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A METHOD FOR DETERMINING THE FOREST FIRE THREAT LEVEL

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Summary: Articles 20, 22, 23, 24 and 27 of the Law on Fire Protection ('Official Gazette of RS', No 111/09) stipulate who and in what manner must prepare fire protection plans and what these plans must contain. The Regulation on classification of buildings, activities and land into a fire threat category ('Official Gazette of RS' No. 76/2010) prescribes a method of categorisation of fire protection subjects, stipulating that the legal entities classified into the first and the second fire threat category must prepare fire protection plans. A novelty in sub-legal regulation is the adoption of a special rulebook on preparation method and content of fire protection plans of autonomous provinces, local self-government units and subjects classified into the first and the second fire threat category ('Official Gazette of RS' No. 73/10). This sub-legal act prescribes the method and guidelines for preparation of fire protection plans, which is a substantial step forward in creation of a uniform procedure on preparation of fire protection plans. A serious shortcoming of this rulebook is that it only takes into account buildings, whereas the Law also stipulates categorisation of land and good-quality forested areas, as well as preparation of forest fire protection plans. Furthermore, the preparation of forest fire protection plans substantially differs from the preparation of fire protection plans for buildings. Creation of a planning act, such is a forest fire protection plan, entails development of methodologies that will provide the basis for the assessment of threat, or a fire occurrence risk, in a specific forest area.

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METODA ODREĐIVANJE STEPENA UGROŽENOSTI ŠUMA OD POŽARA

Rezime: Zakonom o zaštiti od požara ('Sl.glasnik RS' br.111/09) svojim članovima 20,22,23,24 i 27 reguliše ko mora i na koji način da donese planove zaštite od požara i šta ti planovi moraju da sadrže. Uredbom o razvrstavanju objekata, delatnosti i zemljišta u kategoriju ugroženosti od požara ('Sl.glasnik RS' br.76/2010) daje se način kategorizacije subjekata zaštite od požara, prema kojoj pravni subjekti razvrstani i prvu i drugu kategoriju ugroženosti od požara moraju da izrade plan zaštite od požara. Kao novina u podzakonskoj regulativi je donošenje posebnog pravilnika o načinu izrade i sadržaju Planova zaštite od požara autonomnih pokrajina, jedinica lokalne samouprave i subjekata razvrstanih u prvu i drugu kategoriju ugroženosti od požara ('Sl.glasnik RS' br.73/10). Ovaj podzakonski akt daje način izrade planova zaštite od požara i smernice za izradu planova, što je suštinski pomak u jedinstvenom postupanju prilikom izrade planova zaštite od požara. Ono što je veliki nedostatak ovog pravilnika je to što on uzima u obzir samo građevinske objekte, dok Zakon definiše i kategorizaciju zemljišta i površina pod kvalitetnom šumom, i izradu planova zaštite šuma od požara koji se drastično razlikuju od izrade planova zaštite od požara za građevinske objekte. Da bi se izradio jedan planski akt kao što je plan zaštite šuma od požara, moraju se odrediti metodologije po kome će se određivati ugroženost, odnosno rizik od nastanka požara na određenom šumskom području.

1. INTRODUCTION

The Regulation on classification of buildings, activities and land into a fire threat category ('Official Gazette of RS' No. 76/2010) stipulates classification of land, that is, certain plan-covered areas, into the following fire threat categories:

- Category 1.7.: protected and high-quality forest areas with a surface area greater than 10,000 ha
- Category 1.8.: protected and high-quality forest areas with a surface area greater than 500-10,000 ha
- Category 2.1.: protected and high-quality forest areas with a surface area greater than 800-5,000 ha
- Category 2.2.: protected and high-quality forest areas with a surface area greater than 800 ha

The above-mentioned land categorisation entails preparation of forest fire protection plans not stipulated by the Rulebook on preparation of fire protection plans.

One of the key elements in preparation of fire protection plans is a fire threat assessment, the preparation of which requires development of a threat assessment methodology. Presently, a fire threat assessment in Serbia is performed in a manner in which only impact element taken into account is vegetation, without considering other elements that affect forest fire threat. However, this type of assessment method often does not provide a true picture of potential danger. Consequently, there was a need for preparation of a specific methodology for

determination of forest fire threat, which would include all the elements that affect forest fire threat and be adjusted to domestic conditions of forest management.

A level of forest fire threat is not the same for all forests. It depends on a number of factors whose impact determines the individual level of threat. The statistics indicates that there is a continuous increase in number of forest fires and extent of burnt areas. The increase of forest fires correlates with numerous factors, the most important being the frequency and duration of drought periods, increased presence of people in forests, etc. A preventive and repressive action directly depends on a level of forest fire threat. Identifying this level enables timely and effective forest fire protection. The extent of burnt areas is directly related to the organisation and preparedness of subjects participating in forest fire prevention. Identifying a forest fire threat level entails anticipating potential dangers and determining forest fire prevention measures to be taken in a certain period. The main objective of this method, which may be subject to further enhancement, is to provide a technique and tactic for preparation of an effective forest fire prevention plan.

The increasing number of forest fires requires more organised and professional approach to forest fire protection. The risk of forest fire occurrence is defined as a probability function of adverse event occurrence and possible consequences. The probability of forest fires occurrence is always present; however, by taking certain preventive and organisational measures these adverse events can be anticipated and appropriate preventive measures can be taken. This can be achieved primarily by implementation of risk management in forest fire protection. Risk management involves a group of prevention measures and procedures, preparedness and responses to an occurred event, as well as remediation of adverse event effects with a view to reducing risk and creating conditions under which the risk level becomes tolerable. In risk management applied in forest fire prevention, preventive protection and a group of measures and activities aimed at preventing fire represent a particularly important segment in an effective forest fire protection. A forest fire threat assessment represents the first and primary segment in determining the initial risk of forest fire occurrence in a particular area. Professional services involved in forest fire protection must be well-acquainted with a forested area, particularly with all adverse changes taking place in that area; they must monitor those changes, record them in a timely manner and, based on the relevant parameters, take relevant prevention measures at the appropriate time.

1.1. FOREST FIRE THREAT ASSESSMENT

Forest fire as an ecological factor has a large impact on stability of ecological system. A number of forest fires and burnt areas are constantly increasing. It is associated with numerous factors, the most important being the frequency and duration of drought periods, climate changes, increased presence of people in forests, violation of legal regulations, etc. A large number of fires inflict a considerable damage, both material, relating to burnt wood mass, and ecological, social and other damage. If an excuse can be provided for an increased number of forest fires, the same cannot be the case with the scope of damage, as it is directly

related to organisation and protection measures applied in forest fire protection. If forest fire protection measures are implemented timely, professionally, and in an organised manner, it can be expected that a number of burnt areas becomes lower, fire and dangers are timely foreseen and their number reduced, and the damage caused by forest fires is significantly decreased.

The main objective of a forest fire threat assessment is:

1. To present an accurate picture of a level of forest fire threat to the institutions involved in forest fire protection.
2. To determine and classify dangers arising from forest fires in a monitored area.
3. To point out to possibility of forest fire protection in a particular area and application of additional protection measures.
4. To point out to specificities and fire dangers in a monitored area to specialised agencies involved in fire protection and fire suppression.
5. To find models of additional protection measures and more effective fire suppression when a fire occurs in a particular area.
6. To present a methodology for performance of a fire threat assessment as the most important element in creation of planning acts such are forest fire protection plans, adjusted to the climate and characteristics of the area.

Parameters used in a forest fire threat assessment

Parameters that produce an impact on forest fire threat are numerous, but for the purpose of practical application of the threat assessment method, it will include only the parameters considered the most important and producing the strongest impact on forest fire threat. The key parameters used in forest fire threat assessment are:

- a) vegetation and combustible material
- b) natural phenomena producing an impact on fire occurrence
- c) anthropogenic factor (human-induced risk)
- d) climate characteristics
- e) length of drought period
- f) geological layer and pedological characteristics
- g) orographic characteristics
- h) openness of forest complex
- i) a development level of an area for tourist and outing activities
- j) other biotechnical protection measures
- k) Fire record in the monitored area

a) Vegetation and combustible material

Vegetation, which consists of represented tree species and various types of combustible material in forest, represents the basis that is subject to direct or indirect impact of all other factors that create different levels of fire threat.

Forests can be classified according to different criteria (types of trees, silvicultural method, age, function, etc); however, they are most commonly divided into: coniferous forests, deciduous forests and mixed forests. Furthermore, specific forms, such as thicket, scrub, maquis, garrigue, degraded forests are also taken into account due to their specificity in terms of fire sensibility. Under further vegetation classification, cultures in artificially established plantations are singled out as a specific category, regardless of their age, since the age does not affect a level of forest fire threat (in natural forests, as the age increases, the level of forest fire threat decreases), while in case of cultures, that difference is negligible.

A further division of natural coniferous, mixed and deciduous forests was conducted according to a forest's need for light and its age, although certain other properties of specific forest types also affect their fire threat level (content of resin, tannin, etheric oils, forest canopy, ground vegetation).

The main vegetation parameters used for determination of a forest fire threat level are presented in the Table 1

Table 1. *Vegetation parameters used for determination of a forest fire threat level*

FOREST TYPE	Number of points
Category I	
Xerothermal and mesothermal coniferous forests (natural and artificial) type with a high resin content	200
Natural and artificially established black pine forests	200
Natural and artificially established white pine forests	200
Category II	
IIa – Xerothermal broadleaf forests	180
Downy oak forests	180
Flowering ash forests	180
Oriental hornbeam forests	180
Turkish oak forests	180
IIb – Mesothermal broadleaf forests in warmer exposures	180
Hop hornbeam forests	180
Sessile oak forests	180
Dalechampii oak forests	180
Category III	160
Mesophilic and frigoriphilic forests (natural and artificial); type with a lower resin content	160
Fir forests	160
Spruce forests	160
Serbian spruce forests	160
Macedonian pine forests	160
Artificially established larch stands	160
Artificially established Douglas-fir stands	160
Artificially established eastern white pine stands	160
Artificially established abies grandis stands	160
Artificially established stands of other species of the same characteristics	160
Category IV	140
IVa – Broadleaf and coniferous mesophilic and frigoriphilic mixed forests (natural and artificial)	140
Fir forests	140
Spruce forests	140
Beech forests	140
IVb – Mesophilic and mesothermal broadleaf mixed forests	140
Common hornbeam and sessile oak forests	140
Category V	120
Forests dominated by mesophilic deciduous species	120

Beech forests	120
Common hornbeam forests	120
Birch forests	120
Aspen forests	120

Stand condition based on a degradation level	Number of points
Degraded stands	100
Thickets	160
Scrubs	160

Stand age	Number of points
Under 30 years of age	80
31 to 60 years of age	60
Above 60 years of age	40

Barren land condition	Number of points
Category II	
Barren land in warmer exposures, thickly covered with ground vegetation	180
Category III	
Barren land on shady side, thickly covered with ground vegetation	140
Barren land on sunny side, sparsely covered with ground vegetation	
Category IV	
Barren land thickly covered with ground vegetation, dominated by <i>Vaccinium myrtillus</i> , <i>Vaccinium vitis-ideus</i> , <i>Vaccinium uliginosum</i> , <i>Aristostaphylos uva-ursi</i> and similar perennial plants	120
Category V	
Barren land mainly without ground vegetation	40
Barren land in ground vegetation dominated by moss (particularly <i>Sphagnum</i> sp. and <i>Hylocomium</i> sp.) or ferns <i>Equisetum</i> sp.	20
Marshy smaller areas regardless of a coverage level and vegetation composition	10

b) Natural phenomena that have an impact on forest fire occurrence

Although natural phenomena that cause forest fires account for only 1% of the total fire causing agents in forests, this occurrence requires a particular attention. There are areas exposed to activity of certain natural phenomena, which can become frequent causing agents of forest fire occurrence in a particular period. The most common natural phenomena causing forest fires are atmospheric discharge and thunderbolt, along with the effect of sun heat, when the heat acquires certain focus and leads to ignition of combustible material, most frequently in form of dry grass. An increasing attention has been given to a theory that many forest fires occur by the agency of 'sun winds'; however, this theory has not been scientifically proved yet, therefore it will not be considered in the framework of this methodology. A natural phenomenon that occurs as a causing agent of a forest fire is atmospheric discharge.

Parameters identified on the basis of observation and the relation between danger and atmospheric discharge traces on trees are presented in Table 2.

Table 2. Parameters used for determination of forest fire threat caused by atmospheric discharge

Number of atmospheric discharge traces on trees within a 5 km ² surface area	Danger of tree and forest fire occurrence	Number of points
above 10	considerable danger	20
under 5	danger exists	10
under 2	low danger	0

Atmospheric discharge is more common in higher than in lower mountain regions, as the tree height increases with an altitude. Discharges into high broadleaf trees are more frequent than discharges into coniferous trees.

c) Anthropogenic factor – human-induced risk

Nearly 98% of forest fires are directly or indirectly related to human activity. The presence of man in forests as a shepherd, tourist, forest fruit collector or hunter increases a specific forest fire threat. A particular threat arises from a man's activity related to fire ignition: burning of stubble or plant litter and use of fire in forests for any other type of purpose. Therefore, the anthropogenic threat occupies an important position among the forest fire threat factors.

Some of the indicators of anthropogenic impact on the forest fire threat level are presented in Table 3

Table 3. Parameters of anthropogenic impact on forest fire occurrence

Category 1	Number of points
Tourist and recreation forests; forests in the vicinity of agricultural land and waste disposal sites	60
Category 2	
Forests intersected by public roads, long-distance power lines or forests used as pasture	40
Category 3	
Forests in which forest fruit collection takes place, forests used for hunting and fishing and forests in which silvicultural works are performed	20

If it is possible to classify forests into several categories according to a human-induced risk, than the impact of these factors on forest fire threat will be expressed by a total number of points.

d) Climate and climate impact on forest fire threat

Climate produces a joint effect with all other factors that have an impact on forest fire threat. Despite the fact that numerous climatic parameters have an impact on desiccation of combustible material (air temperature, relative air humidity, precipitations, wind, cloud cover, drought periods, etc.), only the tree most important parameters are used in a forest fire threat assessment: mean annual air temperature, mean annual amount of precipitation and mean annual relative humidity. When using these parameters, it is also necessary to include the duration

of drought periods and their distribution in the course of a year into the assessment of climate impact on forest fire threat.

Some of the parameters used for assessment of climate impact on forest fire threat are presented in Table 4

Table 4. *Parameters used for determination of the impact of climatic elements on forest fire*

Climate characteristics	Number of points
Mean annual air temperature	
above 12°C	30
9,1-12,0°C	20
below 9,0°C	10
Mean annual amount of precipitation	
below 800 mm	30
801-1200 mm	20
above 1200 mm	10
Mean annual relative air humidity	
below 70%	30
71-80%	20
above 80%	10

e) Drought period and its impact on forest threat

A drought period and duration of drought period are also important in the assessment of level of forest fire threat. Duration of drought period, expressed by a number of days, is one of the most important elements used for determination of a level of forest fire threat. In order to identify the real danger and threat of forest fire, a classification into four three-month periods according to a corresponding level of danger, has been conducted, since the threat level is not the same in January or February, for instance, as it is July or August, when that danger is higher as a result of high air temperature. Furthermore, a number of dry days is also important for determination of a level of forest fire threat, since the length of duration of drought period is a relevant factor – it is natural that the danger is higher when a drought period is longer, particularly in months when the air temperature is extremely high - July, August and September, and when that danger is most serious.

Classification and division of drought periods based on months and number of days, along with a drought period impact on forest fire threat level expressed by points, are presented in Table 5.

Table 5. *Drought period parameters used for determination of a level of forest fire threat, [44]*

Number of dry days as per months	Number of points
FIRST PERIOD - January, February, March	
under 10 days	10
10 - 20 days	20
more than 20 days	30
SECOND PERIOD - April, May, June	
under 10 days	40

10 - 20 days	50
more than 20 days	60
THIRD PERIOD - July, August, September	
under 10 days	70
10 - 20 days	80
more than 20 days	90
FOURTH PERIOD - October, November, December	
under 10 days	10
10 - 20 days	20
more than 20 days	30

f) A layer (parent substrate and soil type) and its impact on forest fire threat

A layer, i.e., parent substrate and soil type, also has an impact on forest fire threat. The moisture content in combustible material (needles, leaves, twigs), along with a soil type, has an impact on condition and retention of water in ground and inner layers, which affects combustibility and the threat arising from combustible material in forests.

Classification of soil into categories and the corresponding fire threat level are presented in Table 6.

Table 6. *Classification of soil and its impact on a level of forest fire threat*

Soil type	Subtype	Number of points
A. Automorphic soils		
I – (A)-C or (A)-R undeveloped		
Stone field (Lithosol)	On acid rocks	80
	On neutral and basic rocks	80
	On peridotite	80
	On limestone and dolomite	80
Sierozem on loose substrate (Regosol)	Siliceous	80
	Siliceous-calcareous	80
	Sand-dolomite	80
Eolic 'quicksand' (Arenosol)	Quartz	80
	Siliceous	80
	Siliceous- calcareous	80
Colluvial soils (Colluvium)	District-siliceous	80
	Calcareous	80
	With fossil soil	80
II – A-C or A-R (Humus-accumulative)		
Limestone – dolomite black soil (Calcomelanosol)		
Rendzina	On marl and marly and soft limestone	80
	On loess and loess-like sediments	80
	On moraine	80
	On dolomite regolith	80
	On calcareous sand	80
	On calcareous gravel	80
Humus-siliceous (Ranker)	Eutric	80
	Dystric	60
Chernozem	On loess and loess-like sediments	80
	On carbonate eolic sand	80
	On alluvial deposits	60
Smonitza (Vertisol)	Calcareous	60
	Non-calcareous	60
	Brownish	60

III – A-(B)-C or A-(B)-R (Cambic)		
Eutric brown (Eutric cambisol)	On loess and loess-like sediments	40
	On basic and neutral eruptive rocks	40
	On peridotite and serpentinite	40
	On pond sediments	40
	On alluvial, colluvial and eolic deposits	40
	On claystone	40
Distric brown or acidic brown (Distric cambisol)	On amphybolite shales	40
	Deep	20
Brown on limestone and dolomite (Calcomelanosol)	Very deep	60
	Shallow and medium deep	40
Red soil (Terra rossa)	Deep	60
IV – A-E-B-C or A-E-B-R (Fluvial illuvial)		
Ilimerised or loess affected (Luvisol)	On limestone	40
	On siliceous rocks	40
Podzol		40
Brown podzolic (Brunipodzol)	On quartz sandstone	20
	On quartz	20
	On hornstone	20
	On acidic eruptive rocks	20
	On phyllite	20
	On sand	20
V – P-C (Anthropogenic)		
Rigolano soil (Rigosol)		
Garden soil (Hortisol)		
VI – Technogenic I, II, III		
Disposal site soil (Deposol)		
Flotation material (wastewater deposits – Flotisol)		
Air precipitates (Aeroprecipitate)		

B. Hydromorphic		
I – A-E/g-Bg-C – (Pseudogley)		
Pseudogley		40
II – Layers or (A)-G ili (A) – C (Undeveloped)		
Fluvial or alluvial (Fluvisol)	Calcareous	20
	Calcareous gleyed	20
	Calcareous gleyed, saline and alkaline	20
	Non-calcareous	20
	Non-calcareous gleyed	20
	Non-calcareous gleyed, saline and alkaline	20
III – A-C-G – (Semi-gley)		
Fluvial meadow (Humofluvisol)		20
IV – A-G – (Gley)		
Pseudogley		40
Marsh black soil (Humogley)		20
Marsh gley (Eugley)		20
V – T-G – (Peat)		
High peat		40
Combined high and low peat		20
Low peat (Planohistosol)		20
VI – P-G – (Anthropogenic)		
Rigolano peat		0
Rice field soils		0
Hydromeliorated		0

C – Halomorphie soils		
I – Asa-G or Asa- CG – (Saline)		
Solonchak		40
II – A/E-Asa-BT,na-C (Solonetz)		
Solonetz		40

g) Orographic characteristics

Among orographic characteristic, an altitude, inclination and terrain exposure have a pervasive impact. On terrains with a different altitude, exposure and inclination, the duration and intensity of sunrays are different and, consequently, so are the conditions for drying of combustive material (Table 7).

Table 7. *Orographic parameters that have an impact on a level of forest fire threat*

Orographic characteristics	Number of points
Exposure	
South and level land	20
East and West	10
North	5
Altitude	
below 500 m	15
501-800 m	10
above 800 m	5
Inclination	
above 45%	15
31-45%	10
15-30%	5

h) Forest complex openness

Openness of a forest complex for roads is the basis for a successful prevention of forest fire occurrence. That includes a proper maintenance of fire prevention clearance area, where twig removal and twig pruning are carried out, as well as thinning and reduction of combustible material.

Forest complex openness	Number of points
Forest complex is open (a large area of forest complex is accessible through a developed road network, fire prevention rail tracks are regularly maintained)	5
Forest complex is partially open (larger areas of forest complex are poorly accessible, or accessible by forest roads unsuitable for fire trucks; fire prevention rail tracks are poorly maintained)	20
Forest complex is not open, there are no fire prevention rail tracks	40

i) the development level of an area for tourist and outing activities

Development level	Number of points
Forest complex is well-developed for tourist and outing activities (areas designed for fire making are properly marked and their safety is ensured, barrels with sand for extinguishing smaller fires	5

in the initial phase are provided, forest fire danger signs are properly placed)	
Forest complex is partially developed for tourist and outing activities (forest fire danger signs are properly placed)	20
Forest complex is fully undeveloped for tourist and outing activities (there are no marked areas for making fire nor forest fire danger signs)	40

j) Other biotechnical protection measures

Development level	Number of points
Forest complex has provided biotechnical protection measures (representation of mixed forests, combustible material that is less susceptible to fire, construction of fire protection rail tracks, condition and maintenance of water supply stations, construction of observation points and organisation of forest monitoring system, creation and implementation of a fire occurrence assessment system)	5
Forest complex has no biotechnical protection measures	40

k) Fire record and its impact on forest fire threat

Fire record, or number of fires in a particular time interval in a specific area, has an impact on determination of the forest fire threat level. More specifically, the number of fire in a monitored area indicates what part of an area is more susceptible to fire occurrence and how increased a fire threat is. Furthermore, combustible material is not the same in areas with frequent fire occurrence, since the weather conditions that produce an impact on condition of combustible material susceptible to ignition, also change in that area. Some characteristics used for determination of a forest fire threat level, related to fire frequency in a monitored area within 10 years, are presented in Table 10.

Table 8. *Fire record parameters that have an impact on a level of forest fire threat*

Number of fires in an area within a 10 year period	Number of points
5 and above	40
2 – 4	20
below 2	10

4.3. A level of forest fire threat

Based on the above-mentioned parameters used for the assessment of forest fire threat, the points earned from the represented parameters are added; a level of forest fire threat is determined according to the total number of points.

Categorisation of forest fire threat based on the number of points is presented in Table 9.

Table 9. Forest fire threat categorisation

Forest fire threat level	Total number of points	Colour
Level one – extremely high threat	631-705	red
Level two – high threat	556-630	orange
Level three – medium threat	481-555	yellow
Level four- low threat	405-480	green

Based on certain numeric indicators of forest fire threat, fire threat maps are created in which areas exposed to fire threat are presented in relevant colours.

CONCLUSION

An increasingly frequent occurrence of forest fires and extensive burnt areas require a timely preventive forest fire protection. A type of forest fire threat assessment, which would include all elements that constitute and have an impact on forest fire threat, has not been conducted in Serbia by now, except for the threat assessment that is based on representation of tree species, while other parameters were not taken into consideration. A successful risk management in forest fire protection requires a first-hand knowledge and proper treatment of forests, particularly the understanding and observance of all adverse changes in forests, their timely recording and implementation of relevant fire prevention measures based on relevant parameters. Therefore, a timely detection of harmful occurrences requires a thorough knowledge of events that might cause forest fires, which is gained thorough a constant monitoring, data gathering and certain findings. A method for forest fire threat assessment has for its aim to determine, at any moment and based on a number of significant parameters, a level of forest fire threat in the observed area. Together with the system for forest fire threat assessment, the method for forest fire threat assessment provides the basis for an organised and professional approach to forest fire protection. A method for forest fire threat assessment must be the basis for any risk management applied in forest fire prevention. As any other, this method is also subject to changes and enhancement; however, in its present form, it provides a good basis for an appropriate assessment of forest fire threat. By means of application of this method, forest fire threat in any area can be determined in a more adequate manner. This type of method provides the basis for preparation of planning acts on classification of soils into categories according to forest fire threat. These plans fundamentally differ from the plans for building fire protection and therefore the current Rulebook on preparation of fire protection plans needs to be amended, primarily by defining the content and manner of preparation of these plans, as well as by defining a threat assessment method for preparation of forest fire protection plans.

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