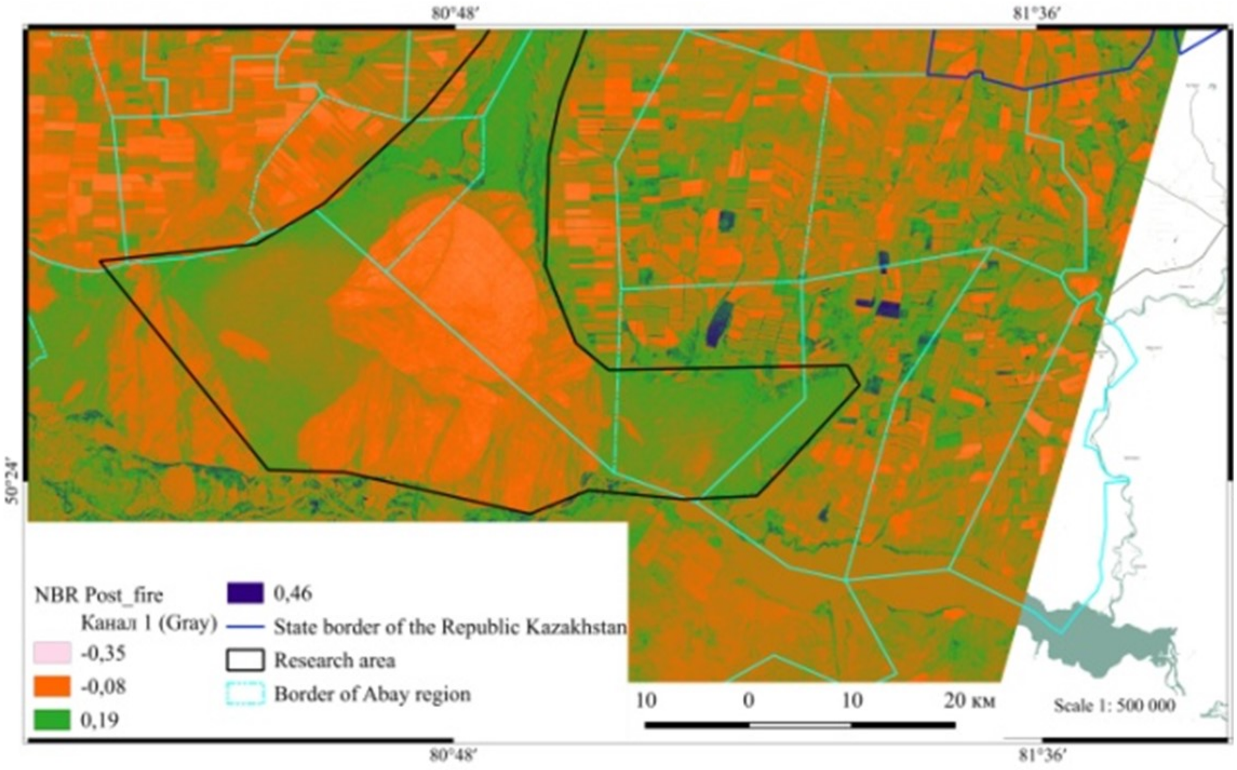
To analyze the severity of the fire, four classes without image control “unsupervised-K-Means Clustering for Grids” were identified in the SAGA GIS program according to the limit values (Fig. 4). When looking at the fire intensity maps, the high-risk area is shown as forest vegetation, and conversely, the grazing and agricultural land in this area is shown as low-risk.

In the analysis carried out was analyzed the method of analyzing the means of segmentation of object images “Object Based Image Segmentation” with the combination of a set of tools for easy representation of geo-objects in the form of polygons to determine the fire hazard by class (Table 4).

After segmentation, the dNBR result (Fig. 6) was identified as burned area, bare ground, conifer, deciduous, and water classes. The accuracy of the classified image was evaluated by user accuracy, with the used materials accuracy and K-mean statistics. The OBIA results concluded that the Landsat-8–9 OLI/TIRS provides an overall accuracy of 95 % and a K-mean of 0.945.



a)



b)

Fig. 5. Results, NBR: a) before the fire, b) after the fire

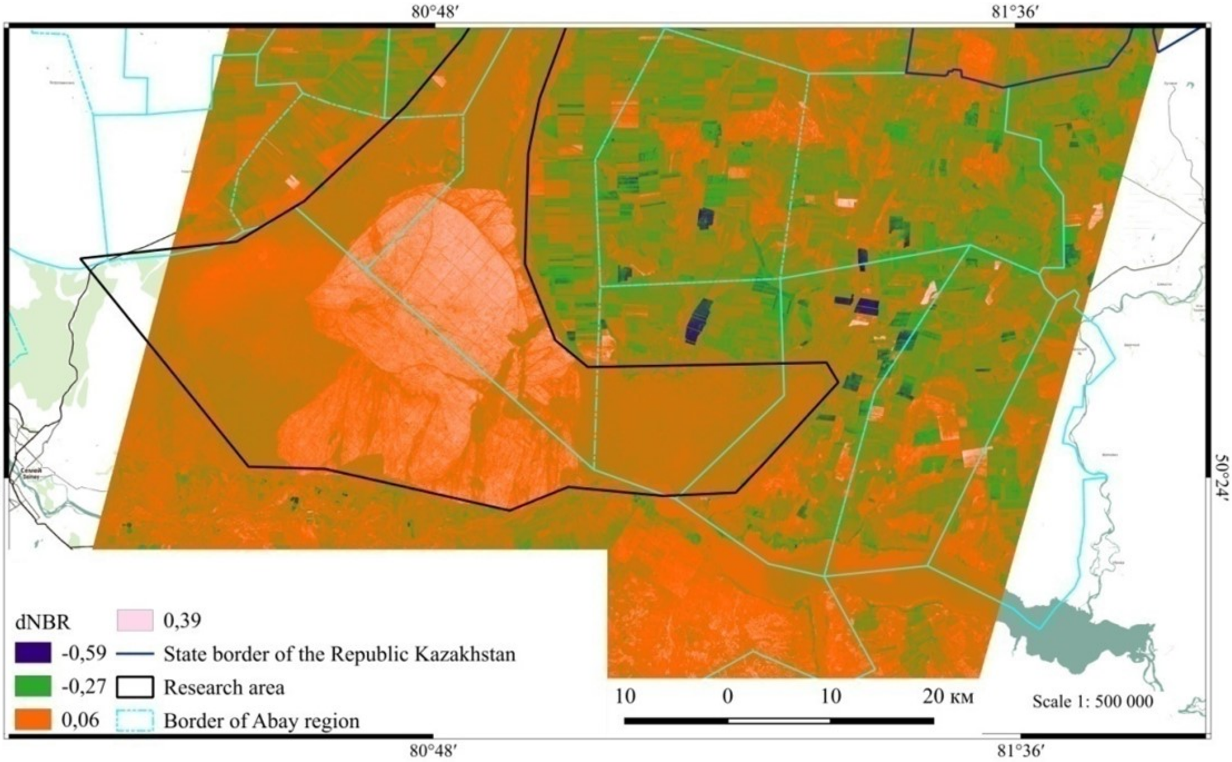


Fig. 6. Differenced Normalized Burn Ratio (dNBR)

Table 4. Accuracy assessment OBIA

Total land area classified for study 202 790,98 Ha		
Classes	**PA (%)**	**Std.Dev. (%)**
Coniferous	96 %	98 %
Deciduous	93 %	83 %
Water	93 %	100 %
Bareland	93 %	94 %
Burned area	94 %	96 %
Overall Accuracy	**95 %**	
K-Mean	**0.945**	

Forest fire hazard assessment is often carried out by specialized services that use various methods and simulations to predict and control forest fires, but before conducting an analysis, it should be considered that performing the necessary data identification increases the accuracy of the data obtained from satellite images. To do this, data sets are taken from local authorities, which include the analysis of the fire hazard in them, the assessment or use of fire hazard with the help of GIS. Based on the study, 5 key data sets were identified that were needed:

1) census units and Population Data “regions with the largest population”;
2) satellite images “normal vegetation difference index — NDVI”;
3) digital elevation model “aspect and slope — DEM, digital elevation model”;
4) forest fire that occurred “spatial structure/clustering”;
5) factors that negatively influence the occurrence of fires “amount of precipitation, reservoirs, soil moisture, river valleys, etc.”.

After that, it is necessary to take a statistical multiplier, dividing the data set into three different categories, which will give values that can be calculated against each other, fire hazard, vulnerability factors and backlash factors.

CONCLUSIONS

The study analyzed the importance and versatility of using remote sensing data in mapping, analyzing, and detecting wildland fires. Thus, instead of expensive and time-consuming work traditionally carried out on the ground, a much more economical, faster and safer study of the environment using GIS technologies with results of a certain accuracy was given. The study included research to identify potential fire risk factors and to determine the actual situation of a forest fire that occurred using various satellite methods, algorithms, areas and indices. After the study, the advantages and disadvantages of the results obtained were evaluated and a method was determined that gave the appropriate result. The resulting indices, with the results of object classification, serve as a typical example of timely observation of possible fire zones by local authorities.

To obtain high precision results on the Landsat object-oriented classification satellite, it is recommended that you perform the panchromatic sharpening conversion process, which allows you to reduce pixel sizes at high spatial resolution so that the image is rotated in more pixels and produces a larger pixel size. Also, statistical multipliers to account for fire risk, vulnerability factors, and backlash factors must then be incorporated into the standard channel ratio.

Although object-oriented classification gives good results, it requires experience in processing. The limits, the chosen index, may vary depending on the situation, although it is an effective way to quickly map the course of a fire, as it quickly determines the location of the burn and the severity of the fire to be mapped. In general, the generation of satellite data using the methods presented in these studies has the potential to provide economical conclusions for fire control and management in large areas of dense pine forests.

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