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Lot 02. Assessing forest (fire) risks for priority habitats and species and proposal for its mitigation

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Contents

1. BACKGROUND

Increased frequency and severity of wildfires are recognised as one of the major impacts of climate change and can have devastating effects on both communities and natural resources. Forest composition, management choices, and location also directly influence the risk, emphasizing the need for mindful forest management to mitigate wildfires.

Effective fire management can help mitigate these impacts by reducing wildfire risks, preserving ecosystems, and protecting livelihoods. However, the efficiency of the response to a wildfire largely depends on effective communication, access to necessary resources, and the ability to adapt and adjust to changing circumstances.

The report provides baseline arguments to increase broader awareness of the effects that fire management has on the environment, society, and the economy. Outcomes will further provide knowledge-exchange towards improved forest ecosystems resilience, improvements in air quality, reduction in wildfire risk to communities, and increased economic benefits from sustainable forest management practices.

Collaboration between beneficiaries to minimise the risk of natural disasters affecting both socioeconomic and natural dimension of a landscape is a key to minimising the immediate and long-term effects and their mitigation. Within this context, the establishment of a cross-border cooperation network will provide a joint platform to address the common challenges of climate-related disasters and improve the capacity and readiness to tackle natural disasters by improving the prevention, response, and resilience to natural disasters and risks, in order to minimize their impact on the natural and human environment. Conclusively, the anticipated exchange of knowledge, harmonization of methods, and joint planning and deployment of tools and models can be seen as an important advance toward the setup of a common framework of measures for increasing the resilience of land and forested areas to climate change.

Established effective baseline for rapid forest fire suppression relays fire risk probability assessment for different ecosystems in NP “Pelister” and further includes burn severity assessment and forest fire inventory of historic fire occurrences in the last 20 years. All aforementioned outputs contribute towards an integrated fire risk management in NP “Pelister” with reference to priority species and habitats and outline general actions and for forest fire prevention and fire control for sustainable forest management. General management actions and recommendations focus on creating new and/or improving existing forest management actions including guideline for increasing fire resilience.

Successful implementation of the project activities will increase awareness on the benefits of fire management on the environment, society, and the economy and provide argumentative baseline for further detailed forest management plans with focus on natural disaster management. Project outputs will also further contribute towards increased sustainability in management of forest ecosystems and safeguarding biodiversity whilst increasing public safety, and strengthening capacities of local communities in responding to climate change effects. Finally, project outputs strengthen NP “Pelister” disaster resilience and emergency preparedness and improve the operational efficiency and the administrative capacity in natural disaster management.

By considering the outputs, outcomes, and impacts of fire management NP “Pelister” can evaluate the effectiveness of their fire management strategies and make informed decisions about future management actions.

1.1. Fire risk probability assessment

Employing forecasting tools to simulate forests function of growth and succession while accounting for both environmental and anthropogenic disturbances and threats has emerged as an important tool for assessing the fitness of management actions (Sotnik et al. 2021).

Hence, assessing and mapping fire risk is an important step towards efforts to minimize future possible fires and identifying appropriate, practical, and pragmatic restoration goals. With consideration to data

availability and in absence of specific data on forest composition, arrangement, age, biomass, fire disturbance history etc. simulating the success and applicability of different scenarios of re-vegetation approaches (Ziegler et al. 2019; Keane et al. 2004) is not feasible. Instead, combining geospatial data and GIS was selected as most appropriate method for fire risk assessment (Adab et al. 2011).

Forest-related wildfire drivers are intrinsic to the forest and its structure, health and composition. On the other hand, external drivers influence wildfire risks even though they are not related to the characteristics of the forest. However, in practice, these drivers are all closely interlinked.

The composition and structure of a forest, including the topography of the site (slope, aspect) where the forest is located, as well as the activities influencing the forest tree composition have an impact on wildfire risk and its occurrence. Deciduous trees are usually less prone to wildfires compared to conifers, mainly because they thrive in a moister microclimate and possess fewer flammable resins. Young coniferous forests, coppice woodlands and shrubs, are particularly susceptible to wildfires. Equally, very dense young forests in newly afforested areas with significant biomass accumulation are also at risk. In addition, mono-species and mono-age stands can be more prone than a forest with more complex structures and diverse species and age compositions, especially if they are not managed properly. Tree density is another factor that can influence the wildfire risk, as does the presence of shrubs and flammable vegetation in between the ground and the crown level (vertical continuity).

Another factor influencing wildfire risk is forest location, its accessibility and traditional rural activities developed in the area. Traditional land management practices like burning stubbles, or pasture management are another factor that increase to fire risk. Rural abandonment also contributes to an increased fire risk and propagation, through the lack of people to manage the fuel load. On the opposite increase human presence, particularly non-residents and tourists also increase fire risk. A higher number of human-related activities within a forest area increases probability of ignitions. People are at times victims of wildfires, while at the same time majority of fires are caused by humans, either accidentally, by negligence or deliberately. Accidental wildfires can occur because of damaged power lines among others.

In this context fire risk was assessed taking into account both external and vegetation-related factors contributing factors.

The assessment of fire risk was carried with joint consideration of vegetation moisture (NDWI), slope, aspect and elevation to account for the internal factors contributing to fire risk. Distance from roads, vicinity of settlements and known camping sites and tourist routes were also considered to account for the external contributing factors. All criteria were assessed according to their impact and then weighted in accordance to their contribution to fire risk.

Prioritizing the evaluation of fire risk within Pelister National Park, the project extends its assessment beyond the park's borders to incorporate the probability of fire risks from the surrounding areas. This comprehensive assessment encompasses the entire Pelister Mt. (Melovski et al. 2013), taking into account potential fire hazards from the surrounding areas adjacent to the national park. Cumulative probability assessment of fire risk is presented on Figure 1.

Results show that as an overall 20% of Pelister Mt. is assessed to be under low to moderate fire risk, 31% is assessed to be under moderate to high fire risk, while 49% is assessed to be high to very high risk. Within NP “Pelister” borders, 19% of the area is assessed to be under low to moderate fire risk, 58% is assessed to be under moderate to high fire risk, while 22% is assessed to be high to very high risk. In the area outside of NP “Pelister”, confined to Pelister Mt, 11% of the area is assessed to be under low to moderate fire risk, 52% is assessed to be under moderate to high fire risk, while 37% is assessed to be high to very high risk.

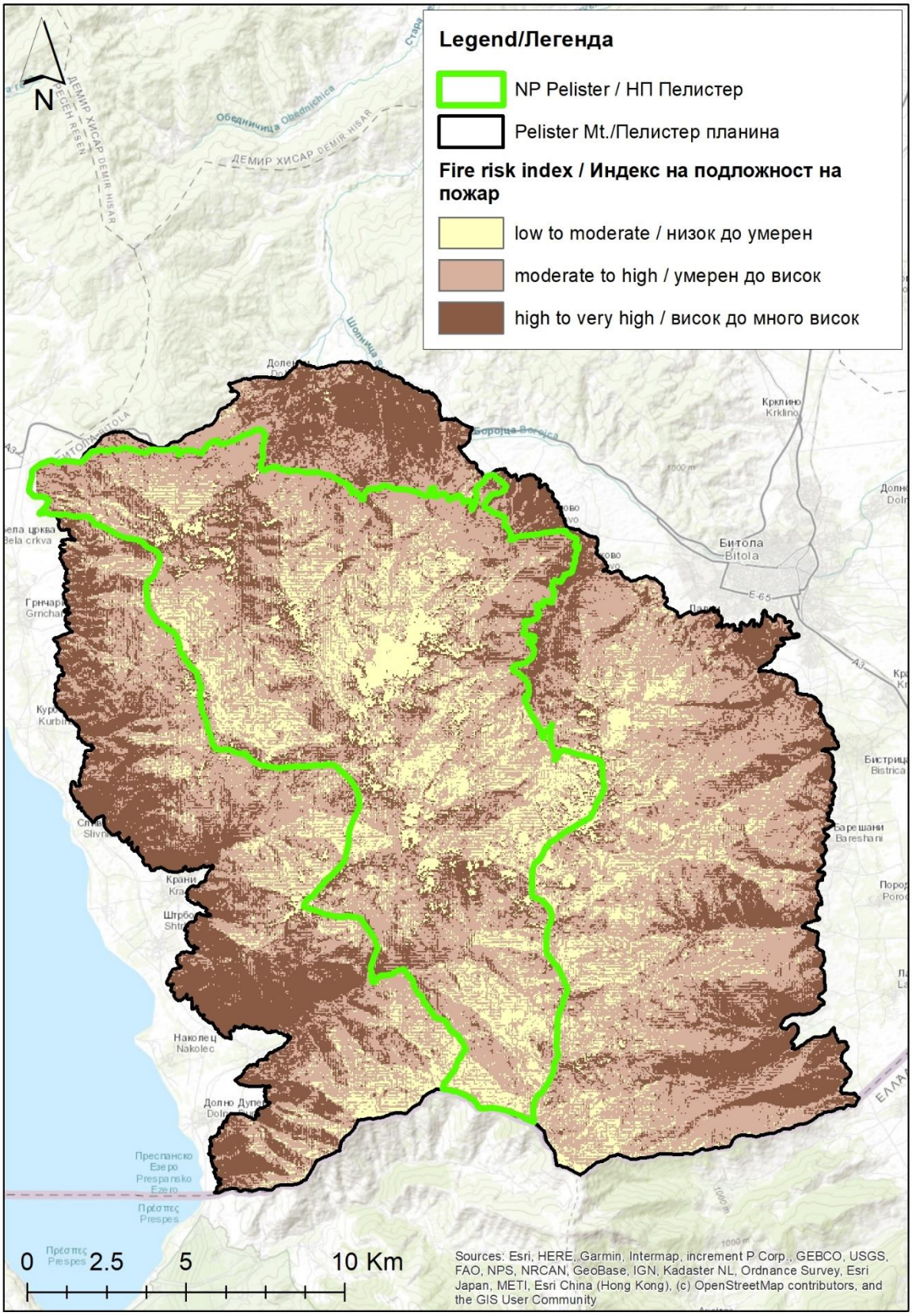


Figure 1. Fire risk index

2. ASSESSMENT OF FOREST FIRE RISK FOR DIFFERENT ECOSYSTEMS IN NP "PELISTER" WITH REFERENCE TO PRIORITY SPECIES AND HABITATS

Conducting a comprehensive assessment of forest fire risks in Pelister National Park whilst integrating available information on species and habitats allows assessment of vulnerability of different habitats to fires whilst providing a sustained baseline for tailoring fire management actions for priority species and habitats.

General assessment of forest fire risk for different ecosystems was carried by intersection of customised Corine Land Cover (EEA 2018) data and Fire risk index output. Results show that fire risk probability on Pelister Mt. varies for different ecosystem types and is assessed as highest for agricultural ecosystems, pastures and traditional-woodland scrub. Forest ecosystems are largely assessed to be under moderate to high risk with coniferous forests being assessed to have highest coverage under high to very high fire risk.

Owing to variations in the coverage ratios of ecosystem types within and outside the confines of Pelister National Park, the fire risk assessment reveals heightened level of fire risk in the neighbouring regions adjoining the national park. This specifically pertains to the segments of Pelister Mountain that lie beyond the management jurisdiction of Pelister National Park.

Fire risk assessment by ecosystem type within the boundaries of NP "Pelister" are provided in Table 1. Fire risk assessment by ecosystem type in the area of Pelister Mt. that lie beyond management jurisdiction of NP "Pelister" are provided in Table 2. General overview of fire susceptibility by vegetation type is provided in Figure 2.

Fire risk assessment for priority species and habitats in NP "Pelister" is provided in Table 3.

Table 1. Fire risk assessment by ecosystem type in NP "Pelister"

Ecosystem type	Fire risk area (%) by habitat type		
	low to moderate (%)	moderate to high (%)	high to very high (%)
Broad-leaved forest	18	65	17
Coniferous forest	31	59	10
Mixed forest	22	67	11
Transitional woodland-shrub	29	57	14
Grasslands and heathland	26	53	21
Pastures	4	39	57
Sparsely vegetated areas	48	28	24
Agricultural land	12	31	56
Area (ha/%) on Pelister Mts. inside of NP Pelister	**28**	**55**	**17**

Table 2. Fire risk assessment by ecosystem type in the area outside of NP "Pelister", confined to Pelister Mt.

Ecosystem type	Fire risk area (%) by habitat type		
	low to moderate (%)	moderate to high (%)	high to very high (%)
Broad-leaved forest	13	64	23
Coniferous forest	11	60	30
Mixed forest	23	58	19
Transitional woodland-shrub	9	48	43
Grasslands and heathland	32	53	15
Pastures	1	13	86
Sparsely vegetated areas	49	24	27
Agricultural land	2	34	64
Area (ha/%) on Pelister Mts. outside of NP Pelister	**12**	**52**	**37**

Table 3. Fire risk assessment for priority species and habitats

Habitat type ref. Habitat Directive *Habitat type ref. EUNIS*	*Fire risk area by habitat type (in ha)*			*Fire risk area by habitat type (in %)*		
	low to moderate	*moderate to high*	*high to very high*	*low to moderate (%)*	*moderate to high (%)*	*high to very high (%)*
4060: Alpine and Boreal heaths	**731**	**1505**	**383**	**28**	**57**	**15**
F2.2: Evergreen alpine and subalpine heath and scrub	471	861	144	32	58	10
F2.231: Mountain Juniperus nana scrub	261	644	240	23	56	21
5130: Juniperus communis formations on heaths	**23**	**152**	**96**	**8**	**56**	**35**
F3.164: Sub-Mediterranean common juniper thickets	23	152	96	8	56	35
6220*: Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea	**14**	**13**	**37**	**22**	**20**	**57**
E1.33: East Mediterranean xeric grassland	14	13	37	22	20	57
62D0: Oro-Moesian acidophilous grasslands	**575**	**1091**	**339**	**29**	**54**	**17**
E4.39: Oro Moesian acidophilous grassland	575	1091	339	29	54	17
6430: Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	**3**	**6**	**1**	**27**	**64**	**9**
E5.57: Eastern oro-Mediterranean and Balkan tall-herb communities	3	6	1	27	64	9
6520: Mountain Hay Meadows	**0**	**1**	**0**	**9**	**83**	**8**
E2.3: Mountain Hay Meadows	0	1	0	9	83	8
6540: Sub-Mediterranean grasslands of the Molinio-Hordeion secalini	**5**	**29**	**15**	**10**	**59**	**31**
E3.31: Helleno-Moesian riverine and humid Trifolium meadows	5	29	15	10	59	31
8150: Medio-European upland siliceous screes	**959**	**439**	**358**	**55**	**25**	**20**
H2.33: Southeast European mountain siliceous screes	959	439	358	55	25	20
8220: Siliceous rocky slopes with chasmophytic vegetation	**342**	**257**	**321**	**37**	**28**	**35**
H3.152: Carpatho-Balkano-Rhodopide campion siliceous cliffs	342	257	321	37	28	35
91AA: Eastern white oak woods	**23**	**398**	**163**	**4**	**68**	**28**
G1.7: Thermophilous deciduous woodland	23	398	163	4	68	28
91W0: Moesian beech forests	**1017**	**3068**	**604**	**22**	**65**	**13**

Habitat type ref. Habitat Directive *Habitat type ref. EUNIS*	*Fire risk area by habitat type (in ha)*			*Fire risk area by habitat type (in %)*		
	low to moderate	*moderate to high*	*high to very high*	*low to moderate (%)*	*moderate to high (%)*	*high to very high (%)*
G1.69: Moesian Fagus forests	1017	3068	604	22	65	13
9270: Hellenic beech forests with Abies borisii-regis	**224**	**174**	**4**	**56**	**43**	**1**
G3.171: King Boris's fir forests	224	174	4	56	43	1
9280: Quercus frainetto woods	**16**	**414**	**185**	**3**	**67**	**30**
G1.6B: Mediterraneo Moesian Fagus forests	16	414	185	3	67	30
95A0: High oro-Mediterranean pine forests	**677**	**1365**	**190**	**30**	**61**	**9**
G3.621: Pelagonide Macedonian pine woods	677	1365	190	30	61	9
7160: Fennoscandian mineral-rich springs and springfens	**0**	**0**	**0**	**90**	**10**	**0**
C2.1: Springs, spring brooks and geysers	0	0	0	90	10	0
3130: Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoeto-Nanojuncetea	**5**	**0**	**0**	**89**	**8**	**3**
C1.1.: Permanent oligotrophic lakes, ponds and pools	4	0	0	90	7	3
C1.6: Temporary lakes, ponds and pools	0	0	0	80	20	0
7220*: Petrifying springs with tufa formation (Cratoneurion)	**0**	**0**	**0**	**2**	**76**	**22**
C2.121: Petrifying springs with tufa or travertine formations	0	0	0	2	76	22
7140: Transition mires and quaking bogs	**1**	**1**	**0**	**48**	**50**	**2**
D2.2: Poor fens and soft-water spring mires	1	1	0	48	50	2
Other	**128**	**547**	**220**	**14**	**61**	**25**
AREA (HA) ON PELISTER MTS.	**4742**	**9461**	**2918**	**28**	**55**	**17**

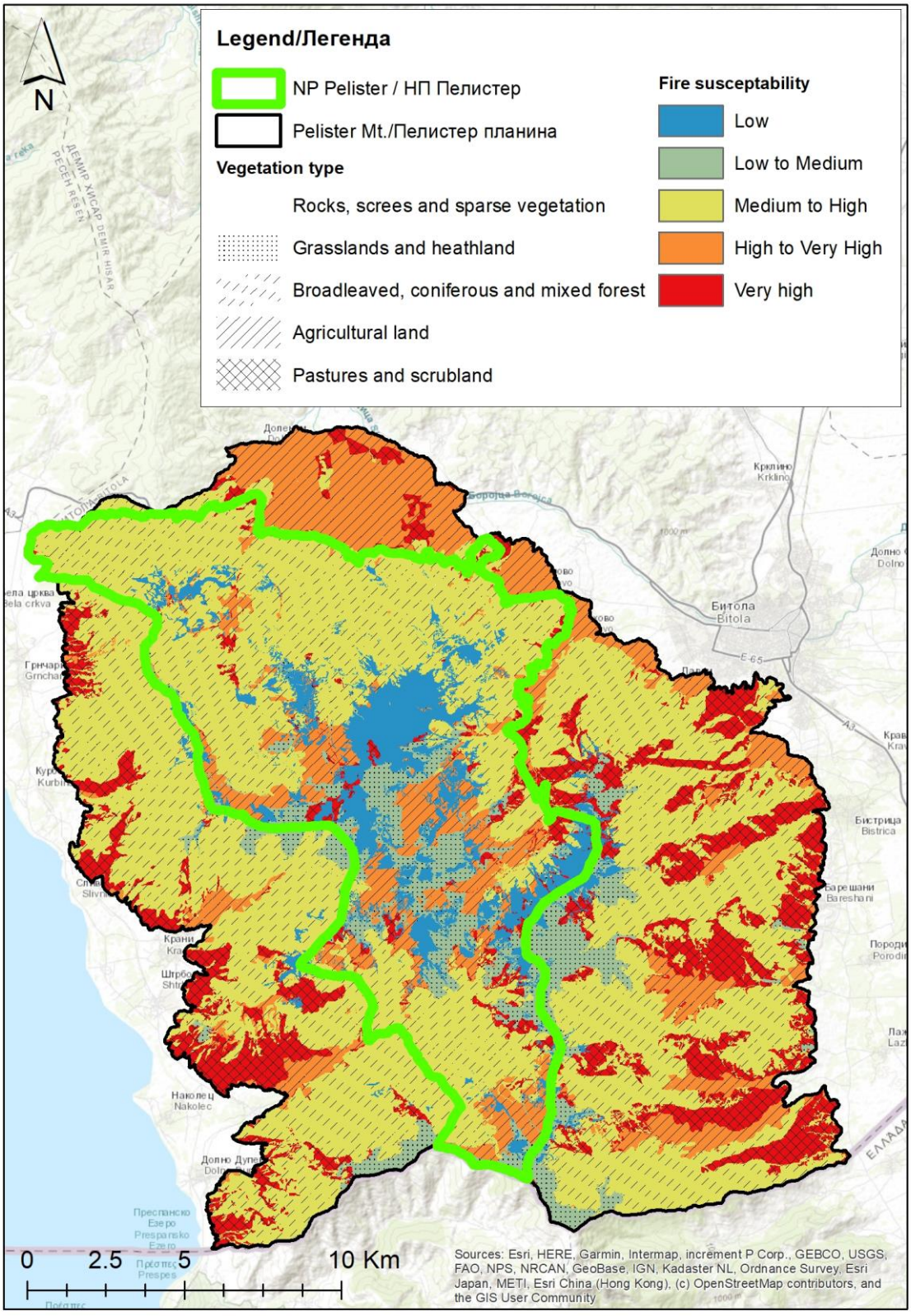


Figure 2. Overview of fire susceptibility by vegetation type

The fire assessment outlines ***6220*: Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea*** *(*Eunis ref. *E1.33: East Mediterranean xeric grassland)* as a habitat type at highest percentage of high to very high fire risk.

Following, the ***5130: Juniperus communis formations on heaths*** *(*Eunis ref. *F3.164: Sub-Mediterranean common juniper thickets)*, then ***6540: Sub-Mediterranean grasslands of the Molinio-Hordeion secalini*** (Eunis ref. *E3.31: Helleno-Moesian riverine and humid Trifolium meadows*) are assessed to have more than one third of their area coverage at high to very high fire risk. The remaining portion of these habitat types is assessed to be at moderate to high fire risk.

Other grassland communities are largely assessed to be under moderate to high fire risk, particularly **6520: Mountain Hay Meadows** (Eunis ref. E2.3: *Mountain Hay Meadows*). A notable portion of **6430: Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels** (Eunis ref. *E5.57: Eastern oro-Mediterranean and Balkan tall-herb communities*) is also assessed to be at medium to high fire risk.

Alongside, a significant portion of habitat types **4060: Alpine and Boreal heaths** (Eunis ref. F2.2: *Evergreen alpine and subalpine heath* and scrub and F2.231: *Mountain Juniperus nana scrub*) and **62D0: Oro-Moesian acidophilous grasslands** (Eunis ref. *E4.39: Oro Moesian acidophilous grassland*) has also been assessed at medium to high fire risk. A notable portion of these habitat types is also assessed to be at high to very high fire risk.

The oak forests, ***91AA: Eastern white oak woods*** **(**Eunis ref. *G1.7: Thermophilous deciduous woodland*) and ***9280: Quercus frainetto woods*** (Eunis ref. *G1.6B: Mediterraneo Moesian Fagus forests*) are other two habitat types that have around 30% of area coverage assessed to be at high to very high fire risk. The remaining portion of these habitat types is again assessed to be at moderate to high fire risk. However, thermophilus oak forests and coniferous forests are assessed to be more susceptible to fire than mesophillous beech and mixed forests, particularly outside of the borders of NP "Pelister" where the forests are more open and the surrounding vegetation is more thermophilic

Habitats of more mesophillous forests have been largely assessed to be at medium to high fire risk, the highest being for the **91W0: Moesian beech forests** (Eunis ref. G1.69: *Moesian Fagus forests*) that also include patches of mixed forests with conifer and **95A0: High oro-Mediterranean pine forests** (Eunis ref. G3.621: *Pelagonide Macedonian pine woods*). Notable portion of the habitat **9270: Hellenic beech forests with Abies borisii-regis** (Eunis ref. G3.171: *King Boris's fir forests*) has been assessed to be at low to medium fire risk. However, portion of this habitat type is also assessed to be at medium to high risk.

Habitat types **8150: Medio-European upland siliceous screes** (Eunis ref. H2.33: *Southeast European Mountain siliceous screes*) and **8220: Siliceous rocky slopes with chasmophytic vegetation** (Eunis ref. H3.152: *Carpatho-Balkano-Rhodopide campion siliceous cliffs*) have also been assessed to have a significant area coverage at medium and high to very high fire risk. The remaining portion of these habitat types is assessed to be at low to moderate fire risk. However, this outcome is largely a result of the mapping approach for both habitat types, as the delineated area of both habitats also includes a significant portion of chasmophitic communities and intersecting patches of grassland that alongside with medium to high fire index of surrounding forest communities and scrubland contribute to the portion of this habitat assessed as moderate to high and very high risk.

Due to their immediate surroundings and the low are coverage of water and wetland habitats, parts fall under areas assessed as moderate to high fire risk. A notable portion of the habitat ***7140: Transition mires and quaking bogs*** (Eunis ref. *D2.2: Poor fens and soft-water spring mires*) and the habitat ***7220*: Petrifying springs with tufa formation (Cratoneurion)*** (Eunis ref.: *C2.121: Petrifying springs with tufa or travertine formations*) are assessed to fall under moderate to high fire risk areas. Habitat types ***7160: Fennoscandian mineral-rich springs and springfens*** (Eunis ref.: *C2.1: Springs, spring brooks and geysers*) and ***3130: Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoeto-Nanojuncetea*** (Eunis ref.: *C1.1: Permanent oligotrophic lakes, ponds and pools* and *C1.6: Temporary lakes, ponds and pools*) largely fall under low to moderate fire risk areas.

3. BURN SEVERITY ASSESSMENT AND FOREST FIRE INVENTORY OF HISTORIC FIRE OCCURRENCES IN THE LAST 20 YEARS

Data on historic fire occurrences were assessed by collating NASA fire records (Modis, NASA 2023) and NP "Pelister" fire records in the last 20 years (from 2000 to 2023). Historic data shows that historically most severely affected were the areas of Rzhana (Garvan), Ljubojno and Dupeni and surrounding area of Magarevo and Capari upwards to Jorgov Kamen and Kale (Figure 3).

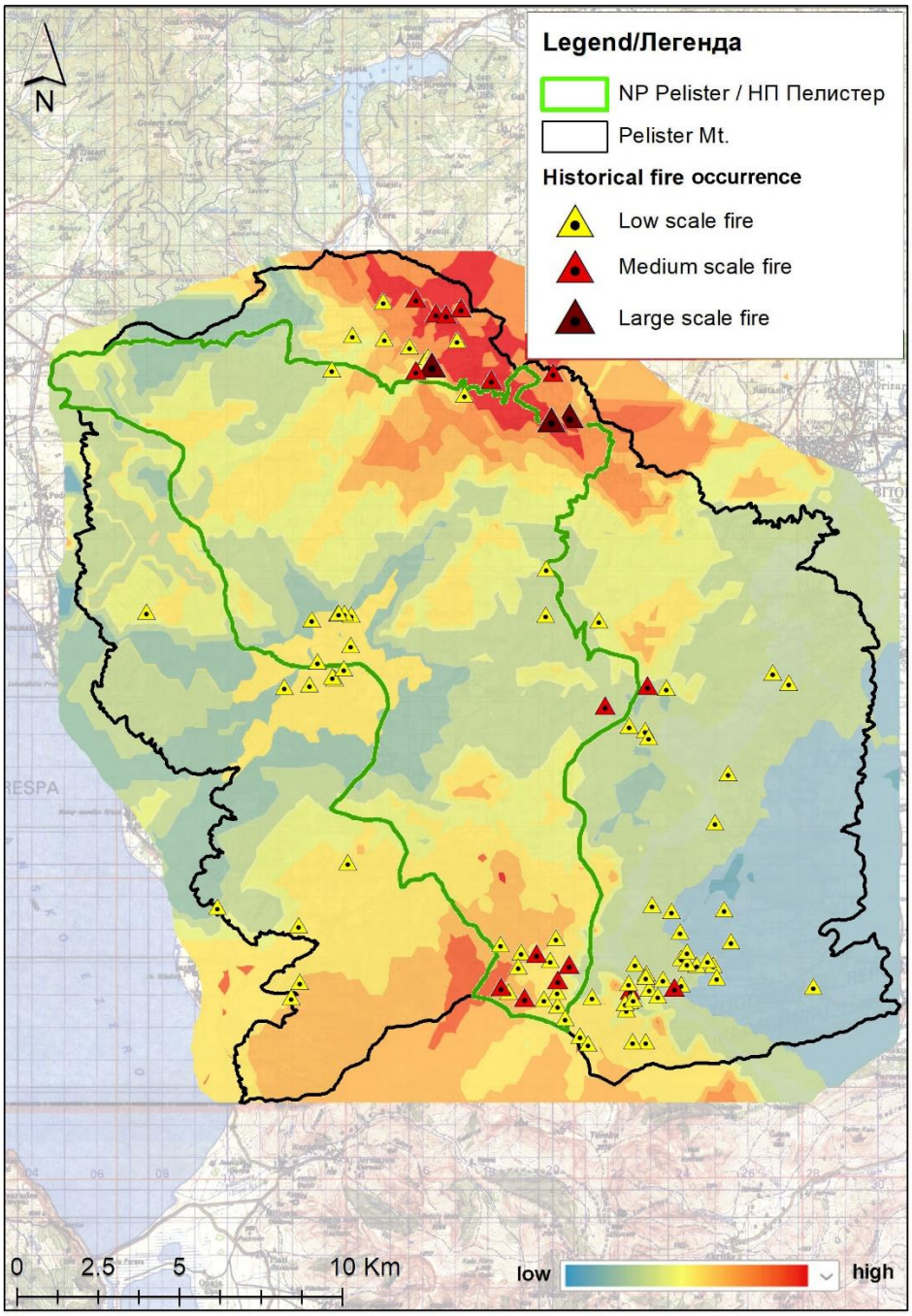


Figure 3. Records of fire occurrences in NP "Pelister" and adjacent area confined to Pelister Mt. including extrapolation of fire severity (low - blue to high - red).

Habitat types with reference to Habitat Directive and historic records of fire are presented on Figure 4, with respective intersect data provided in Table 4.

As no habitat map exist for the entire mountain, and with intention to approximately show in which habitat types fires most frequently occur, we have used Corine Land Cover as a base to produce Figure 5 and Table 5.

Tables 4 and 5 confirm highest risk from fires for high-mountain scrubs, pastures, beech forests and conifer forests.

Table 4. Intersect of fire occurrences with regard to habitats in Pelister NP

Habitat type with reference to Habitat Directive (in bold) and EUNIS	**Fire occurrences**		
	Medium scale fire	Small scale fire	Total
4060: Alpine and Boreal heaths	**2**	**6**	**8**
F2.2: Evergreen alpine and subalpine heath and scrub	1	5	6
F2.231 Mountain Juniperus nana scrub	1	1	2
62D0: Oro-Moesian acidophilous grasslands	**1**	**6**	**7**
E4.39: Oro-Moesian acidophilous grassland	1	6	7
8150: Medio-European upland siliceous screes	**1**		**1**
H2.33: Southeast European mountain siliceous screes	1		1
8220: Siliceous rocky slopes with chasmophytic vegetation	**1**		**1**
H3.152: Carpatho-Balkano-Rhodopide campion siliceous cliffs	1		1
91AA: Eastern white oak woods		**1**	**1**
G1.7: Thermophilous deciduous woodland		1	1
91W0: Moesian beech forests	**1**	**4**	**5**
G1.69: Moesian Fagus forests	1	4	5
9270: Hellenic beech forests with Abies borisii-regis		**2**	**2**
G3.171: King Boris's fir forests		2	2
95A0: High oro-Mediterranean pine forests		**1**	**1**
G3.621: Pelagonide Macedonian pine woods		1	1
Total	6	20	26

Table 5. Intersect of fire occurrences with regard to Corine Land Cover in Pelister mountain.

Corine Land Cover type	**Low scale fire**	**Medium scale fire**	**Large scale fire**	**Total fire occurrences**
Broad-leaved forest	26	2		28
Mixed forest	1			1
Coniferous forest	4			4
Grasslands - Moors and heathland	7			7
Grasslands - Natural grasslands	6	1		7
Transitional woodland-shrub	18	3		21
Pastures	3			3
Agricultural land - Land principally occupied by agriculture, with significant areas of natural vegetation	2	2	1	5
Agricultural land - Complex cultivation patterns	8	1	1	10
Agricultural land - Vineyards	1	4		5
Agricultural land - Fruit trees and berry plantations		1		1
Agricultural land - Discontinuous urban fabric			1	1
Sparsely vegetated areas	2	2		4
Total	78	16	3	97

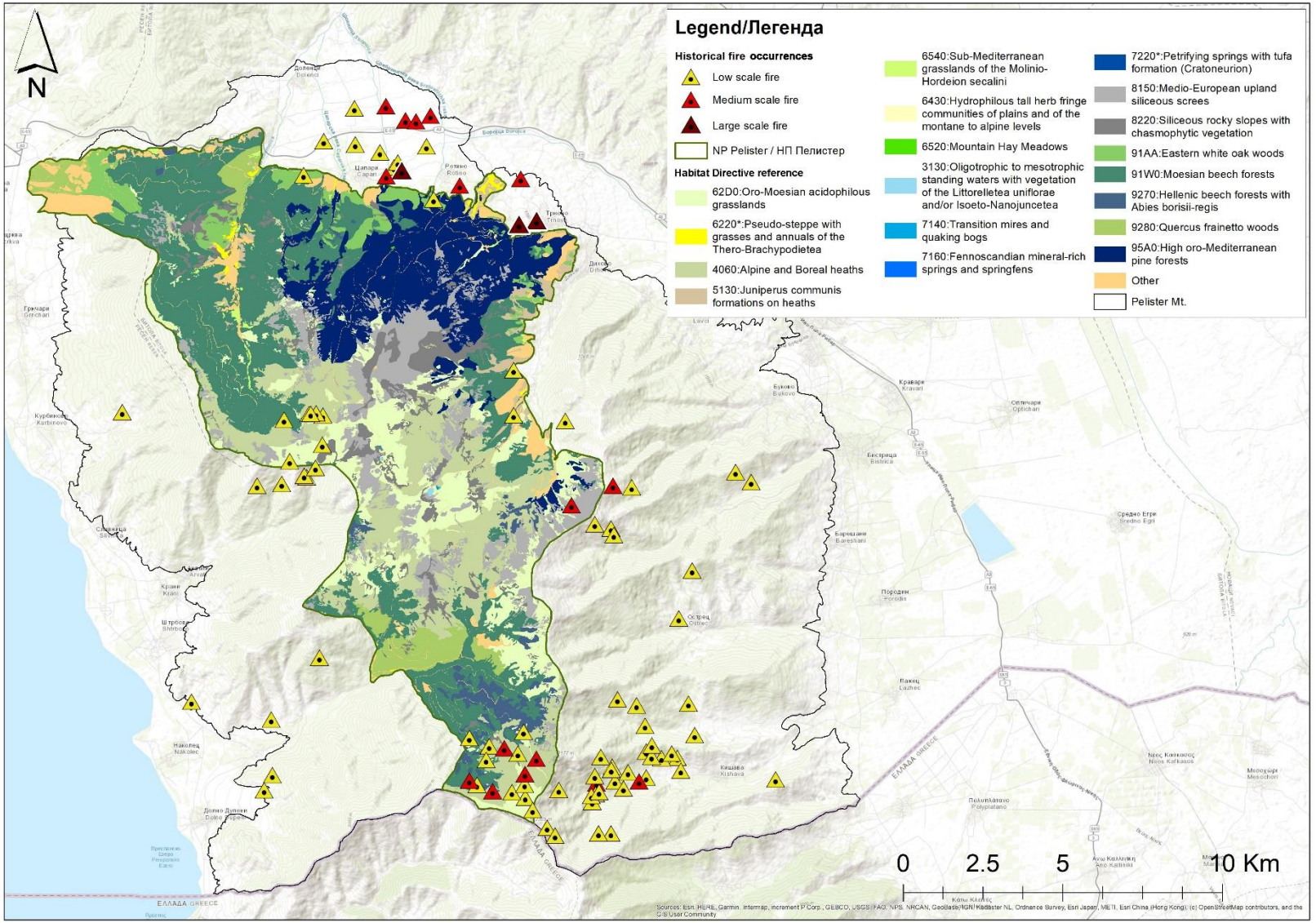
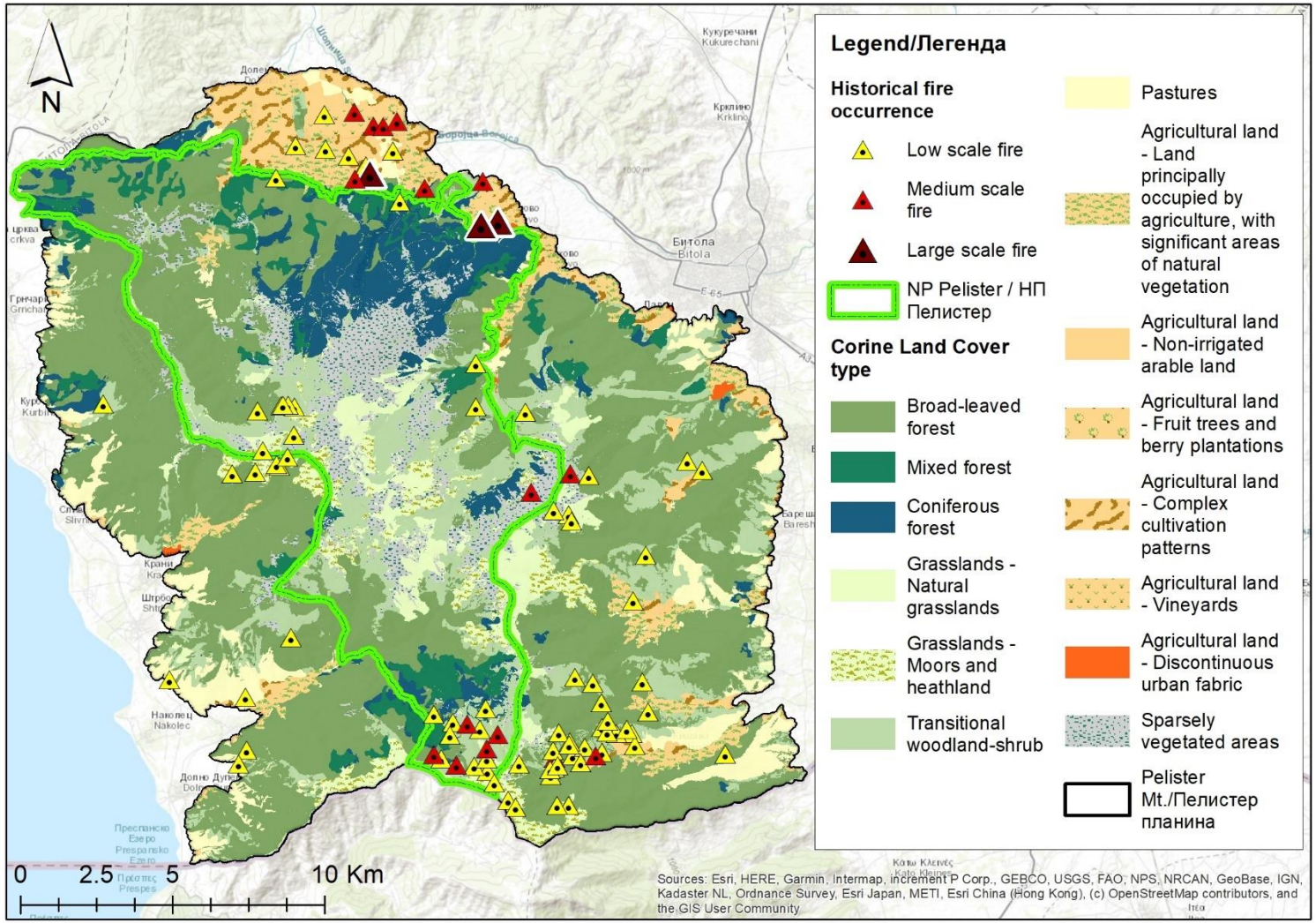


Figure 4. Habitat types with reference to Habitat Directive and historic records of fire

Figure 5. Historic records of fire and land cover types with reference to Corine Land Cover (as modified for the purpose of this assessment)



4. RISKS TO PRIORITY SPECIES AND HABITATS

The selection of species for which the risk from wildfires have been assessed is severely limited by the availability of spatial and habitat data. Although the Valorization Study for "Pelister" NP provides extensive lists of species from different taxonomic groups in the Park, very rarely precise locations are given, or habitat is provided in older literature data. Fortunately, exact spatial information is available for the important species from the recent surveys of the flora, fungi and fauna of the Park. These data are scarce however, partially because the species are not always common. From these lists, we have selected several terrestrial species for which the risk from wildfires has been assessed, on basis of their habitat preference, known distribution, and fire risk. Similarly, we have selected relevant Habitat Directive Annex I habitats, having in mind their susceptibility to fires (therefore, no aquatic, wet or rocky habitats), diversity among groups, dependence on habitats, priority for conservation, and national importance. The selected species and habitats are:

Plants: *Tozzia carpathica* – listed in Habitat Directive, Pelister is the only locality in the country, five locations are known in total.

Fungi: *Tricholoma acerbum* - Vulnerable (VU) according to the IUCN Red List.

Fauna: Orthoptera: *Poecilimon ebneri* – local endemite, Endangered (EN)*;* Coleoptera (Beetles, notably Ground beetles Carabeidae)*: Molops rufipes rufipes* - stenoendemic, *Tapinopterus monastirensis monastirensis* – stenoendemic, *Synuchidius ganglbaueri* - stenoendemic; Lepidoptera (butterflies)*: Phengaris arion* (Endangered – EN), Aves (Birds)*: Dryocopus martius, Dendrocopos leucotos, Lanius collurio* – Bird Directive Annex I, Mammalia*: Ursus arctos, Myotis myotis/blythii* (Habitat Directive).

Habitats: 6220* *Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea*, 6230* *Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)* (both priority habitats in the Habitat Directive) and *95A0 High oro-Mediterranean pine forests* (molika pine forests, Habitat Directive, national importance).

Some indicative maps of selected species are shown on Figures 6 and 7, in relation to Corine Land Cover and fire susceptibility combined with main vegetation types. These maps are for informative purposes only, as they show only actual findings of these species, while the species is actually present on more locations in the same or similar habitat. Therefore, Table 6 summarizes the species distribution per main habitat types (Habitat Types, EUNIS), with the Fire Risk Index (FRI) for the respective habitat type, thus giving indication for the possible consequences of fire on the selected species. The actual effect is of course dependent on the fire coverage and severity. This result should e seen as an exercise only, and it should be repeated in intervals after new data become available, or with other species, in accordance with the research and monitoring activities of the biodiversity in the National Park.

Table 6 actually shows that some of the selected species (Brown Bear *Ursus arctos*, Red-backed Shrike *Lanius collurio,* Black woodpecker *Dryocopus martius*) might potentially be highly affected by fires, as they are spread in several habitats that are at medium to high risk or high to very high risk of fires. This means that a widespread fire in these habitats has the potential to severely affect species of high priority for conservation. This is of course something that can be inferred by expert opinion, but the analytical approach used here allows that the same exercise is repeated when more data on the distribution of these or other species are collected (or species distribution is modeled in regards with habitat suitability with high precision), species can be ranked. Likewise, the three ground-beetles are also under relatively high risk from wildfires.

Table 6. Presence of selected species in the appropriate habitats (EUNIS classification) and their susceptibility to fires

Species group	Species	EUNIS	Fire risk index
Plants	*Tozzia alpina* subsp. *carpathica*	F2.2: Evergreen alpine and subalpine heath and scrub	low to medium
		G1.1112: Eastern European poplar-willow forests	low to medium
		G1.7: Thermophilous deciduous woodland	high to very high
		G3.621: Pelagonide Macedonian pine woods	medum to high
Fungi	*Tricholoma acerbum*	G1.7: Thermophilous deciduous woodland	medum to high
Ground beetles	*Molops rufipes rufipes*	F2.2: Evergreen alpine and subalpine heath and scrub	medum to high
		F2.231: Mountain Juniperus nana scrub	low to medium
		G3.171: King Boris's fir forests	medum to high
		G3.621: Pelagonide Macedonian pine woods	medum to high
		H2.33: Southeast European mountain siliceous screes	low to medium
			medum to high
		J2.2: Rural public buildings	medum to high
	Synuchidius ganglbaueri	F2.2: Evergreen alpine and subalpine heath and scrub	medum to high
		G1.69: Moesian Fagus forests	medum to high
		G3.171: King Boris's fir forests	medum to high
		G3.621: Pelagonide Macedonian pine woods	medum to high
		J2.2: Rural public buildings	medum to high
	Tapinopterus monastirensis monastirensis	G1.69: Moesian Fagus forests	medum to high
		G3.171: King Boris's fir forests	medum to high
		G3.621: Pelagonide Macedonian pine woods	medum to high
		H2.33: Southeast European mountain siliceous screes	low to medium
			medum to high
		J2.2: Rural public buildings	medum to high
Daily butterflies	*Phengaris arion*	G1.6B: Mediterraneo-Moesian Fagus forests	medum to high
		J2.2: Rural public buildings	high to very high
Orthopterans	*Poecilimon ebneri*	F2.231: Mountain Juniperus nana scrub	low to medium
		G3.621: Pelagonide Macedonian pine woods	medum to high
Birds	*Dendrocopos leucotos*	G1.69: Moesian Fagus forests	medum to high
	Dryocopus martius	E3.31: Helleno-Moesian riverine and humid Trifolium meadows	medum to high
		G1.69: Moesian Fagus forests	low to medium
			medum to high
		G3.621: Pelagonide Macedonian pine woods	low to medium
			medum to high
		J4.2: Road networks	high to very high
			low to medium
			medum to high

Species group	Species	EUNIS	Fire risk index
	Lanius collurio	E4.39: Oro-Moesian acidophilous grassland	high to very high
			low to medium
		E4.39: Oro-Moesian acidophilous grassland	medum to high
		F2.2: Evergreen alpine and subalpine heath and scrub	medum to high
		F2.231: Mountain Juniperus nana scrub	medum to high
		G1.69: Moesian Fagus forests	high to very high
			low to medium
		G3.4F: European Pinus sylvestris reforestation	medum to high
		G3.621: Pelagonide Macedonian pine woods	low to medium
			medum to high
		H3.152: Carpatho-Balkano-Rhodopide campion siliceous cliffs	low to medium
		J4.2: Road networks	medum to high
Mammals	*Myotis myotis/blythii*	G3.621: Pelagonide Macedonian pine woods	high to very high
			medum to high
		J4.2: Road networks	medum to high
	Ursus arctos	G1.69: Moesian Fagus forests	high to very high
			medum to high
		G1.6B: Mediterraneo-Moesian Fagus forests	high to very high
		G1.6B: Mediterraneo-Moesian Fagus forests	medum to high
		G1.7: Thermophilous deciduous woodland	medum to high
		G3.621: Pelagonide Macedonian pine woods	high to very high
			low to medium
			medum to high
		H2.33: Southeast European mountain siliceous screes	low to medium
		H2.33: Southeast European mountain siliceous screes	medum to high
		J4.2: Road networks	high to very high
			low to medium

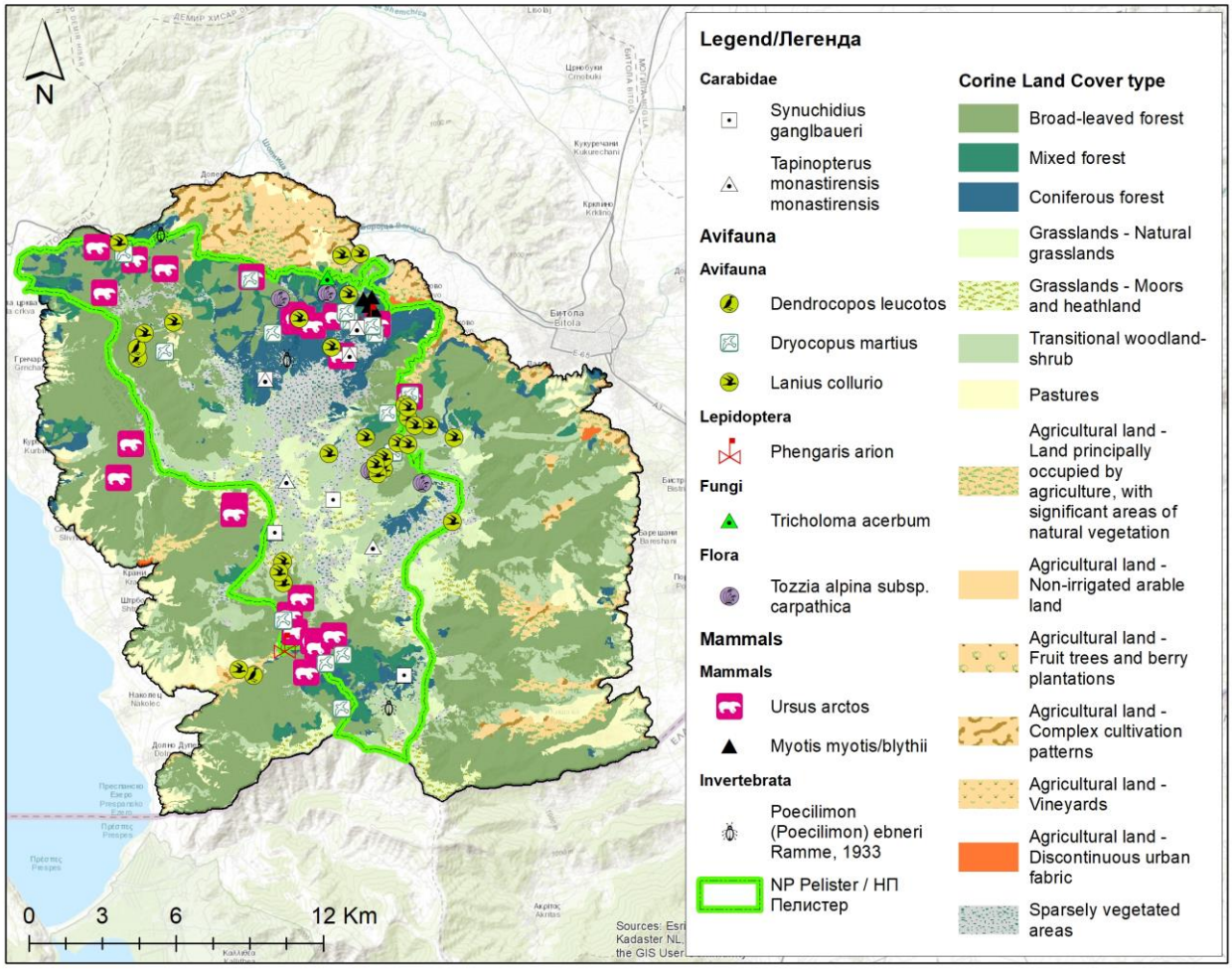


Figure 6. Distribution of selected species in accordance to Corine Land Cover

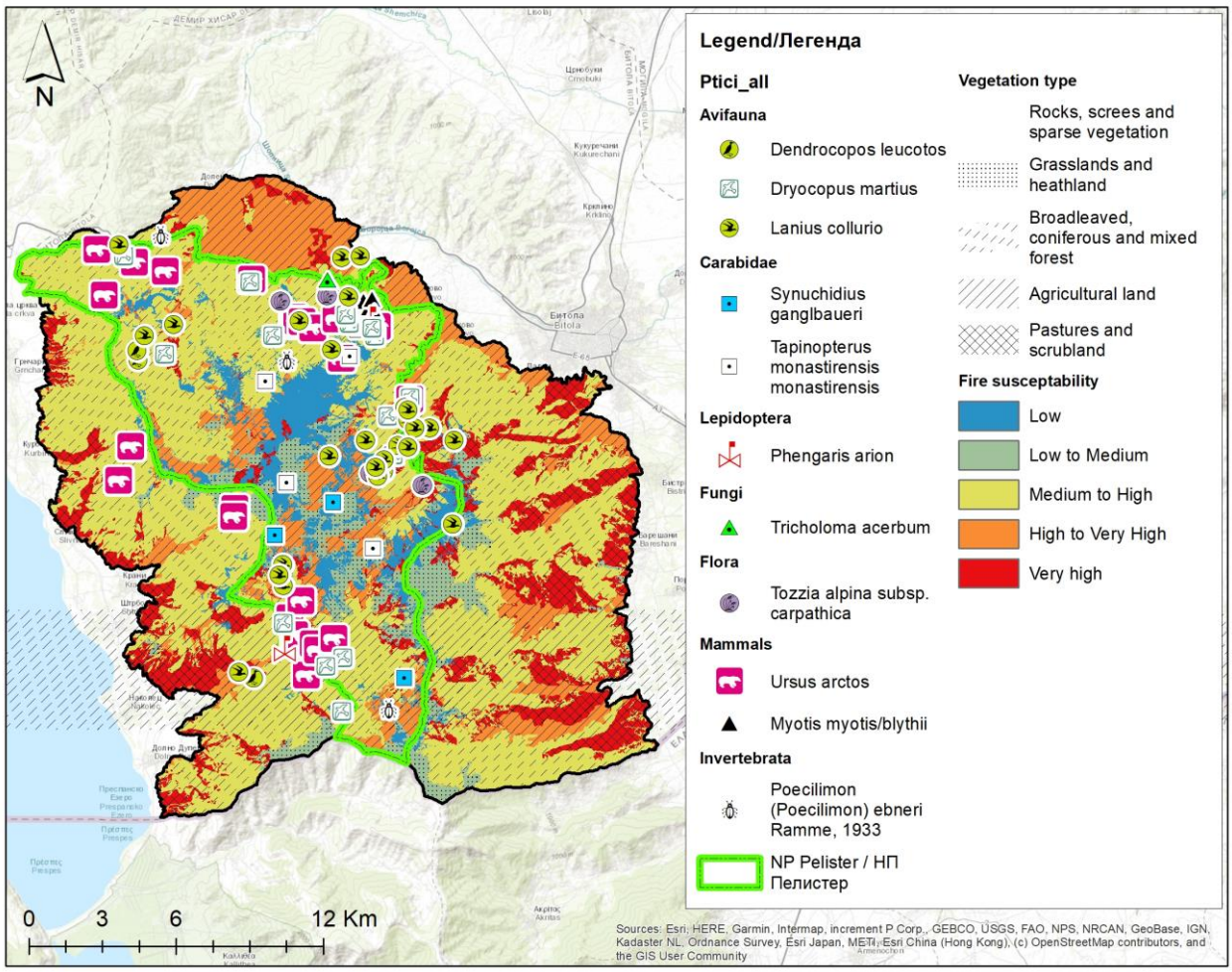


Figure 7. *Distribution of selected species in accordance to fire susceptibility and vegetation type*

5. GENERAL MANAGEMENT ACTIONS AND RECOMMENDATIONS FOR FOREST FIRE PREVENTION AND BEST APPROACHES FOR INCREASING FIRE RESILIENCE

The outcomes of the fire risk assessment are a reference point for further developing management actions and recommendations. These primarily focus on increasing fire resilience by proposing new and improved forest management practices, to be further integrated into the National Park's existing management plan.

Based on the outputs of Fire Risk Index and taking into account fire occurrences and fire severity in NP “Pelister” and adjacent area confined to Pelister Mt. it is recommended to install and maintain fire stations for immediate response in Magarevo, Kazhani and Brajchino villages, but also at Rzhana and L.K. Shiroka. Regular road maintenance is recommended to secure access to sites as presented on Figure 5.

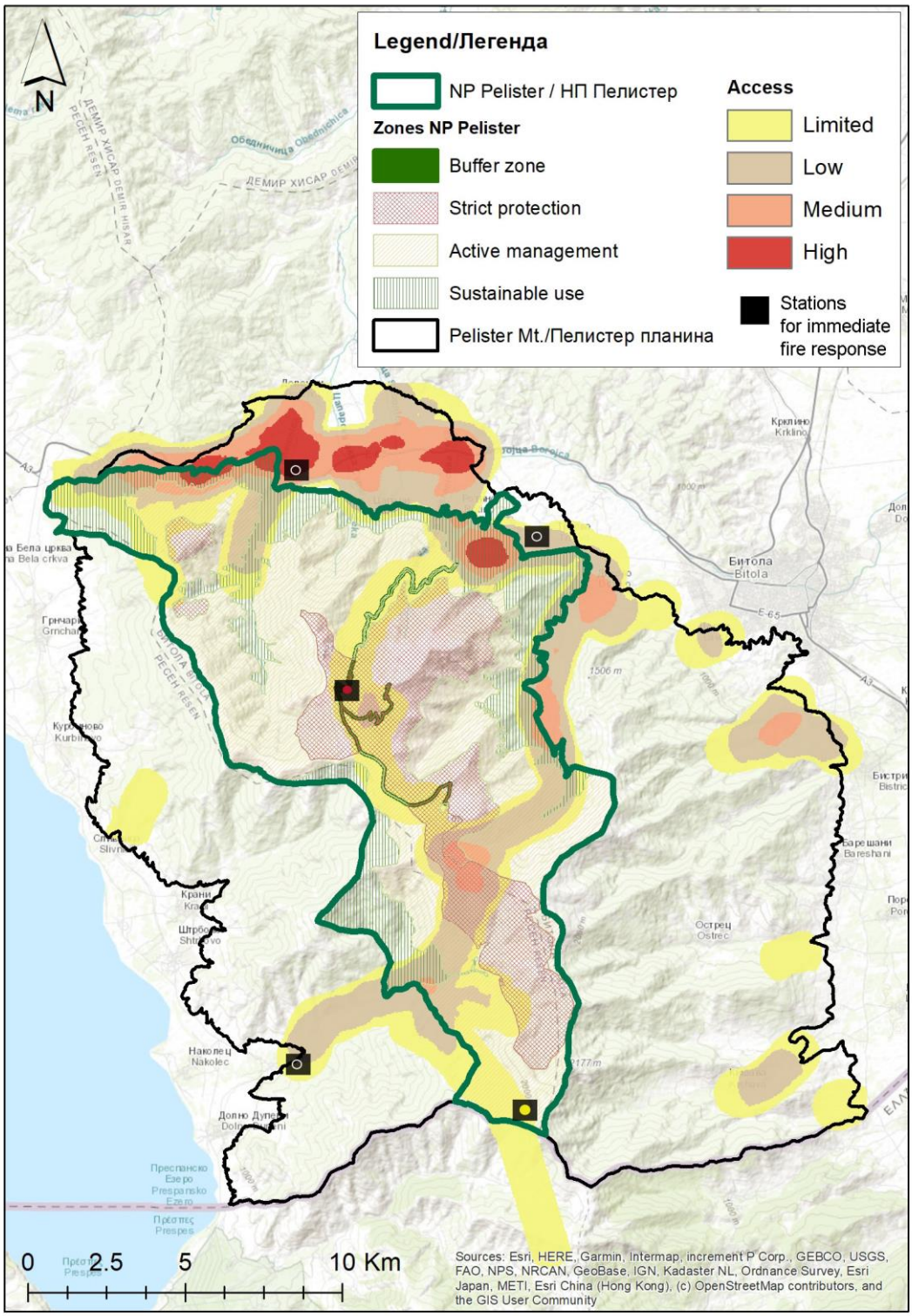


Figure 8. Scheme for maintenance of access roads and stations for immediate fire response (marked with black squares).

Other management actions and recommendations for forest fire prevention should focus on, but not be limited to:

5.1. General Management Actions and Recommendations:

Community Engagement and Education:

- Conduct regular awareness campaigns about the dangers of forest fires and methods for prevention.

  Involves consistently organizing informative initiatives to educate the public about the potential risks associated with forest fires. These campaigns aim to raise awareness about the various causes and consequences of forest fires, emphasizing the importance of preventive measures in order to increase communities' understanding of the critical role they play in mitigating the risks of forest fires.

- Organize community training programs on fire safety and management.

  Designed to provide comprehensive training to community members, equipping them with the necessary knowledge and skills to effectively manage and respond to fire-related emergencies. By conducting hands-on training sessions, workshops, and simulations, participants can learn about crucial fire safety protocols, including proper handling of fire equipment, early detection techniques, and effective fire suppression methods. Moreover, these training programs encourage community members to collaborate and establish coordinated efforts with Park management in addressing fire incidents.

Early Detection Systems:

- Install and maintain a network of early warning systems, including fire detection towers and advanced surveillance technologies.

  Involves setting up a comprehensive network of specialized systems, such as strategically positioned fire response stations and surveillance technologies, designed to detect and monitor potential fire threats in a timely manner. Regular maintenance and monitoring of these systems are crucial to ensure their optimal functionality and reliability, thereby enabling quick response and mitigation in the event of a fire outbreak.
- Employ remote monitoring techniques for timely identification of potential fire outbreaks.

  Employ remote monitoring for timely identification of potential fire outbreaks to continuously monitor and assess the park's extensive geographical area. Use of drones would allow prompt detection of fire hazards, even in remote or inaccessible regions of the park. Timely identification of potential fire outbreaks through remote monitoring allows for swift and targeted response strategies to enhance overall preparedness and strengthen the authority's ability to protect the park's diverse ecosystems.

Collaborative Fire Management Plans:

- Establish collaborative fire management agreements with neighboring landowners and stakeholders.
- Strengthen cooperation with PE "National forests" and foster cooperation among local communities, government agencies, and firefighting organizations.

  Establishing collaborative agreements with neighboring landowners and stakeholders is crucial to enhance park's authorities for a fire response. Such agreements facilitate the coordination of resources and expertise in preventing and managing forest fires. Encouraging cross-border cooperation further strengthens the effectiveness of these efforts, enabling the sharing of best practices, resources, and information across borders. Through joint training programs, mutual aid agreements, and coordinated response strategies, national park authorities and

neighboring stakeholders can work together to develop comprehensive fire management plans that prioritize the protection of biodiversity and natural ecosystems, fostering sustainable conservation practices within and beyond the National park's borders.

5.2. Specific Management Actions and Recommendations

All management activities should be in accordance with the zoning of the National Park "Pelister", i.e. management activities can include careful and minimal actions in the zone of active management and somewhat visible actions in the zone od sustainable development, while taking care that natural values are preserved in both zones, and avoided in the zone of strict protection. This implies that protection of the core zone in the park should rely on preemptive measures undertaken in the two other zones.

Fuel Management (Zone of sustainable development):

- Implement controlled burning and strategic fuel breaks to reduce the accumulation of flammable materials.
- Regularly clear and maintain firebreaks along sensitive areas and infrastructure to minimize the build-up of combustible materials, such as dry vegetation and underbrush, thereby reducing the overall risk and potential intensity of wildfires.

Forest Management Practices:

- Encourage sustainable forestry practices that promote diversity and reduce the prevalence of high fire risk vegetation (zone of sustainable development and zone of active management).
- Prioritize selective thinning and the removal of dead and diseased trees to reduce fire fuel (zone of sustainable development and zone of active management).
- Apply thinning and pruning, ensuring the discontinuation between the ground and crown level, substituting risky species for more resistant ones and introducing or removing certain structural elements according to the site conditions and management goals (zone of sustainable development).

Infrastructure Development:

- Improve accessibility for fire-fighting vehicles by constructing and maintaining well-mapped roads and tracks (zone of sustainable development, buffer zone).
- Install water reservoirs and fire hydrants at strategic locations, preferably underground, under the existing roads, to ensure a readily available water supply for firefighting efforts (zone of sustainable development, buffer zone)

Emergency Response Preparedness:

- Conduct regular drills and exercises to train local firefighting teams in effective response strategies (zone of sustainable development, but all relevant staff should also familiarize with tracks and paths in the other zones as well).
- Develop and rehearse comprehensive evacuation plans for local communities and wildlife in case of an emergency.

Legislative Measures:

- Enforce strict penalties and fines for irresponsible activities that may lead to forest fires.
- Review and update existing fire-related regulations and policies to ensure comprehensive protection and prevention measures.

By implementing these general and specific management actions and recommendations, NP "Pelister" can substantially reduce the risks associated with forest fires, ensuring the preservation of the species and habitats and the safety of local communities.

5.1. Recommendation for data collection, to enable future wildfire modeling and management

Several fire modeling techniques exist, implemented in various software, that enable almost real-time modeling of the wildfires. It seems that most commonly used are the so called "Rothermel modelling system" and Crown Fire Initiation and Spread (CFIS) (Rothermel, 1972, 1991), which can be implemented in open software R using the package firebehaviouR (Ziegler, 2019). Presently, this approach was avoided as data on habitat structure were not readily accessible. Park authorities should in future plan to routinely collect the following information from all forest habitats from several localities in the park (on different altitudes, exposition and relief) so that modeling becomes possible in future.

Following information should be available as input variables for modelling using firebehaviouR functions, and they should be secured in the future.

Variable	Units
Fuel stratum gap	m
10-m Open wind speed	km/hr
Fuel moisture content	%
Canopy bulk density	kg/m^3
Separation distance	m
Basal area	m^2/ha
Average stand tree heights	m
Trees per hectare	trees/ha
Relative humidity	%
Temperature	degrees C
Month	Month of the year (1-12)
Hour	Hour of day (1-24)
Topographic aspect	N, S, W, or E
Topographic slope	%
Heat per unit area	kJ/m^2
Fire rate of spread	m/min
surface fuel load	Mg/ha
Surface area to volume	$m^{2/}m^3$
Fuelbed depth	cm
Moisture of extinction	%
Heat content	J/g
Canopy fuel load	kg/m^2
Wind direction	0-360
Wind adjustment factor	Ratio of 20-ft open wind speed to midflame wind speed
Crown ratio	%
Canopy cover	%

Note that some of these values can be extrapolated from present forestry plans using the built-in functions of the package firebehaviouR, but collecting them purposefully will make the modeling more precise. Once this information becomes accessible for at least one location, preliminary models should be run and eventually NP "Pelister" staff or external partners should be trained to implement the models in R. Respective database will also be needed, and it needs to be developed.

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7. ANNEXES

All GIS layers used for analysis and output files produced during the analysis are submitted to NP Pelister as annexes to this report.