Forest fires: methods and means for their suppression

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Abstract. It is noted that for the Russian Federation the forest is of great importance in the development of the economy. The causes of forest fires that cause great damage to nature and society are considered. It is indicated that the annual economic damage from forest fires can amount to billions of rubles. A brief description of forest fires possible types is given with an indication of the causes of their occurrence and the conditions of the course. The existing methods of extinguishing natural deflagrations are analyzed, which, according to the nature of the effect on the combustion process, are divided into active and passive. The design of the fire-fighting soil-thrower machine is presented to extinguish forest fires with soil. The authors carried out experimental studies of the functioning of the developed aggregate. With the purpose of analyzing the effectiveness of the introduction and further application of the presented machine, the calculation of the economic efficiency of its operation was performed. The obtained results show that the specific current costs when using the gun are reduced by 15% compared to the serial available analog.

1. Introduction

Forest is very important for the Russian Federation, since the forest fund occupies more than half of the territory of the country. Russia occupies special, unique position. A fifth of all the world's forests and half of the world's coniferous forests are located on its territory of about 1690 million hectares. The total area of the forest fund and forests that are not included in it is about 1178.6 million hectares in Russia. This is approximately 70% of the entire country. In the forests of the Russian Federation, the world's largest timber reserves are concentrated - almost 80 billion m³, 85% of which is the most valuable softwood, there are about 2 hectares of forest-covered area for each inhabitant of our country. Forest fires in the country annually cover up to 2 ... 5 million hectares of forest area.

Forest fires occur mainly as a result of careless handling of fire. The share of fires of natural origin in comparison with fires caused by anthropogenic activity is small. The available statistical data do not allow tracing the dynamics of forest fires over the years, and therefore the forecasting of the number of forest fires is possible only based on meteorological conditions of the terrain.

Fires are easier to prevent than to liquidate, but in our country the system of forest monitoring is not sufficiently developed, which leads to untimely notification of the occurrence of fire.

Forest fires bring great damage to ecosystem; their consequences are negative for wildlife, and for the atmosphere, hydrosphere, and lithosphere. And the economic damage from forest fire is estimated in billions of rubles per year. Also, forest fires can lead to death of people, especially if the fire comes to population center. Smoke from fire adversely affects people's health [1-3].

There is a threat of destruction of adjacent settlements and businesses (burning of wood storages,
wooden houses and other economic objects) by forest fires. As a result, timber is destroyed, including valuable species. Due to the smoke in surface layer of the atmosphere in the fire zone, flights of aircraft on local airlines and navigation of river vessels are stopped. As a result, a decrease in the dose of solar radiation on the underlying surface occurs and causes later maturation of crops [4].

The purpose of the work is development of forest fires suppression perspective method with use of soil and the technical tool for its realization which use is economically expedient.

2. Results and discussion

Forest fires almost always start on the ground. For whatever reason a fire arises, mosses and lichens, forest litter, fallen trees begin to burn. Then undergrowth, young growth and, under favorable conditions, crowns of mother’s canopy burn. If there are layers of humus or peat in the path of fire, fire can be drowned in them. Only fires from lightning usually begin with burning trees themselves [5-7].

2.1. Types of forest fires

Creeping fires. The most favorable conditions for running grassland fires are formed in spring, when only the uppermost layer of small combustible materials dries out. Fire quickly burns everything that can burn and move on. Such fires are observed in both coniferous and deciduous plantations. The burning temperature at the edge of the fire is 400-500 °C. The propagation velocity along the front is about 0.5 km/h, sometimes faster. The height of the flame is up to 1.0 m. The shape of fire is ovoid one. The color of smoke is light gray. Such fires bring the least damage.

Creeping steady fire (several tens of m/h) slowly moves along dried litter. Forest litter, ground cover, breakage, undergrowth and young growth burns. The form of fire is oval one. The temperature at the edge reaches 800 °C. The smoke is gray. The damage is considerable, especially in plantations with superficial root system [5, 6, 8, 9].

Crown fire. They are characterized by the spread of fire on the crowns of trees in the upper tiers. Coniferous young growth is most susceptible to such fires, in which fires are possible during the entire fire season. Crown fires are derived from creeping fire, which later becomes a part of it. Formation of crown fires is facilitated by coniferous young growth and large clutter of plantations, uneven-aged structure of stands and presence of resin-soaked streaks on trees, dry weather, high temperature and strong wind, steep slopes.

Stable crown fire can spread in a weak wind and even in windless weather. In such a fire, the fire on the crowns spreads slowly, about 1-2 km/h, as the edge of creeping fire moves ahead. Simultaneously, forest litter and breakage, young growth and undergrowth, branches burns; tree trunks are usually strongly burnt. The fire moves like a solid wall. Such a fire is often called a general fire, since there are only burnt charred trunks after such fires. The shape of fire is rounded one; combustion temperature is up to 1000 °C. Smoke color - dark.

Running crown fire occurs when the wind is strong. The fire spreads along the tree canopy irregularly, periodically outstripping the front of the ground fire. In this case, heat from the creeping fire, rising obliquely, heats the tree crowns in front of the front of the fire at a considerable distance. Then a single spark is enough to warm up the crowns. The fire quickly covers the heated zone, goes forward for 70 ... 90 m and slows down the movement. The front of the ground fire passes through the area with burnt crowns, heating the next section. The speed of fire during the jump is 15 ... 25 km / h and even more. Ahead of such a fire, new foci of fire emerge from burning branches, hags, bark that fly to tens and even hundreds of meters, which increase the spread of the fire. The shape of fire is elongated one, the temperature is 900 °C. Smoke color - dark [5, 8-10].

Ground (peat) fires. They spread in layers of peat or a thick layer of humus, when peat layer or humus horizon of the soil is sufficiently dry. The fire of the ground fire gradually penetrates into the soil. Light smoke drifts above the surface of the soil, sometimes flames erupt. In this case, peat burns all up to the mineral layer. The roots of tree and shrub vegetation in these layers are completely burnt, so trees fall out on the burnt areas.
Peat fires most often occur in the second half of the summer. They spread very slowly, passing a day from several decimeters to several meters. To a greater extent, the thickness of the burned layer is taken into account. The form of fire is usually close to a circle, temperature is more than 1000 ° C. Underground fires are very dangerous because it is very difficult to completely stop burning in them [6, 7, 8, 10].

2.2. Methods of forest fire suppression
According to the nature of the impact on the combustion process, two methods of fighting fires are include: direct impact on the edge of the fire is direct suppression, and the methods used in this case are active methods of the method associated with deliberate loss of area when creating barrier strips and barriers that prevent the spread of fire. This method was called passive or indirect one [6, 7, 10].

The active method, as a rule, is used for suppression creeping fires, while the passive method is used to suppression crown ones. The passive method is safer, provides the possibility of extensive mechanization of work, especially suppression dangerous fires.

There are many methods to suppression forest fires, which are caused by the variety of fires and the conditions in which they occur and flow. All methods of suppression fires can be divided into four groups according to the principle of their impact on fire:
- overfilling, deflagration or ground throwing of the edge of the creeping fire;
- fire suppression with water or solutions of fire suppression chemicals;
- laying of mineralized strips and ditches;
- clean burn [6, 8, 9].

2.3. Use of soil-thrower for forest fires suppression
In 2017 Voronezh State University of Forestry and Technologies named after G.F. Morozov has conducted an experimental study of forest fireproof soil throwing machine, which allows to provide better preventive and fireproof work in conditions of heavy soils, saturated with roots of tree and shrubby cover (Figure 1).

This development combines the work of passive and active working bodies, which significantly increases its efficiency and scope. Fireproof soil throwing machine can create fireproof protective strips with a width of 2 to 8 meters, and also extinguish the edge of creeping fire at a distance of up to 20 meters [10, 11].

Figure 1. Forest fireproof soil throwing machine.
To analyze the issue of the efficiency of implementation and further application of the developed fire-fighting soil throwing machine, a calculation of the economic efficiency of its work was made.

Calculation of the economic efficiency of the proposed development is expedient to perform in comparison with the serially produced milling soil-thrower ALF-1.

Calculation of the cost of manufacturing the machine is based on the estimated costs for materials and purchased units necessary for its manufacture. The cost of the tool also takes into account the labor costs for processing of used parts and assembly units and assembly of units into a single machine.

The annual loading of the tractor on all types of work was made on the basis of existing norms and rules. Calculation of direct operating costs and calculation of the annual economic effect was made per unit of output (1 running kilometer) [11].

The results of the calculation are given in the Table 1.

Table 1. Indicators of economic efficiency of the introduction of fireproof soil throwing machine.

| Indicators                                 | Unit measures | Equipment level |
|--------------------------------------------|---------------|-----------------|
|                                            |               | basic          | designed       |
| Productivity of the tool:                  |               |                |                |
| - per hour                                 | 2             | 2.4            |
| - per shift                                | 16            | 19.2           |
| - per year                                 | 2240          | 2688           |
| The current costs per unit of output       | rub.          | 1090.6         | 925.7          |
| Specific capital investments               | rub.          | 893.8          | 765.3          |
| Annual economic effect                     |               |                | 495129.6       |
| Coefficient of economic efficiency         |               |                | 1.83           |
| Payback period of additional capital       |               |                | 0.54           |
| investments                                |               |                |                |
|                                           |               |                |                |

3. Conclusions
According to the results of the economic calculation, the following conclusions can be drawn. Use of developed forest fireproof soil throwing machine for extinguishing forest fires allows reducing labor costs per unit of output - 1 running kilometer - by 164.9 rubles. Specific current costs are reduced by 15.1%. The annual economic effect from the implementation of the proposed design is 495,129.6 rubles with a payback period of additional capital investments of about 6 months.

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