

# Analysis of forest fires in arid landscapes of the Orenburg region

*Galia Bastaeva*<sup>1\*</sup>, *Olga Lyavdanskaya*<sup>1</sup>, *Andrey Kubasov*<sup>1</sup>, *Alexander Altaev*<sup>2</sup>, and *Petr Maltsev*<sup>1</sup>

<sup>1</sup>FSBEU HE Orenburg State Agrarian University, 18, st. Chelyuskintsev, Orenburg, 460014, Russia

<sup>2</sup>Buryat Research Institute of Agriculture – branch of Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, 25z, st. Tretyakova, Ulan-Ude, 670045, Russia

**Abstract.** At the present stage of economic development of the forestry complex of the Russian Federation, solving problems with forest fires is key and fundamental. The inevitability of forest fires and the impossibility of preventing the loss of forest resources have led to the need to conduct analytical work to assess the fire rate of forests, which is an indicator of the conditionally permissible area of forest fires for a certain area or forestry for a certain period. The article presents the results of a review of forest fires in the Orenburg region in the context of 27 forest districts for the analyzed period from 2010-2020. Assessing the results of forest fires is necessary to solve current applied problems when planning work in subsequent fire seasons. The study found that for the period (2005-2023), the most fire-dangerous years in terms of the number of fires were 2010 and 2021. An assessment of the relative fire rate in forest districts of the region made it possible to establish that low fire rate is typical for 6 forest districts (22%), moderate and medium fire rate is established in 8 forest districts (30%), and strong (high) fire rate is found in 13 forest districts - 48%. High values of relative fire intensity with values of 0.9, 0.5 and 0.6 were established, respectively, in the Dombarovsky, Orenburgsky and Kvarkensky forest districts, the main reason for their occurrence is the anthropogenic factor. Depending on the geographical location of forestry areas, the number of fires increases; the reliability of the approximation was  $R^2=0.83$ .

## 1 Introduction

On the territory of the Russian Federation, forest fires annually destroy significant areas of forest plantations, causing significant damage not only to forest ecosystems, but also to the entire economy of the subjects. An urgent national economic task is the comprehensive fight against forest fires, and the development of measures to prevent their occurrence. Forest plantings perform an important ecological function in fixing atmospheric carbon, increasing air humidity, which generally contributes to climate moderation; on agricultural

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\* Corresponding author: [oren78@mail.ru](mailto:oren78@mail.ru)

lands, forest plantings help retain snow throughout the land use area, protect from dry winds, and help combat erosion processes.

Currently, forest fires are recognized as one of the main problems of forestry, due to the colossal damage caused by their scale of impact. Careless handling of fire in the forest, burning last year's dry grass on agricultural land, are recognized as one of the main causes of fires in the Orenburg region, thunderstorm activity is rated as the second most common cause. According to official data, in the densely populated European part of the Russian Federation, up to 98% of fires occur due to human fault; in remote northern areas the figure is below 50% [1].

In the Orenburg region, due to regular periods of prolonged atmospheric drought and precipitation deficiency, forest fires have noticeably increased. Regularly, in municipal areas, due to large-area forest fires, emergency situations (ES) are introduced [2].

Everywhere, the development and comprehensive implementation of protective and preventive measures against forest fires is acutely felt. To combat effectively, it is necessary to have knowledge of both regional characteristics in the dynamics of forest fires and the dominant causes of their occurrence in the vast territory of the Orenburg region, the length of which from west to east is 760 km, and from north to south 445 km.

The forestry industry of the Orenburg region suffers significant losses from the impact of forest fires, especially in 2010 and 2021, when the duration of the fire season dates from the moment the snow cover melted and ended with stable autumn rainy weather. The most fire-hazardous conditions usually occur in early spring, due to the presence of dry grassy vegetation, however, weather conditions also play a significant role in the occurrence and spread of forest fires. The years 2005 and 2010 were especially dangerous for fires, when in some areas of the region there was no precipitation for about three months and there was hot, dry weather. The fire danger period of 2021 in the region lasted from April 7 to November 15, and was characterized by the predominance of high and extreme fire hazard classes throughout its entire length.

Fire danger in a forest, depending on weather conditions, is determined using a complex indicator characterizing meteorological (weather) conditions, therefore, the degree of fire danger in forests directly depends on the amount of precipitation, temperature and thunderstorm activity; cloudiness can be indirect.

Analysis of a sufficient number of scientific works conducted by A.L. Morozova and M.I. Pudovkin, indicate that changes in atmospheric circulation are associated with the level of solar activity, which were recorded both during the 11-year cycle of solar activity and in shorter time periods [3].

The problem of forest fires in the Orenburg region is not new, and many of its aspects are being solved, for example, the fleet of forest fire equipment has recently been significantly updated, but there is no practically oriented scientific research on forest fires and the resulting consequences in the dynamics of fires.

The purpose of the work is to analyze the fire rate of forests in the Orenburg region, to establish the dynamics of forest fires for the period from 2005-2023 in the forest districts of the region.

The article provides materials only on the forest fund of the subject under study; data on specially protected natural areas, the Ministry of Defense of the Russian Federation and rural lands were not analyzed.

## **2 Materials and methods**

The study to analyze the fire rate of forests in the Orenburg region was based on official materials of the Ministry of Natural Resources, Ecology and Property Relations of the Orenburg Region, and the forest plan of the Orenburg region [4]. The fire rate of forests

was assessed by the number of fires and the area covered by fire, using the methodology of G.A. Mokeev [5]. Data processing and analysis were carried out using the Microsoft Excel 2010 analysis package and the Statistica software package.

### 3 Results

The Orenburg region is geographically located in the foothills of the Southern Urals, and the uniqueness of the relief allows us to divide the object under study conditionally into three parts - western, central and eastern.

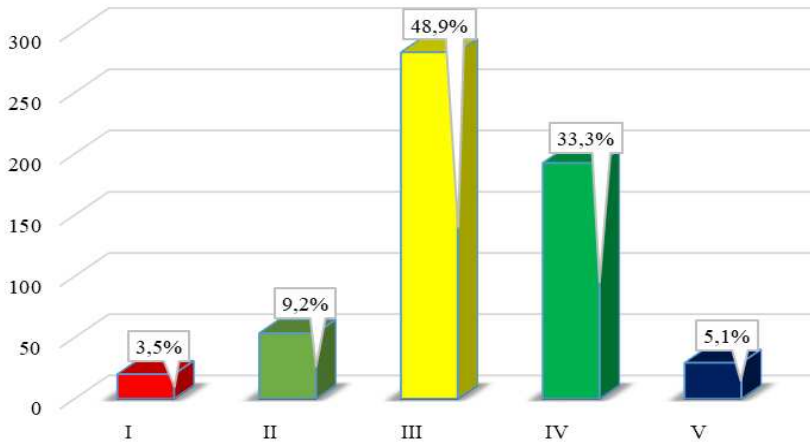
The modern relief was formed as a result of the erosion of the Ural folds and pre-Ural syrt plains, which occurred for quite a long time, under the influence of tectonic movements. The Herzen orogeny determined the flat and mountainous terrain of the subject under study, allowing the unhindered penetration of air masses from the south, causing strong dry winds. Due to the location of the Orenburg region in the depths of Eurasia, there is no moderating effect of sea air masses, which underlies the formation of continental climatic conditions.

The Orenburg region is characterized by hot summers and cold winters, there is little precipitation and is distributed unevenly throughout the region; if in the northwestern regions their annual amount can reach 450 mm, then in the southeastern regions it is only 250 mm per year, and high annual amplitudes growing towards the eastern part of the region. In winter, the region's territory cools and is influenced by high pressure formed over the territory of Siberia and Mongolia. Anticyclones of Siberian origin periodically pass over the region. In summer, anticyclones come from the west and carry tropical air from the Mediterranean Sea. Dry and hot winds from Kazakhstan and Central Asia bring "desert breath" to the territory of the region. The Orenburg region belongs to the zone of insufficient moisture. The amount of precipitation decreases from 450 mm per year in the north-west to 250 mm in the south-east of the region. About 70% of the annual precipitation occurs during the warm period of the year from May to August [6].

The area of the Orenburg region is 124 thousand km<sup>2</sup>, it includes 29 municipal districts, 13 urban districts, 445 rural settlements. The regional center is Orenburg, the largest cities are Orsk, Novotroitsk, Buzuluk, Buguruslan and Gai.

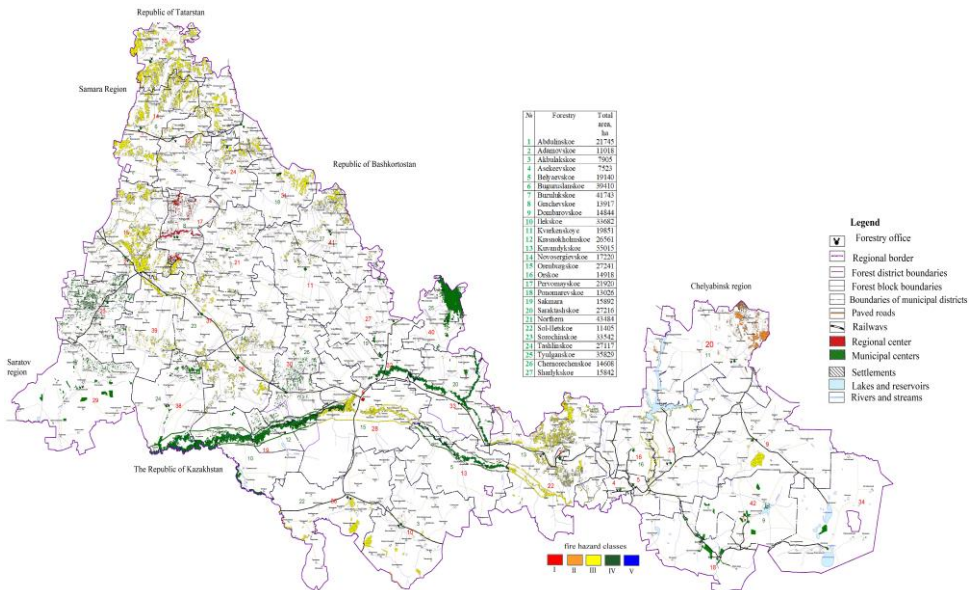
The total area of forest fund land is 630.7 thousand hectares. The distribution of the forest fund area of the Orenburg region by natural fire hazard classes as of 01/01/2023 is ranked as follows: class 1 – 20.0 thousand hectares (3.5%); 2nd class – 53.4 thousand hectares (9.2%); 3rd class – 282.8 thousand hectares (48.9%); 4th class – 192.5 thousand hectares (33.3%); Class 5 – 29.3 thousand hectares (5.1%) (Figure 1), i.e. more than half of the territory is classified as class 3 - fires that occur spread quickly.

The share of forest fund areas of I-III fire hazard classes is 61.6%; ground fires here are possible throughout the entire fire season. Fire danger class I occupies 3.5% of the forest fund area; crown fires occur throughout the entire fire season. During periods of peak fires, crown fires are possible in forest plantations of class II fire danger on an area of 53.4 thousand hectares (9.2%). Forest fires in forest areas of IV-V fire hazard classes (38.4%) are possible only during periods of fire maximums or after long droughts. The average class of natural fire danger in the forests of the Orenburg region is III, however, in arid climates, periods of high fire danger due to weather conditions can be long. On average, the fire season lasts more than 6 months.



**Fig. 1.** Distribution of forest lands in the Orenburg region by fire hazard classes.

The territory of the Orenburg region, according to the order of the Federal Forestry Agency dated January 26, 2022 No. 22, is classified as a zone for ground detection and suppression of forest fires (Figure 2) [7]. In areas that provide ground protection of forest areas, in order to effectively combat forest fires, it is necessary to have a developed network of transport routes. The road transport network throughout the forest fund of forest districts of the Orenburg region is distributed extremely unevenly. More than half of the region's forest districts have insufficient length of unpaved forestry roads - less than 10 km per 1000 hectares. Forestry roads in the off-season, and in the summer after rains, fall into unsatisfactory condition, and travel on such roads is possible only for special equipment with increased cross-country ability.



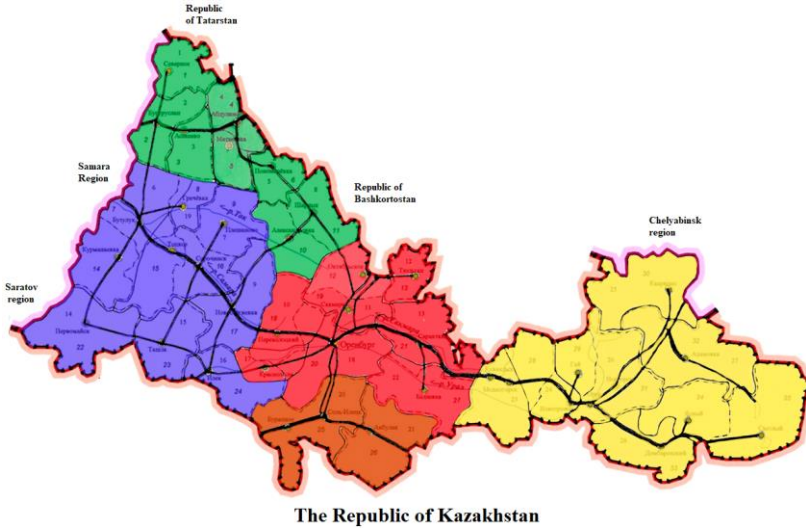
**Fig. 2.** Scheme map of the Orenburg region indicating forest districts and fire danger classes [3].

Order No. 312 of the Federal Forestry Agency dated October 16, 2008 established that 28 forest districts were created within the boundaries of 40 municipal districts on the territory of the forest fund of the Orenburg region [8]. Currently, the total number of forest districts is 27 (Table 1). All forests of the Orenburg region are classified as protective forests.

For further work, forestry areas in the Orenburg region are divided into zones, relative to their geographical location (Table 1, Figure 3).

**Table 1.** List of forest districts of the Orenburg region.

<b>Forestry</b>	<b>Total area, ha</b>	<b>% forest cover</b>
Northern zone		
Abdulinskoe	21745	5.2
Asekeevskoe	7523	2.9
Buguruslanskoe	39410	13.0
Ponomarevskoe	13026	5.2
Northern	43484	18.8
Sharlykskoye	15842	2.2
South zone		
Akbulakskoye	7905	0.6
Sol-Iletscoe	11405	1.6
Western zone		
Buzulukskoe	41743	22.0
Grachevskoe	13917	7.4
Ilekskoye	33682	12.4
Novosergievskoe	17220	3.4
Pervomayskoe	21920	2.1
Sorochinskoe	33542	4.4
Tashlinskoe	27117	5.8
Eastern zone		
Adamovskoe	11018	1.1
Dombarovskoe	14844	0.3
Kvarkenskoe	19851	2.7
Kuvandykskoe	55015	8.4
Orskoe	14918	1.5
Central zone		
Belyaevskoe	19140	2.7
Krasnokholmskoe	26561	10.9
Orenburgskoye	27241	4.3
Sakmara	15892	2.7
Saraktashskoe	27216	7.0
Tyulganskoe	35829	17.3
Chernorechenskoe	14608	4.2

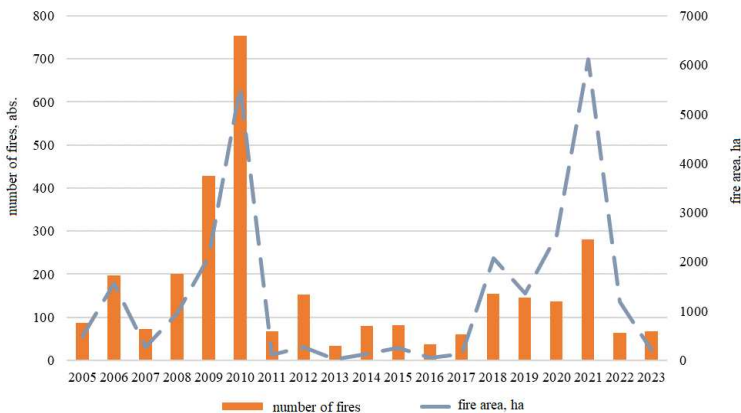


**Fig. 3.** Schematic map of forest areas of the Orenburg region, divided relative to geographical location.

Over the 19-year analyzed period, from 2005-2023, in the Orenburg region, the total number of recorded forest fires amounted to 3,100 units, on a total area of 25,402.3 hectares (Figure 4), while the culmination of the number and area of forest fires occurring in 2010 and 2021 is clearly visible, the time period is 11 years.

The year 2010 was especially catastrophic in terms of the number and area of fires that occurred, as in the whole territory of the Russian Federation; the number of recorded forest fires was 754, covering 5,561.6 hectares. In 2021, the burned area was 6112 hectares with a total of 281 units.

On average, over the analyzed period, more than 163 fires occurred; fires annually covered 1,337 hectares of forest plantations. The number of fires and the area of fires is directly related to the amount of precipitation, and the human factor is also significant. The parameters of the fire season and the timing of its beginning are determined by the magnitude of deviations from the norm (long-term average values) of hydrometeorological parameters, including autumn soil moisture, snow reserves at the beginning of the fire season, air temperature, amount and type of precipitation during the fire season.



**Fig. 4.** Long-term dynamics of forest fires in the Orenburg region (2005-2023).



An analysis of the long-term dynamics of forest fires (2005-2023) in the region allowed us to establish that the maximum value for the number of fires that occurred occurred in 2010 and 2021, respectively 754 units. and 281 units, so the time period of the maximums was 11 years. The minimum number of forest fires lasting 3 years was recorded in 2013 - 34 units. and 2016 - 37 units. These periods in the scientific literature are interpreted as double weakly manifested 3-year periods corresponding to the duration of heat and cold waves, the duration of which ranges from 4-8 years [9]. It is known that air temperatures correlate with the 11-year cycle of solar activity, thunderstorm activity anticorrelates with the solar activity cycle [10], and humidity and cloudiness in the Northern Hemisphere anticorrelates with solar activity. On a local scale, weather conditions behave depending on the geographic latitude and orographic conditions of the territory, determined by changes in the path of cyclones and anticyclones, thus the fire danger in the forests of a particular area changes in a complex way in the cycle of solar activity.

According to published data from the Ministry of Natural Resources, Ecology and Property Relations of the Orenburg Region, the cause of forest fires in 38% of cases is the passage of fire from lands of other categories, about 35% of fires were caused by human factors and 18% of recorded cases were caused by lightning discharges, short circuit of power lines.

However, the main causes of forest fires are violations of fire safety rules in the forest. Owners of lands adjacent to the forest fund (agricultural producers) often burn straw in the fields or burn weeds; it is from here that the fire often enters the forest fund territory. An analysis of natural fires that have occurred shows that the main reason for their occurrence is still the population's failure to comply with the basic requirements of fire safety rules. The main causes of fires: careless handling of fire, uncontrolled burning of dry grass, leaving fire pits.

## 4 Discussion

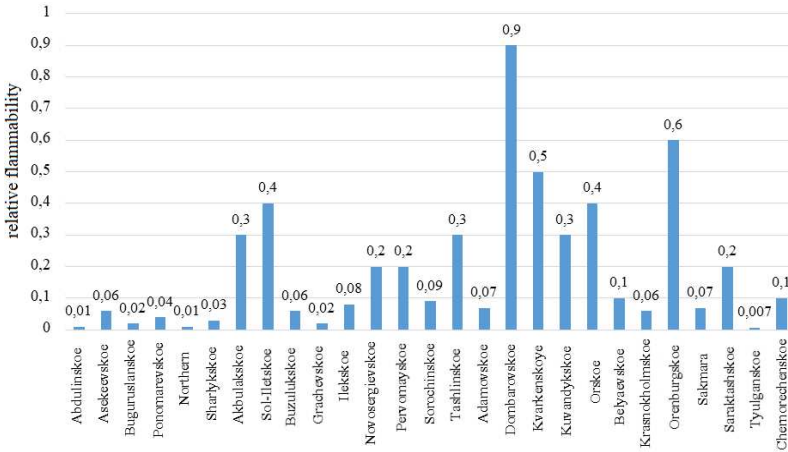
In the forest fund of the Orenburg region, the situation with forest fires is varied; a detailed study of individual forest districts provides an analysis of the relative fire rate of forests; the period of study was taken from 2010-2020.

An assessment of the relative fire rate according to the scale of G. A. Mokeev [5] indicates that out of 27 forest districts, low fire rate was established in 6 forest districts (22%), moderate fire rate in 4 forest districts (15%), average fire rate is typical for 4 forest districts (15 %), strong (high) fire in 13 forest districts of the region (Akbulakskoye, Sol-Iletskoye, Novosergievskoye, Pervomaiskoye, Tashlinskoye, Dombarovskoye, Kvarenskoye, Kuvandykskoye, Orskoye, Belyaevskoye, Orenburgskoye, Saraktashskoye, Chernorechenskoye) - 48% (Figure 5). Severe forest fire conditions occurred in 2010 and 2021, which is explained by the extremely high intensity of the fire season due to weather conditions. Forest districts with relatively low fire rates include Tyulganskoye, Abdulinskoye and Northern forest districts. Dombarovskoye, Orenburgskoye and Kvarenskoye forest districts stand out. In 2010, 883.6 hectares (58%) burned in the Dombarovskoye forestry over the entire 11-year period under analysis; the main reason was difficult weather conditions, the rapid spread of a steppe fire, which made it almost impossible to quickly localize the fire and stop the spread of fire.

In the Kvarken forestry in 2010, 292.75 hectares of forest burned (24.4%) during the analyzed period, and in 2018, due to the fault of a local resident, a large-scale fire occurred at a natural monument, with the predominant species being Scots pine (*Pinus sylvestris* L.), radius The fire's perimeter was about 100 km.

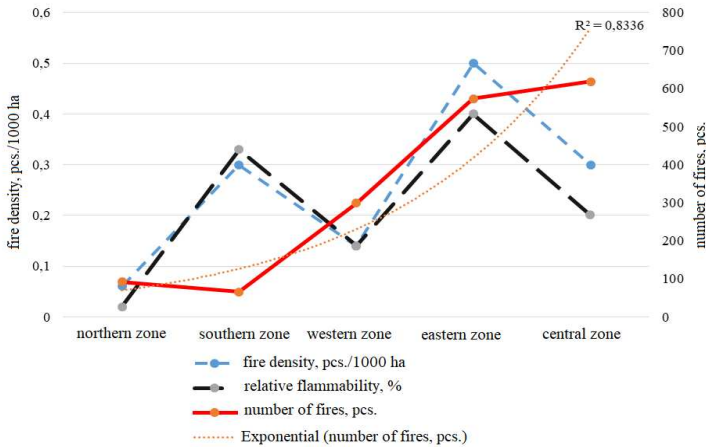
The forest fire spread to the neighboring Chelyabinsk region, then more than 1000 hectares of forest burned, 770.18 hectares (50.4%) in the forestry area.

The Orenburg forest district is located in the regional center of Orenburg, the population density here is quite high (2213.36 people/km<sup>2</sup>), hence the increased fire rate compared to other forest districts. In 2010, the area covered by forest fires in the territory of the Orenburg forestry amounted to 1104.7 hectares (62.6%), in 2020 - 438.846 hectares (25%) of the total area for the 11-year analyzed period.



**Fig. 5.** Relative forest fire rate by forest districts of the Orenburg region.

The relative burning intensity actually follows the density curve of forest fires (Figure 6). The minimum values for the density and number of fires are established for the northern and western zones of forestry (Table 1, Figure 5).



**Fig. 6.** Number of fires and their density by forestry zones.

The eastern zone with forest districts – Adamovskoye, Dombarovskoye, Kvarkenskoye, Kuvandyk'skoye, and Orskoye are the absolute “leaders” in the number and intensity of forest fires.

In the southern zone, with the Akbulak and Sol-Ilet'sk forest districts, 66 forest fires with a density of 0.3 were recorded.

There are 7 forest districts concentrated in the central zone (Table 1), the density of fires is 0.3, and the total number of forest fires is 619 units. The dominant position is occupied



by the Orenburg forestry, only 269 units were recorded here. forest fires, fire intensity is 0.9, and relative burning intensity is 0.6.

To identify the trend in the number of fires, an exponential function was chosen; a tendency for the number of fires to increase depending on the geographical location of the forestry was traced; the reliability of the approximation was  $R_2 = 0.83$ .

## 5 Conclusion

An assessment of the fire rate of forest districts in the Orenburg region showed a significant difference in its degree. In the central zone, where the regional center of Orenburg is located on the territory of the Orenburg forestry and the population density is more than 2200 people/km<sup>2</sup>, naturally, increased indicators of the number of forest fires and their density have been established in the Orenburg forestry.

The outbreaks of forest fires were not always eliminated promptly, and in remote areas the areas covered by fires were significant in the Kvarken and Dombarovsky forest districts. The number and area of forest fires are determined mainly by human activity, but there are cases of thunderstorm activity, temperature and humidity in the summer, the parameters of which depend on solar activity, the manifestation of which has a latitudinal effect.

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