

Assessing the impact of forest management activities on fire areas in Russia

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Abstract. As a result of the work done, the volumes of the main forestry activities carried out on the territory of Russia and affecting the occurrence and spread of forest fires over 10 years, starting in 2012, were analyzed. These included care cabins, sanitary and health measures and certain types of fire-fighting measures. During the same period, the number of fires and the area of forests traversed by fire were established. The relationship between the volume of each type of event and the area of fires was also revealed. A multiple regression analysis was performed, as a result of which it was found that the preventive controlled fire-fighting burning of brushwood, forest litter, dry grass and other forest combustible materials does not significantly affect the occurrence and spread of fires. The final equation of the relationship between the volumes of significant measures (logging, sanitary and health measures, measures for fire protection of forests, including the creation of forest roads, glades, fire breaks, mineralized strips, their maintenance and renewal) with the area of forest fires is obtained.

1 Introductions

Three conditions are necessary for a forest fire to occur: combustible forest materials, the possibility of ignition and the source of fire. If the possibility of fire is determined mainly by meteorological conditions, then forestry measures have a direct impact on the amount of combustible forest materials. They also have a partial effect on the possibility of fire, but indirectly.

The measures carried out in the course of economic activity in the forest can be divided into fire-fighting, aimed specifically at preventing the occurrence of forest fires, their rapid detection and preventing their spread, and purely forestry, carried out mainly to form and maintain plantations in order to implement their main functions. The latter include such types of activities as logging, carried out for the purpose of caring for forest plantations, and sanitary and recreational activities.

Considering the impact of forestry measures on fire danger in forests, it should be borne in mind that their planning and implementation are regulated by relevant regulatory documents. These are the Rules of forest care [1], Rules of sanitary safety in forests [2], Rules for the implementation of measures to prevent the spread of harmful organisms [3], Fire

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safety rules in forests [4], Standards for fire-fighting forest management [5], Recommendations for fire prevention in forests and regulation of forest fire services [6]. The above regulatory documents define the conditions of appointment, terms and volumes of forestry activities, depending on the condition and taxation characteristics of the plantation. On this basis, forest development projects, forestry regulations and forest plans of the subjects are drawn up. The planned events are mandatory throughout Russia. Their implementation has a positive effect on the fire-fighting condition of forests.

2 Materials and methods

In order to study the relationship between the volume of activities carried out and the burning of forests, we analyzed the activities carried out for the territory of the Russian Federation according to industry reporting form No. 15 - IPR (Table 1) and the area covered by fire for 2012-2021. The volumes of fires were taken in ISDM-Rosleshoz [7] according to space monitoring data (Table 2). The main forestry measures by their types were analyzed: logging carried out for the purpose of forest care, sanitary and health measures, measures for fire-fighting forest management. Of the care cabins, their main designed and implemented types were considered – clearing, clearing, thinning and pass-through cabins. Their total volume in hectares was taken into account. Sanitary and wellness measures include continuous sanitary logging, selective sanitary logging, cleaning of illiquid wood (cleaning of clutter). Of the measures for fire protection of forests, we considered only those that directly prevent the spread of the fires that have arisen. This is the creation and reconstruction of forest roads; laying of clearings, fire breaks and mineralized strips, as well as their care in the form of cleaning and updating, carrying out preventive controlled fire-fighting burning of brushwood, forest litter, dry grass and other forest combustible materials. All of these measures, except the last one, are measured in kilometers, that is, they are linear in nature. Their volumes are combined into one value. And fire-fighting burning of combustible materials is considered separately, since it is measured by the area of its implementation in hectares.

Table 1. The volume of forestry activities in the territory of the forest Fund of the Russian Federation.

Events	Units of measurement	Years										
		2012	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Care cabins	Thousand, ha	plan	867.9	867.9	867.9	867.9	867.9	867.9	867.9	867.9	545.0	541.1
		fact	595.5	568.9	550.9	530	545.3	541.9	469.0	459.9	430.8	394.4
Sanitary and health measures	Thousand, ha	plan	399.2	457.9	410.6	357.5	368.4	323.7	287.4	300.9	233.9	262.4
		fact	447.9	406.9	387.3	361.0	265.7	260.2	186.1	145.4	123.3	86.9

Fire-fighting measures of a linear nature	thousand km		plan	925.8
	fact		944.4	898.7
Carrying out preventive controlled fire-fighting burning of brushwood, forest litter, dry grass and other forest combustible materials	Thousand, ha		plan	209.8
	fact		997.2	1070.4
			835.5	799.4
			742.2	690.7
			735.9	694.9
			679.5	673.6
			514.5	341.1
			347.1	368.7
			181.0	158.8
			202.9	188.5
			643.2	698.9
			633.3	690.3
			656.6	698.3
			637.6	

When analyzing the materials in Table 1, it was noted that the volumes of care felling carried out are significantly less than the planned values and amount to 53 to 73% of the latter separately by year. Sanitary and health measures exceeded the plan by 12% only in 2012, and in subsequent years their volume has been steadily decreasing and in 2022 does not exceed 34%. Fire-fighting measures of a linear nature are slightly overfulfilled throughout the period under review. As for the preventive controlled fire-fighting burning of brushwood, forest litter, dry grass and other forest combustible materials, in 2012 its actual volume exceeds the plan by almost 5 times, and since 2013 it has been gradually decreasing, the implementation of the plan is carried out by 66-96%.

Table 2. Fires on the territory of the forest fund of the Russian Federation according to space monitoring data.

Events	Units of measurement	Years										
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Quantity of fires	pieces	8733	4921	6822	4833	4991	4112	7029	6403	7773	7534	5474
A forested area traversed by fire	thousand ha	6164.5	1550.3	2502.6	1907.5	2646.2	1229.3	3010.9	1689.3	1509.1	5170.9	1230.7
The average area of one fire	ha	705.9	315.0	366.8	394.7	530.2	299.0	428.4	263.8	194.1	686.3	224.8

Analyzing Table 2, it can be noted that the number of forest fires that have occurred in Russia varies significantly by year. So in 2012, 2018, 2020, 2021, maximum values are

observed, the least fires were in 2017. According to the table, there was no dependence of the area covered by fire on the number of fires.

The main types of care felling aimed at the formation of plantations in the process of their growth are clearing, clearing, thinning and pass-through felling. Figure 1 shows a graph of the relationship between the volumes of actual logging from 2012 to 2020 (Table 1) with the corresponding fire areas next year on forested lands. When analyzing this dependence, it was found that there is a moderate feedback for care felling on the Cheddock scale [8] (Figure 1). The correlation coefficient in this case is "-0.49", and the equation looks like this:

$$y = -7197\ln(x) + 97216 \quad (1)$$

where y - the area of fires, thousand hectares;

x - the area of logging, ha.

The reverse nature of the relationship in this case is logical, since a decrease in combustible forest materials in plantations as a result of harvesting dry trees from them and potential loss during felling helps to reduce fire danger. The area covered by the fire decreases with the increase in the area of this event.

Sanitary and health measures that reduce the fire danger in the forest include selective, continuous sanitary logging and cleaning of illiquid wood (cleaning from clutter). They directly affect the fire danger in the forest by reducing the volume of forest combustible materials. From the analysis of the graph in Figure 2, it can be said that, in general, for the total areas of the sanitary and health measures carried out, there is a noticeable feedback with the area of fires next year with a correlation coefficient $r = -0.55$. The nature of the relationship is close to a linear relationship, but the alignment can be most accurately carried out by a logarithmic equation. Therefore, the regression equation is obtained using a logarithmic function and has the following form:

$$y = -1967\ln(x) + 27069 \quad (2)$$

where y - the area of fires, thousand ha;

x - the total area of sanitary and health measures (continuous and selective sanitary logging, harvesting of illiquid wood), ha.

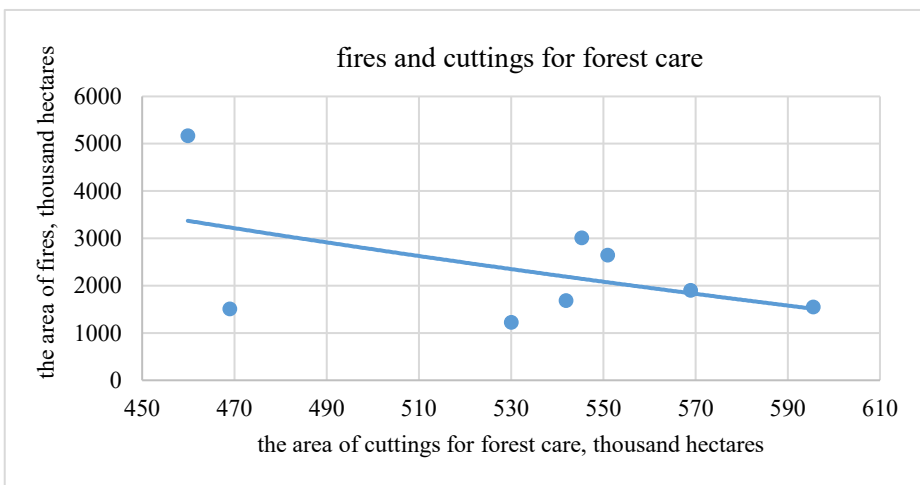


Fig. 1. The relationship of the area of fires on the forested lands of the Russian Federation with the total area of cuttings for forest care.

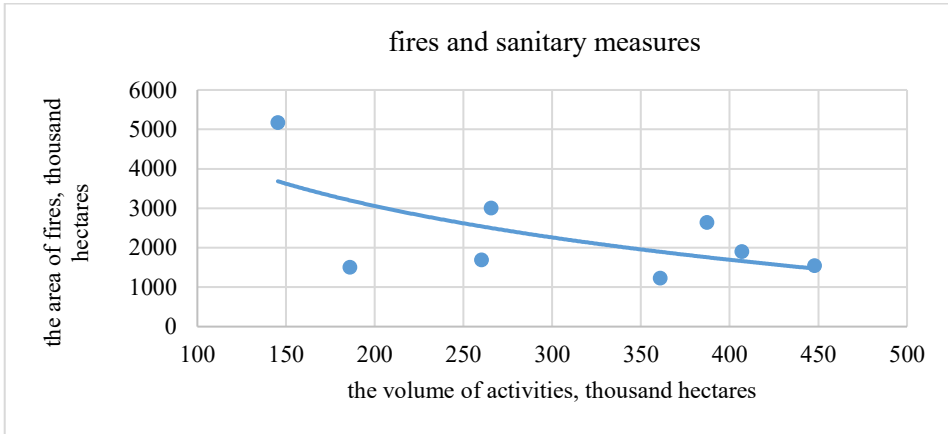


Fig. 2. The relationship of the area of fires on forested lands of the Russian Federation with the total area of sanitary and health measures carried out.

The fire prevention measures under consideration, as noted earlier, are divided by us into two groups taking into account the difference in units of measurement when taking into account their volumes. The first group includes measures that are measured in kilometers, that is, having a linear nature. This includes the total length of the creation of roads, clearings, fire breaks, mineralized strips, as well as maintenance in the form of their reconstruction and renewal. Their relationship with the area of fires is demonstrated in the graph (Figure 3). Between these total volumes of creation and maintenance of forest roads, clearings, fire breaks and mineralized strips and the area of fires, a moderate inverse relationship with a correlation coefficient of $r = -0.44$ was revealed. The regression equation has the following logarithmic form:

$$y = -5194\ln(x) + 73072 \tag{3}$$

where y - the area of fires, thousand hectares;
 x - the total length of the creation of roads, clearings, fire breaks, mineralized strips and their maintenance, km.

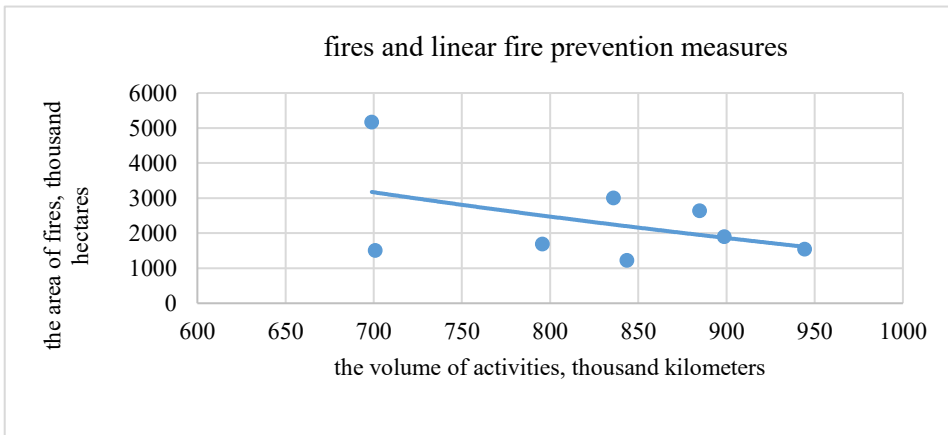


Fig. 3. The relationship between the area of fires on forested lands in the Russian Federation and the total length of the creation of roads, clearings, fire breaks, mineralized strips and their maintenance.

The second group includes only one event, which, unlike the events of the previous group, is measured by the area of its implementation. This is preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials. Its relationship with the area of fires is characterized as moderately inverse ($r = -0.42$). Figure 4 shows a graph of this dependence. Its most accurate approximation is carried out using a logarithmic equation:

$$y = -1315\ln(x) + 19956 \tag{4}$$

where y - the area of fires, thousand hectares;
 x - the area of preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials, hectares.

Taking into account the established closeness of the relationship between individual forestry measures of their groups (linear fire-prevention measures) and types (sanitary and health-improving, thinning) with the area of fires, a multiple regression analysis was carried out. It was carried out for the volumes of the following measures: thinning under consideration; sanitary and health-improving measures; linear fire-prevention measures (measures to create forest roads, clearings, fire breaks, mineralized strips and their maintenance and renewal); preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials.

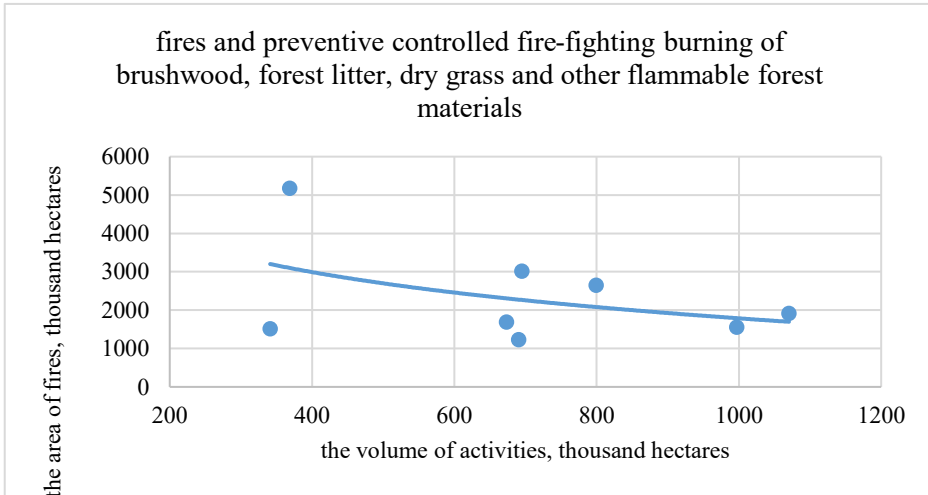


Fig. 4. The relationship between the area of fires on forested lands in the Russian Federation and the area of preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials.

The results of the analysis are presented in Table 3, according to the materials of which it is evident that the lowest significance level for most of the measures is 0.08. At this level, all considered types of measures are significant, with the exception of preventive burning of forest combustible materials. The significance level for this factor is 0.34. Therefore, we exclude it from the calculation of the coefficients of the multiple regression equation as insignificant.

Table 3. Results of the initial multiple regression analysis.

	Beta	Std.Err. of Beta	B	Std.Err. of B	t(3)	p-level
Free member			-2529.511	10441.75	-0.24225	0.824203

Area of cuttings for forest care	-3.009827	1.148976	-0.083587	0.031909	-2.619573	0.07903
Area of sanitary and health measures	-3.489511	1.115819	-0.041257	0.013193	-3.12731	0.052174
Total activities for the creation of forest roads. clearings. fire breaks. mineralized strips and their maintenance	4.906138	1.806654	0.071038	0.026159	2.715594	0.07282
Carrying out preventive controlled fire-prevention burning of brushwood. forest litter. dry grass and other forest flammable materials	0.986193	0.8781	0.0049	0.004363	1.123099	0.343164

Having repeated the regression analysis without this factor, we obtained the final coefficients of the equation of dependence of the area of fires on forestry measures at a significance level of 0.09 (Table 4). At this level (with a probability of 0.91%), all analyzed factors are significant, since their significance indicators (p) are less than 0.09.

Table 4. Final results of multiple regression analysis.

	Beta	Std.Err. of Beta	B	Std.Err. of B	t(3)	p-level
Free member			-9859.64	8412.655	-1.17200	0.306238
Area of cuttings for forest care	-2.49727	1.088352	-0.0694	0.030	-2.29454	0.083439
Area of sanitary and health measures	-3.22006	1.124757	-0.0381	0.013	-2.86289	0.045796
Total activities for the creation of forest roads. clearings. fire breaks. mineralized strips and their maintenance	5.09190	1.856910	0.0737	0.027	2.74214	0.051791

The final equation of dependence will have the following form:

$$Y(x_1, x_2, x_3) = -9859,64 - 0,0694x_1 - 0,0381x_2 + 0,0737x_3, \tag{5}$$

where Y - the area of forested lands in the Russian Federation affected by fire, in thousand hectares;

x_1 - the area of cuttings for forest care (thinning in young stands, thinning, passage cutting), in hectares;

x_2 - the area of sanitary and health measures (clear and selective sanitary felling, removal of illiquid timber), in hectares;

x_3 - forest fire prevention measures, including the creation of forest roads, clearings, fire breaks, mineralized strips, their maintenance and renewal, in km.

3 Conclusions

1. When studying the relationship between the volumes of forestry measures carried out and the area of fires on forested lands of the Russian Federation for 2012-2020, its presence was established for all types of measures under consideration: thinning (thinning, clearing, thinning and passage cutting), sanitary and health measures (clear and selective sanitary cutting, removal of illiquid timber), linear measures for fire-prevention arrangement of forests (creation and reconstruction of forest roads; laying of clearings, fire breaks and mineralized strips, as well as their maintenance in the form of their clearing and renewal) and preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials.

2. The values of the correlation coefficients (r) for thinning are "-0.49", for sanitary and health measures - "-0.55", for linear measures on fire-prevention arrangement of forests (creation and reconstruction of forest roads, laying of clearings, fire breaks, mineralized strips and their maintenance by cleaning and renewal) $r = -0.44$, for preventive controlled fire-prevention burning of brushwood, forest litter, dry grass and other forest combustible materials $r = -0.42$. Thus, an inverse or moderate or significant relationship was established according to the Chaddock scale.

3. As a result of multiple regression analysis it was established that at the significance level of 0.05 the considered measures are insignificant. The equation of dependence (5) between forestry measures and forest flammability (area of fires on forested lands) was obtained for the significance level of 0.09, while three types of measures remained significant. These are thinnings (thinning in young stands, thinnings, passage cuttings), sanitary and health measures (clear and selective sanitary cuttings, removal of illiquid timber) and linear measures for fire-prevention arrangement of forests, including the creation of forest roads, clearings, fire breaks, mineralized strips, their maintenance and renewal.

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