VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

Linda Makovická Osvaldová

DETERMINATION OF SELECTED FUEL VALUES OF WOOD IN CASE OF FOREST FIRE IN AN AREA OF NATURAL DISASTER

Abstract

Forest fires are quite a common phenomenon, even on the European continent. Even if this phenomenon was quite rare in our territory in the past, it needs to be given close attention in the future. Firefighting requires great manpower and resources, in many cases on a long-term scale. The equipment, machinery and tactics of intervention units specializing in forest fire-fighting are always changing. Forest firefighting has become the subject of much research, and predictive scenarios for forest fire development are designed and tested. The latest equipment, geographic information systems (GIS), knowledge of geomorphological and climate conditions, and meteorological conditions are all included in fire simulations. An important factor for such a simulation is knowing what kind of fuel naturally occurs in the area of the potential forest fire. This article aims to compare methods of testing the fire characteristics and differences in fuel properties according to the position of the wood on the tree (branch, trunk and root) for various coniferous tree species (spruce, fir, pine and larch). To determine these characteristics, the test method, in particular the dimensions of the samples, had to be modified. The results of the experiments are presented in this article in the form of charts.

Keywords: forest fire, coniferous tree species, weight loss, burning rate.

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MEGHATÁROZOTT FAFAJOK VIZSGÁLATA ERDŐTŰZ ESETÉN TERMÉSZETI KATASZTRÓFÁK SORÁN

Absztrakt

Európában komoly kihívást jelentenek az erdőtüzek, amelyek egykor még ritkaságnak számítottak Szlovákiában, azonban ma már fokozott figyelmet követelnek. A tűzoltás jelentős erő - és eszközforrást igényel, amelyek az évek elteltével folyamatosan változnak. Az erdőtűzoltás kutatása ma már széleskörű, a tüzek kialakulásának forgatókönyveit pedig fokozatosan tervezik. A tűzszimulációk már tartalmazzák a legújabb felszereléseket, földrajzi információs rendszereket (GIS), valamint a geomorfológiai és éghajlati viszonyokat, is. Egy ilyen szimulációnak egyik alapja, hogy erdőtűz során, milyen biomassza kap lángra. A cikk célja a tűz és biomassza tulajdonságok vizsgálata a fák egyes részein (ág, törzs és gyökér), illetve a tűlevelű fafajok (erdei fenyő, lucfenyő és vörösfenyő) esetében. Egy ilyen vizsgálat módosított kutatási módszerek alkalmazását igényli. A kísérletek eredményeit a szerzők, diagramok formájában mutatják be.

Kulcsszavak: erdőtűz, tűlevelű fafajok, sorvadás, égési sebesség.

1. INTRODUCTION

Fire represents a major danger to forests. It damages individual trees and the entire forest, not only mechanically, but also physiologically. Besides trees, it also destroys all other elements of the forest ecosystem, decimating other plants and animals that live in the area. In some locations (Australia, China, the Philippines, Borneo, USA), fire can at times be an indispensable, positive, ecological factor helping the spread of certain species and the recovery of forests [25]. The situation is worse in the European territory. Damage caused by forest fires has no positive effect on the forests, and it also endangers critical elements of infrastructure and the population.

The situation has worsened significantly since the first months of 2019. According to EFFIS (European Forest Fire Information System), the number of recorded forest fires began to increase sharply in mid-February. By the end of June, there had been approximately 1 400 times more fires than the average number of fires in the same period from 2008-2018 [4]. The area of forest destroyed has also risen five times: from an annual average of 44 500 hectares in the first six months between 2008-2018, to 207 000 hectares (see Figure 1).

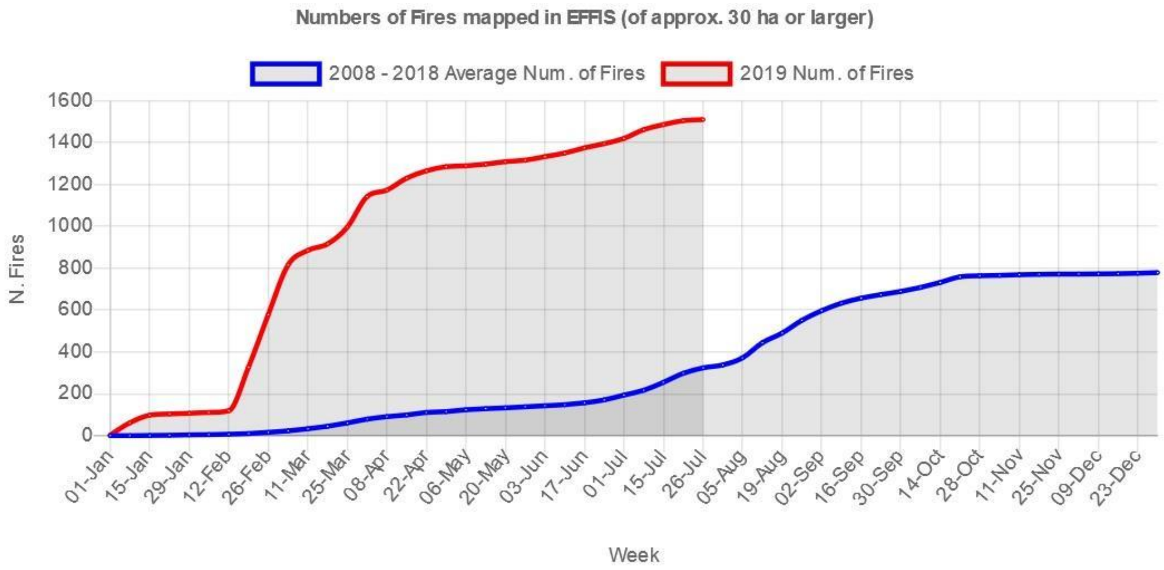
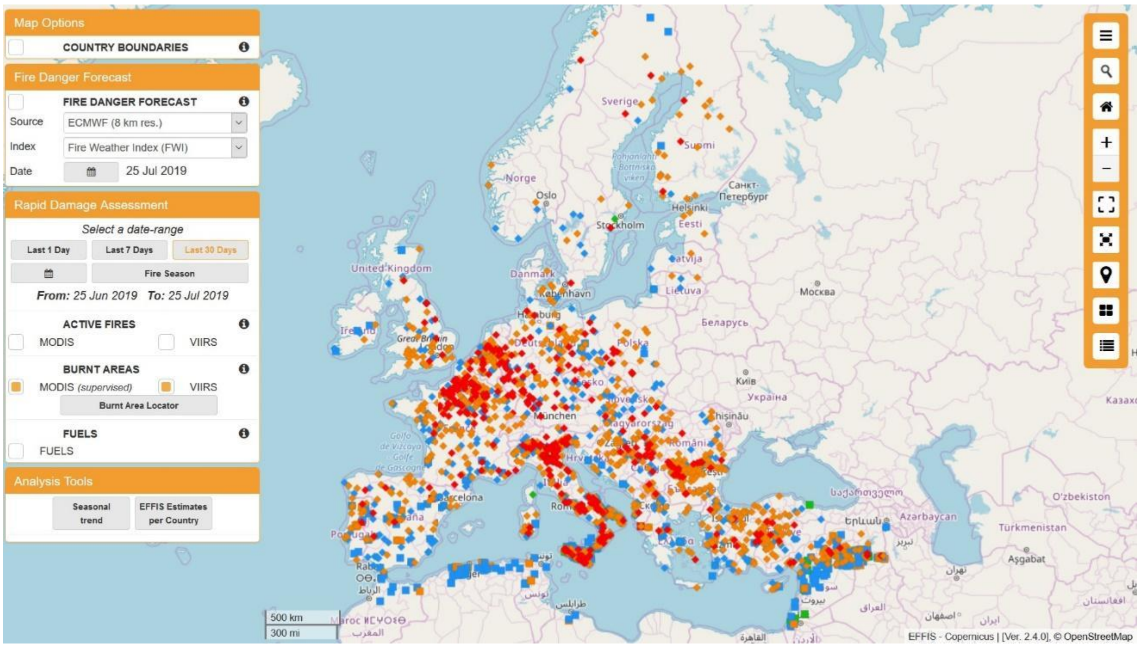


Figure 1 - Forest fires recorded during the given time period according to EFFIS [4].

The situation has also been critical in the last thirty days. EFFIS shows a high concentration of forest fires in the north of France, in the Iberian Peninsula; a number of fires have also been recorded on British Isles and in Scandinavia. (see fig. 2). The most active fires were recorded at that time on the North coast of the Black Sea, and in the regions neighboring Europe - North Africa and the Middle East. However, given the high temperatures and droughts, EFFIS currently reports a high risk of fires in the south of the Iberian Peninsula, in central and southern Italy, and in large parts of Eastern France, Benelux and Germany [4]. Due to high temperatures and droughts at record levels, the situation in Russian and North American Arctic areas is very serious. In Russia, both forests and bogs are burning [22].

The largest fire broke out on July 30, 2005 in the territory of the town of Vysoké Tatry, on the eastern edge of Tatranská Polianka, Poprad district. The fire destroyed 228,85 hectares of forest previously damaged by strong winds. The fire broke out in the area affected by the 2004 strong winds, and subsequently hit. The number and extent of forest fires has risen in Slovakia, too.XXX In 2017, 162 forest fires, 26 more than in 2016, were recorded in the SR on an area of 297,66 hectares (compared to 174,9 hectares in 2016). For 2018 and 2019 (the latest statistics), four serious forest fires occurred near our premises alone (see Table 1[6]).



Source ECMWF (8 km res.)
Index Fire Weather Index (FWI)
Date 25 Jul 2019
From: 25 Jun 2019 To: 25 Jul 2019

Figure 2 - Fires on the European continent 26.6-27.6 2019, EFFIS (source) [4].

Table 1 - Forest fires in Slovakia in 2018 and 2019 [6].

Location/year	Duration of fire (hours)	Area (ha)	Equipment/helicopter
Polomka/2018	92	7.5	56/2
Gader/2018	197	2.5	80/1
Bystrá-Gapeľ/2019	122	5.1	75/2
Blatnica-Ostrá/2019	27	0.05	12/1

2. FOREST FIRES

Forest fire is an extremely harmful factor which is detrimental to all components of the forest’s biological community. A forest fire is a sudden, partially- or fully-uncontrolled, time- and space-limited emergency event, which has a negative impact on all social functions of the forest both directly and indirectly. It can be either anthropogenic, caused by humans, (more common in Slovakia) or caused by a natural harmful factor. It is a complex of physico-chemical phenomena based on the nonstationary (that is, changing in space and time) processes of combustion, gas exchange and heat transfer [4].

Statistics generally indicate that climate change [10, 18, 19, 20, 21, 23] is the cause of the rising number and size of forest fires on the European continent .

Forest fire-fighting is not easy. As Table 1 shows, it usually takes several hours and requires the deployment of manpower and means of ground and air transportation on a large territory [2, 13, 14, 17]. Modern information systems [11, 12] and modern extinguishing agents help in intervention. An important piece of information is the specification of the “fuel” (type of wood) that can burn in the territory [1, 3, 7, 8, 9, 15, 16]. It is necessary to know the composition of the forest according to the types and age of trees. All parts of the tree (branch, stem and root) burn during such an event. How the wood of the individual parts of the tree influences burning is the subject of our experiments.

3. EXPERIMENTAL DESIGN

The experiment, the results of which we describe in this article, required a number of special modifications, particularly with regard to sample sizes. We had testing apparatus and evaluation criteria tested in other experiments, e.g. for the determination of the efficiency of fire retardants. Changes in the dimensions of the test bodies had to be made so that they could be taken from small-scale parts of a tree such as a branch and a root.

a. Material and test specimens for the experiment

Test specimens were prepared from 1 meter-long trunks of several types of trees (pine, fir, spruce, larch) [5]. After dressing the trunks by removing the bark and cutting it into boards, the boards were dried to a constant moisture of 8 % (± 2 %). The boards were then cut into test specimens of 10 mm x 12 mm x 150 mm. No surface finish was used for the test specimens. Specimens from branches and roots were cut in the same manner as the trunk. The diameter of both branches and roots was at least φ 60 mm at the thinner end. These were cut into boards and then into the test bodies (see fig. 3).

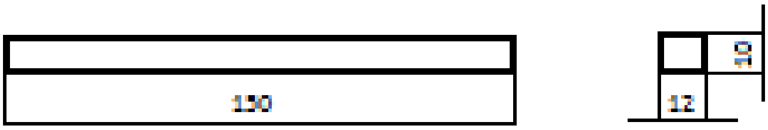


Figure 3 - Dimensions of test specimens for the experiment

3.2 Radiant heat source

An infrared heater was used as the radiant heat source. Heat transfer from the heater was carried out using the diffusion principle of electromagnetic radiation: a wavelength of 0,75 – 12 J/m is, when absorbed by a solid, transformed into heat. The radiator had the shape of a plane curved in the direction of the longitudinal axis of the body. Radiation was emitted by the front wall, the rear wall and the front edges. The side edges of the radiator were neglected because of their poor efficiency for the transfer of radiation. The radiator was made of special ceramic material, cordierite, which is very resistant to sudden temperature changes (temperature differences of more than 70 °C) and to high temperatures (up to 1100 °C). The radiator scheme is depicted in figure 4 [24].

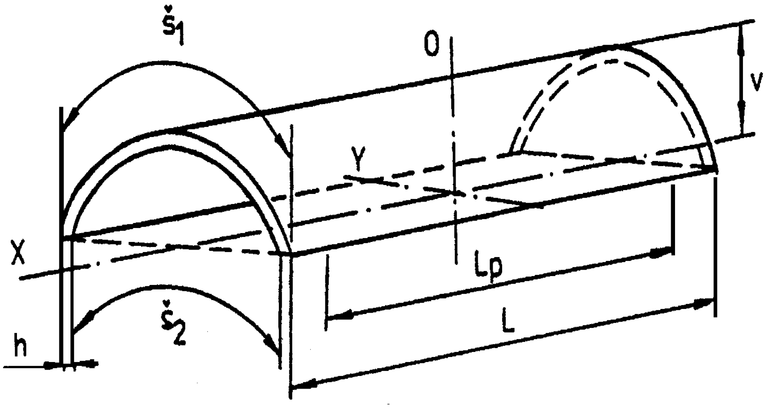


Figure 4 - Diagram of the radiator.

Dimensions and parameters of the heater [24]:

Total length	$l = 245$ mm
Working length	$lp = 200$ mm
Outer width	$\check{s}_1 = 85$ mm
Inner width	$\check{s}_2 = 64$ mm
Thickness	$h = 5$ mm
Height	$v = 30$ mm
Temperature (30 mm from the radiator)	$t = 130$ °C
Power	$P = 750$ W
Surface temperature of heating elements	$t_p = 579{,}4$ °C
Maximum wavelength	$\lambda_{max} = 3{,}34$ µm
Surface of radiator	$S_c = 0{,}0318$ m^2
Emissivity	$\varepsilon = 0{,}84$
Amount of radiated energy	$Q_{cc} = 669{,}95$ W
Intensity of radiation	$E_\gamma = 2{,}105$ W/cm^2

Efficiency η = 89,285 %

3.3. Test Procedure

The radiator was heated up for 15 minutes**.** After this time, a test body was inserted into the stand and the radiant heat applied for 3 minutes. 15 test bodies were tested from each type of tree. The thermal load time was constant at 3 min. The distance of the test body from the radiator was 30 mm. For each test body, the loss in mass was recorded after ten seconds.

3.4 Assessment Criteria

3.4.1 Weight loss

Weight loss was recorded while the sample was exposed to the radiant heat source. Relative weight loss was calculated according to this relation.

$$\delta_m(\tau) = \frac{\Delta m}{m(\tau)}.100 = \frac{m(\tau)-m(\tau+\Delta\tau)}{m(\tau)}.100 \qquad (\%) \qquad (1)$$

where: $\delta_m(\tau)$ – relative weight loss over time (τ) (%)

$m(\tau)$ – sample weight over time (τ) (g)

$m(\tau+\Delta\tau)$ – weight of the sample over time (τ + Δτ) (g)

Δm – weight difference (g)

3.4.2 Relative burning rate

Relative burning rate was determined according to the function (3.2) (3.3)

$$v_r = \left|\frac{\partial \delta_m}{\partial \tau}\right| \quad (\%/s) \qquad (2)$$

or numerically

$$v_r = \frac{|\delta_m(\tau) - \delta_m(\tau + \Delta\tau)|}{\Delta\tau} \quad (\%/s) \qquad (3)$$

where:

v_r – relative burning rate (%/s)

$\delta_m(\tau)$ – relative weight loss over time (τ) (%)

$\delta_m(\tau+\Delta\tau)$ – relative weight loss over time (τ + Δτ) (%)

$\Delta\tau$ – time interval where the weights are subtracted (s).

The foundational parameter was the density of the wood of the test bodies from the individual parts of the tree of the given tree species. As can be seen in Figure 5, the density changed even within the individual parts of the same tree. The humidity was regulated by air conditioning to the required level, so that it did not affect the evaluation criteria.

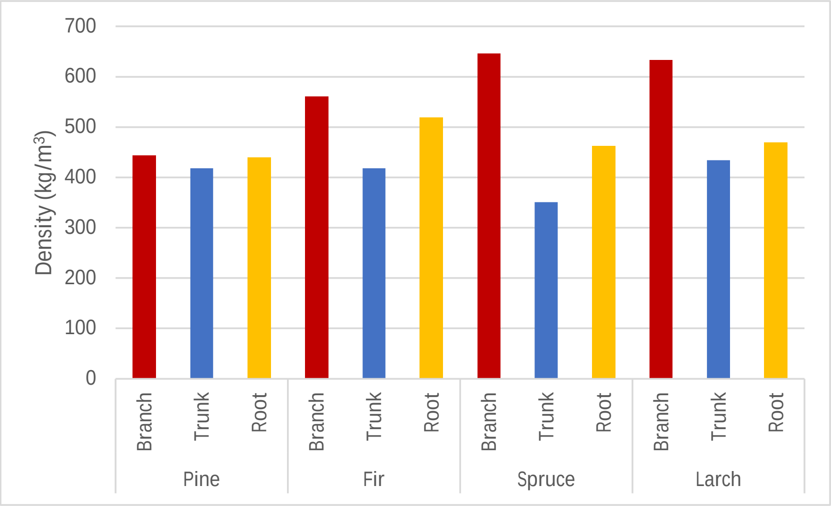


Figure 5 - Average density of wood of the test bodies according to the type of wood and tree part.

4. EVALUATION AND DISCUSSION

The results of the experiment are summarized in Figures 6-8, which display average values based on the 15 measurements of the main evaluation criteria. In addition to the main evaluation criteria, the weight loss (Fig. 6), relative burning rate (Fig. 7), and time of the maximum burning rate (Fig. 8) are also stated.

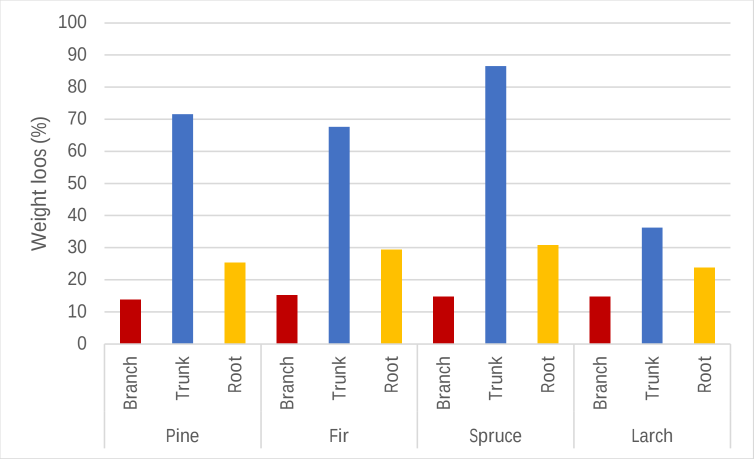


Figure 6 - Average weight loos of wood of the test bodies according to the tree species and the tree part.

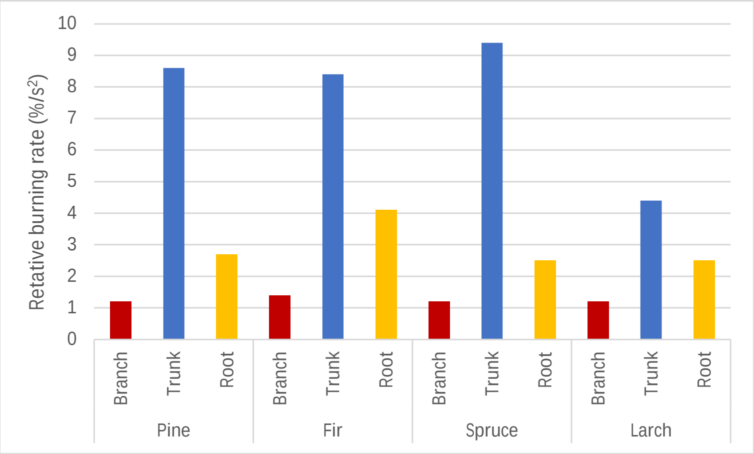


Figure 7 - Average relative burning rate of wood of the test bodies according to the tree species and the tree part.

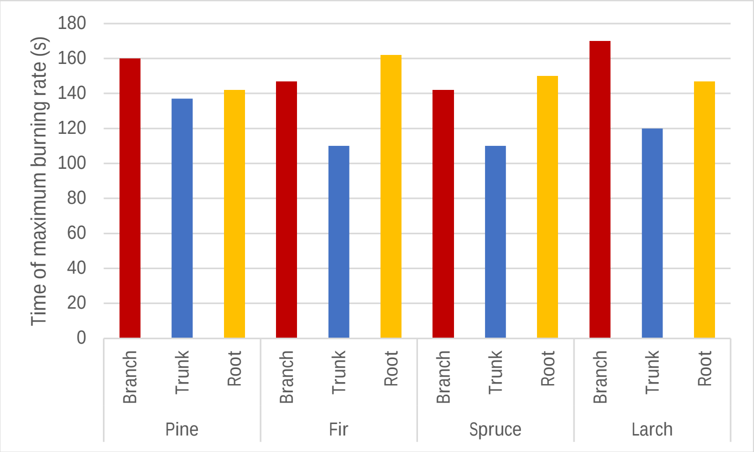


Figure 8 - Average time of maximum burning rate of wood of the test bodies according to wood type and tree part.

When determining the position of wood on the tree (branch, trunk, root), we came to a rather surprising conclusion. The greatest loss in weight for all woody plants was observed first for the trunk, then the root and finally the branch. The overall course of the experiment was influenced by the density of the wood, which for all the given tree species, was the highest in the branches (see Figure 5), followed by the root and finally the trunk with the lowest density.

Comparing the species of trees, the weight loss (branch) was the highest in fir and the lowest in pine. In case of wood from the trunk, spruce surprisingly reached the highest values, and larch the lowest. For the root wood, the highest values were recorded for spruce and the lowest for larch. At the end of this brief evaluation, we conclude that it is justified to observe selected tree species and their wood quality according to their position on the tree with regard to fire-fighting in the event of a forest fire.

The second assessment criterion was the relative burning rate; both weight loss and relative burning rate are important indicators in the development of the fire. In all observed cases, the highest burning rate was recorded for wood from the trunk. This factor is mainly significant when considering potential forest fires in a calamity-hit area where trees are already ‘bark-free’ due to the natural disaster, and the wood is more prone to catching fire. If individual positions are assessed based on the tree species, see (see fig. 7) the highest burning rate was recorded for spruce wood (trunk). The lowest burning rate was recorded for the wood of larch. This factor is also important in the case of root wood, which had a higher burning rate than branches for all three types of wood. This could also affect the development of ground fires where, in certain conditions, fire could smoulder and reignite.

The time to reach the maximum burning rate is shown in Fig. 8. According to the position of wood on the tree, based on the above graph, this factor was seen to be the worst for the wood of the pine (branch), fir (trunk), spruce (trunk) and larch (root). In regards to time to reach maximum burning rate, for the worst results were recorded in pine and fir (branches), fir and the spruce (trunk) and larch and the pine (root).

5. CONCLUSION

In a regular forest fire, the ignition of thin, dry or evergreen parts of the tree must be observed, especially branches that have the ability to cause or contribute to a crown fire. Another important factor is the bark wood, along which a fire can also spread quickly. In a forest fire in a calamity-hit area (the focus of our research), it is necessary to deal with the issue of wood itself. This “exposed” wood is present in the damaged forest in the form of broken branches and trunks, unrooted trees and broken roots. Such wood undergoes a relatively rapid drying, and as it is composed of sharp fragments with small volumes and large surfaces, it is easy to ignite and prone to intensive burning and spreading to more nearby broken and scattered wood. This experiment confirmed that there is a difference in the behavior of wood, which is given both by the wood itself and by the position on the tree. It is given that the experiment was carried out under "sterile" conditions - environment, moisture, dimensions - which do not correspond to the real conditions of a calamity-hit area but were necessary for the accurate measurement of the monitored variables. The results can be used in simulations of forest fire development, combining knowledge of the presence of different wood in the simulated fire area with information on the fire characteristics of such wood, both according to the species of tree and the position of the wood in the trees.

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