Influence of permanent and variable factors on the number and area of forest fires in the Amur region

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Abstract. The article presents a study of the connection between the number and area of forest fires on the territory of the Amur Region from the area of forestries, the length of mineralized belts in each forestry, the natural class of fire hazard, and the class of fire hazard by weather conditions. A stable relationship between the number of forest fires and the fire hazard class by weather conditions has been revealed. This dependence is presented in the form of a model that makes it possible to predict the number of forest fires both on the territory of the forest fund of the entire Amur Region, and for individual forestries.

1 Introductory part

The Amur Region, which is part of the Far Eastern Federal District of the Russian Federation, is especially prone to forest fires. Every year, a large number of fires of various types and intensities occur in the region. Forest fires are a natural factor, but frequent and especially forest catastrophic fires cause hard-to-replace damage both to flora and fauna, and the regional economy, as well as public health [8, 10]. The occurrence and spread of forest fires mainly depend on meteorological conditions, such as temperature and humidity. An enormous part is played by the amount of precipitation and the duration without rainy periods [5, 9, 11, 12].

Many studies have already established the link between forest fires and weather conditions. A number of scientists have highlighted the importance of the precipitation regime (or dry periods) in fire activity in southwestern China [7]. D.R. Anto found that relative humidity shows a higher correlation with the monthly number of fires in Germany compared to temperature or rainfall [4].

Of particular scientific interest is the relationship between the classes of weather fire hazard and the number of forest fires occurring in the territory [4, 13, 15, 17]. Temperature, humidity, wind speed and rainfall determine the number and extent of forest fires. Also, knowing the class of weather fire hazard, it is possible to predict the degree of intensity and speed of spread of a forest fire [16]. Various forest fire hazard rating systems have been developed to prevent and manage forest fires at the country level [14].

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In the vast expanses of Russian forests it is impossible to fight fires in all forest growing zones. the country's economy will not be able to withstand such costs. This is common in many countries. as forest fires in Algeria destroy on average over 32.000 hectares per year. despite the adopted prevention and control plan. They are the most damaging factor in forest degradation and have a major impact on the environment and local economy. Conventional fire prevention and control methods are time consuming and not always reliable due to the complexity and diversity of forest ecosystems [6].

This work is aimed at studying the relationship between the weather fire hazard and the area of forest fires. as well as the volume of preventive forestry activities (creation of fire-prevention mineralized belts) in the forestries of the Amur Region.

The results are expected to justify an increase in preventive fire measures and a decrease in the occurrence of large forest fires in areas with a high weather fire hazard class.

2 Materials and methods

The data on fires were obtained from the state autonomous institution of the Amur Region "Air Base" (hereinafter referred to as the Air Base) and contains information on the number of forest fires in the forestries of the Amur Region. their area for the period 2017–2019.

2.1 Data analysis method

This analysis aims to establish the relationship between the number and area of forest fires. depending on the constant and variable factors that influence the occurrence and spread of fire.

The factors taken into account when determining the dependences of the area and the number of forest fires are divided into constant and variable.

Constant factors:

- the area of forestries and its distribution according to fire hazard classes according to natural conditions;
- the length of the mineralized belts in forestries;

Variable factors:

- class of fire hazard according to weather conditions.

The main method for determining the dependences of the number and area of forest fires on influencing factors is the method of constructing a trend line and determining the value of the approximation reliability.

3 Results

For the emergence and spread of a fire. three conditions must be observed: the presence of combustion products and oxygen. as well as a temperature sufficient for the emergence and maintenance of fire. Elimination of one of the factors contributes to the elimination of the fire. This rule also applies to natural fires. which occur mainly due to the fault of a person with uncontrolled and irresponsible handling of fire.

At present. in the prevention of the occurrence and spread of wildfires. the method of excluding combustible materials from the zone of possible occurrence or spread of fire is used. These methods include carrying out preventive annealing of dry vegetation and the system of mineralized belts.

Since the fall of 2019. the Ministry of Forestry and Fire Safety of the Amur Region (hereinafter referred to as the Ministry) has refused to carry out preventive annealing of dry vegetation on the territory of the state forest fund of the region in favor of arranging and

maintaining fire-fighting forest infrastructure. including the creation and renewal of mineralized belts.

The state forestry fund of the region is organized by the State Agrarian Administration of the Amur Region "Leskhozhes" (hereinafter - leshozhes) and forest users. In the region there are 11 forestry enterprises that carry out fire-prevention arrangement of forests within the framework of the fulfillment of the state assignment. and forest users in the areas used in the framework of the fulfillment of contractual obligations and the requirements of forest development projects.

Control over the quality of implementation of fire-prevention measures is carried out by state forest inspectors of the GKU of the Amur region "Lesnichestvos" (hereinafter - Lesnichestvos). In total. there are 13 forestries in the region. each of which has a certain territory of the state forest fund.

From our point of view. the location of the fire-prevention infrastructure. including mineralized zones. should be determined taking into account the class of natural fire hazard (Table 1). Forest users are limited in choosing the location of mineralized belts by the territory of the site being in use. therefore. the main role in ensuring the most rational location of mineralized belts remains with the executive authority. which. in accordance with the Forest Code of the Russian Federation. has been delegated powers in the field of forest management. Such an organ in the Amur Region is the ministry. which in turn assigns part of the delegated powers to the subordinate institutions of the forestry. forestry enterprises and the Air Base.

Table 1. Class of natural fire hazard of the forestries of the Amur region.

No	Name of forestry	Area. ha						Average class of natural fire hazard
		General	By classes of natural fire hazard					
			I	II	III	IV	V	
1.	Arkharinskoye	887469	55010	242376	309551	237376	43156	3.0
2.	Belogorskoye	803600	11455	8218	726844	57083	0	3.0
3.	Blagoveshchenskoye	73542	73542	0	0	0	0	1.0
4.	Bureyskoye	457262	45005	67937	332105	11459	756	2.6
5.	Zavitinskoye	107095	31572	23019	52504	0	0	2.2
6.	Zeyskoye	879324	312637	1354091	5745172	1214831	166509	3.0
7.	Magdagachinskoye	1308852	83487	363571	827626	34168	0	2.6
8.	Mazanovskoye	2223589	50391	128942	1655221	382497	6538	3.1
9.	Norskoye	4012232	486465	268290	2685034	572443	0	2.9
10.	Svobodnenskoye	349575	7560	204687	58650	8556	2072	2.0
11.	Tyndinskoye	7858015	1194714	2004978	4100138	526663	31522	2.7
12.	Urushinskoye	2483819	489887	1307495	610048	76389	0	2.0
13.	Shimanovskoye	1157749	186273	632075	304426	34416	559	2.2
Total:		22602123	3027998	6605679	17407319	3155881	251112	2.5

Depending on the age and type of forest growing in a particular area. a natural fire hazard class is assigned. The distribution of natural forest fire hazard classes among forestries is not uniform (Table 1) [1. 2]. Determination of natural fire hazard classes is

carried out on the basis of the order of the Federal Forestry Agency dated 05.07.2011 No. 287 "On approval of the classification of natural fire hazard in forests and the classification of fire hazard in forests, depending on weather conditions" [3].

Forestries annually, within the framework of the fulfillment of the state assignment, are brought up the volume of work on the arrangement and renewal of mineralized belts (Table 2).

Table 2. Distribution of the length of mineralized belts by forestry.

No.	Name of forestry	Arrangement of mineralized belts, km			Maintenance of mineralized belts, km			Average length, km
		2017	2018	2019	2017	2018	2019	
1.	Arkharinskoye	88.4	88.4	88.4	378	378	378	466.40
2.	Belogorskoye	190	190	163.4	500	500	500	681.13
3.	Blagoveshchenskoye	126.4	126.4	126.4	513	513	513	639.40
4.	Bureyskoye	138	138	138	189	189	189	327.00
5.	Zavitinskoye	160	160	150	296	296	296	452.67
6.	Zeyskoye	194.4	194.4	194.4	300	300	300	494.40
7.	Magdagachinskoye	206.2	206.2	206.2	205	205	205	411.20
8.	Mazanovskoye	265.1	265.1	265.1	305	305	305	570.10
9.	Norskoye	165	165	165	189	189	189	354.00
10.	Svobodnenskoye	129.6	129.6	129.6	475	475	475	604.60
11.	Tyndinskoye	115	115	115	170	170	170	285.00
12.	Urushinskoye	0	0	0	0	0	0	0
13.	Shimanovskoye	363.4	363.4	400	725	725	725	1100.60
Total:		2141.5	2141.5	2141.5	4245	4245	4245	6386.5

The length of the mineralized belts by forestry in the period from 2017 to 2019 practically did not change, with the exception of three forestries in 2019. The length of the mineralized belts decreased by 26.6 and 10 km in Belogorskoye and Zavitinskoye forestries, respectively. These volumes were fulfilled in Shimanovskoye forestry. Targets for 2020 are identical to those for 2019.

The territory of the Urushinskoye forestry is not equipped with fire-fighting infrastructure within the framework of the state assignment. The reason is the absence of a forestry enterprise, the nearest one is located in Tynda.

Let us compare the data on the length of the mineralized belts to the territory of the state forest fund of forestries by the classes of natural fire hazard (Table 3).

The average length of the mineralized belts per 1 hectare of forest area is 0.3 m. There is no direct dependence of the length of the mineralized belts on the forest area (see Fig. 1). The greatest length of mineralized belts per unit area is observed in the Blagoveshchenskoye, Zavitinskoye, Svobodnenskoye and Shimanovskoye forestries, 8.7 m, 4.2 m, 1.7 m and 1 m, respectively.

Table 3. Distribution of the length of mineralized belts per unit from the area of forestry.

No.	Name of forestry	Average length of mineralized belts. m	Total area of forestry. ha	Length of mineralized belts per unit area. m / ha
1.	Arkharinskoye	466400	887469	0.5
2.	Belogorskoye	681130	803600	0.8
3.	Blagoveshchenskoye	639400	73542	8.7
4.	Bureyskoye	327000	457262	0.7
5.	Zavitinskoye	452670	107095	4.2
6.	Zeyskoye	494400	879324	0.6
7.	Magdagachinskoye	411200	1308852	0.3
8.	Mazanovskoye	570100	2223589	0.3
9.	Norskoye	354000	4012232	0.1
10.	Svobodnenskoye	604600	349575	1.7
11.	Tyndinskoye	285000	7858015	0.0
12.	Urushinskoye	0	2483819	0.0
13.	Shimanovskoye	1100600	1157749	1.0
Total:		6386500	22602123	0.3

Fig. 1. Dependence of the length of the mineralized belts on the area of the forestry.

With the approximation confidence factor equal to $R^2 = 0.123$, it is impossible to speak of a high level of accuracy of the model describing the dependence of the length of the structure of mineralized belts on the area of the forestry. In other words, the length of the mineralized belts does not depend on the area of the forestry in which they are made.

It is possible that the decision on the distribution of the length of the mineralized belts across forest ranges was made regardless of the number of forests of a particular fire hazard class, but on the basis of the average number of forest fires and their area in each of the forestry (Table 4).

Table 4. The number of forest fires and their area by forestry.

No.	Name of forestry	Number of forest fires. pcs / year			Area of forest fires. ha		
		2017	2018	2019	2017	2018	2019
1.	Arkharinskoye	38	31	49	2074	72699	13077
2.	Belogorskoye	0	17	11	0	198872	5294
3.	Blagoveshchenskoye	28	36	21	967	7632	7631
4.	Bureyskoye	23	31	19	19353	44225	1269
5.	Zavitinskoe	12	30	20	2276	16638	4461
6.	Zeyskoye	61	50	75	117068	972748	21528
7.	Magdagachinskoye	37	51	35	13856	155804	57710
8.	Mazanovskoye	11	29	25	5655	345469	19732
9.	Norskoye	15	30	9	22114	133613	4821
10.	Svobodnenskoye	33	29	42	883	69121	31640
11.	Tyndinskoye	36	21	88	38202	72467	85264
12.	Urushinskoye	22	28	39	2928	8065	7982
13.	Shimanovskoye	6	50	22	2019	171208	11000
Total:		322	433	455	227395	2268561	271409

There is no direct dependence of the number of forest fires in forestries on the length of mineralized belts per unit area (Fig. 2).

The largest number of fires on the territory of the state forest fund (SFF) was recorded in 2019. however. the largest area of fires was revealed in 2018.

Fig. 2. The number of forest fires depending on the length of mineralized belts in the State Forest Fund of the Amur Region by forestries for 2017-2019.

The construction of a trend line and determination of the coefficient of accuracy of the approximation. based on the length of the mineralized belts and the number of forest fires. indicates the absence of relationships between these indicators.

As can be seen in Fig. 2. the largest number of forest fires in all analyzed time periods occurs in the Zeyskoye and Tyndinskoye forestries. The greatest length of fire-prevention mineralized belts per unit area (1 hectare) is recorded in the Blagoveshchenskoye forestry.

Fig. 3. Dependence of the area of forest fires on the length of mineralized belts per unit area of the State Forest Fund of the Amur Region by forestry for 2017-2019.

As can be seen from Figs 2 and 3, the dependence of the area of forest fires and their number on the length of the mineralized belts is not traced. The existing length of the mineralized belts practically does not affect the area and number of forest fires. It is possible to recognize the fact of ineffectiveness of the arrangement of mineralized belts to prevent the occurrence and spread of forest fires.

Table 5. The number of forest fires and the class of fire hazard by weather conditions in forestries.

No.	Name of forestry	Number of forest fires. pcs / year			Average annual class of fire hazard by weather conditions		
		2017	2018	2019	2017	2018	2019
1.	Arkharinskoye	38	31	49	2.9	3.0	2.6
2.	Belogorskoye	0	17	11	2.6	2.9	2.9
3.	Blagoveshchenskoye	28	36	21	2.4	3.3	2.4
4.	Bureyskoye	23	31	19	2.9	3.3	2.7
5.	Zavitinskoye	12	30	20	2.3	2.9	4.3
6.	Zeyskoye	61	50	75	1.9	3.4	2.9
7.	Magdagachinskoye	37	51	35	2.1	2.9	2.3
8.	Mazanovskoye	11	29	25	2.4	2.6	2.3
9.	Norskoye	15	30	9	1.9	2.1	1.7
10.	Svobodnenskoye	33	29	42	2.4	3.3	3.0
11.	Tyndinskoye	36	21	88	2.3	2.3	2.6
12.	Urushinskoye	22	28	39	2.6	2.9	3.3
13.	Shimanovskoye	6	50	22	2.4	3.1	2.9
Total:		322	433	455	-	-	-

In connection with the above, we consider it expedient to identify the dependence of forest fires on the fire hazard class in terms of weather conditions.

The fire hazard class for weather conditions was determined as an arithmetic mean value for a fire hazardous season.

Fig. 4. Dependence of the number of fires on the fire hazard class by weather conditions in 2017 on the territory of the state forest fund of the Amur region.

Fig. 5. Dependence of the number of fires on the fire hazard class by weather conditions in 2018 on the territory of the state forest fund of the Amur region.

Fig.s 4, 5. clearly show the dependence of the number of forest fires on the fire hazard class for weather conditions, while the coefficient of approximation reliability (R^2) varies from 0.848 to 0.9127. these values suggest a high model adequacy.

As a result of data processing, three linear equations were obtained for the dependence of the number of forest fires on the fire hazard class according to weather conditions:

- for 2017 $y = 0.533x + 12.962$;
- for 2018 $y = 0.6758x + 15.654$;
- for 2019 $y = 0.978x + 12.385$.

An equation was derived mathematically, taking into account the data for the last three years, which makes it possible to determine the number of fires (y) depending on the fire hazard class by weather conditions (x).

$$y = 0.729x + 13.677$$

With an increase in the amount of data processed using the model, the forecasting accuracy will increase.

4. Discussion

In the presented study, we analyzed the relationship between the number and area of forest fires on the territory of the Amur Region, depending on the area of forestries, the length of mineralized belts in each forestry, the length of mineralized belts per unit area of the forestry, natural fire hazard class, fire hazard class for weather conditions.

Based on the results of data analysis, the absence of dependence of the length of the mineralized belts on the area of the forestry was revealed. We believe that it is necessary for the constituent entities of the Russian Federation to develop clear instructions on justifying the placement of mineralized fire belts.

Also, no dependence was revealed between the number of forest fires and their area on the length of the mineralized belts across forestries. This fact indicates the lack of analysis in the distribution of the length of the mineralized belts across forestries. From our point of view, a controllable variable factor, such as the distribution of mineralized bands, should take into account statistical data on the number and areas of forest fires of previous years and increase in the territories of those forestries where there is a dynamics in the increase in the number and area of fires.

4 Conclusions

A stable relationship between the number of forest fires and the fire hazard class by weather conditions has been revealed. This dependence is presented in the form of a model that makes it possible to predict the number of forest fires both on the territory of the forest fund of the entire Amur Region, and for individual forestries.

The accumulation of statistical data and their analysis, using the model developed by us, will make it possible to make managerial decisions on the distribution of fire-fighting measures in forest districts and the concentration of forces and means of monitoring and fire extinguishing in forest districts.

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