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FOREST FIRE RISK MANAGEMENT INFORMATION SYSTEMS IN MONTENEGRO

SUMMARY

In times of increasingly pronounced climate change, wildfires are among the key threats to forest ecosystems and pose a global environmental and economic problem. Montenegro's forests are particularly endangered due to its geographical position and the increasingly adverse climate effects. Wildfires occur as a causal link between climatic and meteorological conditions, humidity of forest cover, and plant vegetation with social activities in the area concerned (revised Forestry Development Strategy, 2018). Increasing attention is being paid to improving risk assessment and early warning using modern information systems to mitigate the wildfire risk preventively. Research on the capability and capacity of responsible institutions in Montenegro for establishing an information system is particularly important for wildfire risk management. The research showed that Montenegro's capabilities and capacities for risk assessment and early warning of wildfires are limited. The research showed that the system could be improved by establishing a single national wildfire information system. Various forms of early warning and wildfire risk management systems applied, including the Macedonian Forest Fire Information System (MKFFIS), Croatian's Integral Forest Fire Monitoring System (in Croatian IPNAS), and others, have already shown a high level of efficiency. Through a systemic approach, a large part of the tools used by these systems could be realistically developed and subsequently upgraded, taking into account their modularity in terms of software and hardware.

Keywords: forest fires, risk, early warning, information system

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INTRODUCTION

The forests are among the most important natural ecosystems and components on which Montenegro's sustainable development is based. In times of global climate change, wildfires pose one of the key threats to forest ecosystems (Bowman *et al*., 2009), causing economic losses (Bowman *et al*., 2009; Westerling *et al*., 2006; Lohman *et al*., 2007). Only 5% of fires are attributed to natural causes, while 95% are caused by human activities such as negligence (Miguel, 2003). However, investigations of frequent wildfires in unpopulated areas of Canada showed that from 1991 to 2000, there were about 8 000 wildfires per year, of which 48% were started by lightning (Wotton *et al*., 2005). Where there are no people, wildfires have to be caused primarily by natural causes. Furthermore, the role of vegetation is significant, so wildfires link climate characteristics, human activity, and the type of vegetation (Ichoku *et al*., 2003). According to the definition of natural disasters and classification set out in the Annual Disaster Statistical Review of the Centre for Research on the Epidemiology of Disasters (CRED) (Debarati *et al*., 2016:50), wildfires are classified as a group of climatological natural disasters.

Wildfires that burn 200-500 million hectares of land over the year cause damage to larger areas and destroy biomass worldwide more than any other factor (Lavorel *et al*., 2007; Ichoku *et al*., 2008). Thus, the awareness of the damaging effects of wildfire on biodiversity, human health, and the economy is increasing (Lohman *et al.,* 2007). Particular importance is attached to the rising air temperature and relative humidity. Flaming (Flamming *et al*., 2009) claims that wildfires during 2003 were a transient occurrence of what the future will look like and that we can expect more intensive wildfire seasons in the future. Continuous warming will produce greater seasonal contrast, which combined with expected increases of 44% in lightning strikes, will increase burnt areas by 78% over the next 50 years".

Due to the geographical position in the Mediterranean and the increasing adverse climate impacts, Montenegro's forests are particularly vulnerable (Disaster Risk Reduction Strategy, 2017). Wildfires occur as a causal link between climatic and meteorological conditions, relative humidity of forest cover, and plant vegetation with social activities in the area concerned (revised Forestry Development Strategy, 2018).

Montenegro supported United Nations Convention to Combat Desertification (UNCCD) initiative Land Degradation Neutrality Target Setting Process (LDN TSP) in 2016, as a platform for promotion of sustainable land management. LDN TSP resulted in national report containing identification of 15 hotspots and 25 measures with an aim to achieve LDN in Montenegro up to 2030. According to the LDN Report (Land Degradation Neutrality, 2018), main threats and pressures on soil in Montenegro, are urbanization and wildfires.

Even though fires are a highly stochastic phenomenon, Gonzalez *et al*. (2006) have set up a model that can be used in practice. Brown *et al*. (2004) made long-term forecast models for periods (2010-2029, 2030-2049, 2050-2069, 2070-

2089) for the Western United States. International strategies for disaster reduction (ISDR), the Hyogo Framework for Action (2005-2015), as well as the Sendai Framework for Disaster Risk Reduction (2015-2030), highlighted the need for a more comprehensive approach, where efforts would be made to avoid or mitigate the risk before the disaster begins, and today, this proactive concept is recognised and established as a risk management process.

A stable and sustainable risk management system is based on widely-accepted results and proven standards, such as ISO Guide 73:2009 and ISO 31000:2009, which establishes the principles, generic guidelines, and a logical risk management process. It includes five activities: 1) communication and consultation, 2) establishing a context, 3) risk assessment, 4) risk treatment, and 5) monitoring and reviewing activities, which was accepted in Montenegro.

Some common objectives and tasks for carrying out risk assessments, which may be relevant to many, include:

-Develop a risk profile that provides a quantitative analysis of the types of threats the organisation is facing;
-Develop an accurate inventory of available data sets and data resources;
-Provide a rationale for the cost of security measures to mitigate risks and vulnerabilities;
-Development of accurate IT support (software, hardware) and networking;
-Identify, prioritise and document risks, threats, and known vulnerabilities to a related organisation or sector;
-Determining the budget for reduction or mitigation of the risks, exposures and vulnerabilities identified;
-Understanding the return on investment, if the funds are invested in infrastructure or other assets to compensate for potential risks.

Numerous studies describe the risk of wildfire/forest fire as a result of the interaction between the two components - wildfire hazard and vulnerability. Among others, the risks of wildfires are addressed by the European Commission Expert Group on Forest Fires (EC EGFF) in the publication "Basic criteria to assess wildfire risk at the pan-European level" (JRC Technical Report, 2018). The basic wildfire risk components can be illustrated in a simplified manner, as shown in Figure 1. In this context, the wildfire risk components (hazards) concern the likelihood of ignition and spread of wildfire, while vulnerability concerns the susceptibility to damage. The wildfire risk assessment should take into account the most relevant components associated with the wildfire occurrence. To assess when and where the wildfire will cause undesired effects, it is necessary to model also (1) the fire ignition and propagation potential and (2) fire vulnerability (E. Chuvieco *et al*. 2010). Fire risk varies with environmental conditions and characteristics of vegetation types (Servodoni *et al*. 2021). Generally, the factors (triggers) that cause fires can be characterised as external and internal (forest-related). External factors are associated with increased temperatures and droughts, as they predispose fuel to ignition. The internal or forest-related drivers are linked to the forest and vegetation composition and structure, including the topography of the forest location as well as activities affecting the composition of forest trees. The relationship between internal and external factors, which may be significant triggers of wildfires, is illustrated in Figure 2.

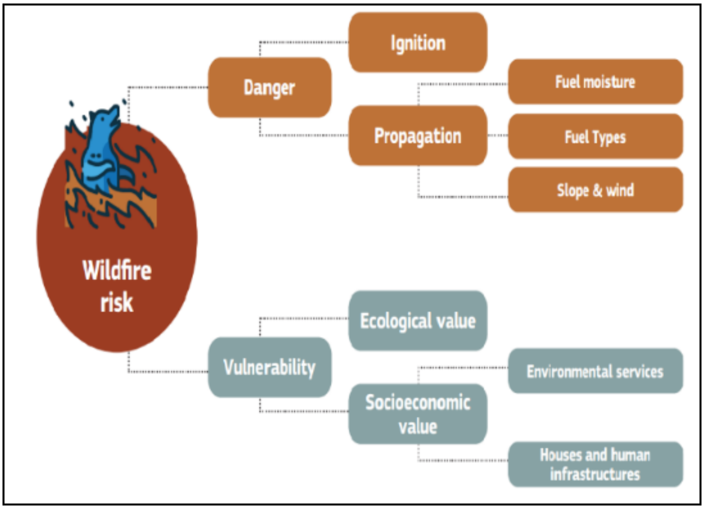

Figure 1. Basic forest risk assessment components (Source: JRC Technical Report, 2018)

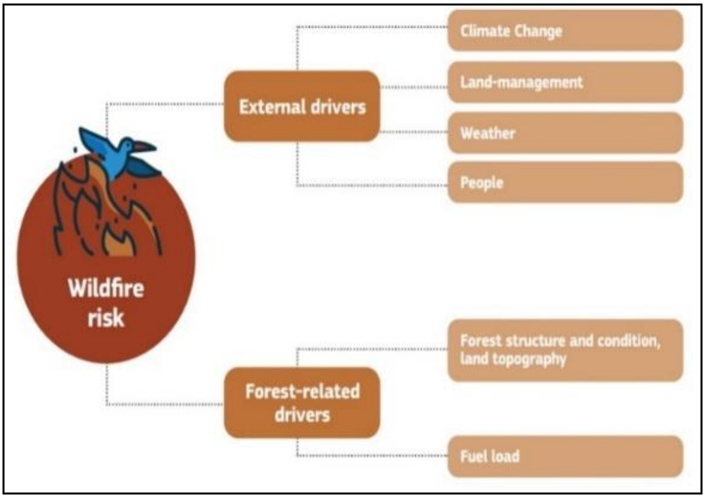

Figure 2. Wildfire risk drivers (Source: JRC Technical Report, 2018)

The development of advanced technologies and programs has enabled the modern methods for wildfire risk component analysis and wildfire effects assessment to find their place in wildfire prevention (Birkmann, 2006; Cardon *et al*.,2012; Kaplan and Garrick, 1981). Accordingly**,** wildfire/forest fire information systems often include dynamic fire risk assessment modules and frequent updates of fire risk components such as fuel distribution, vegetation structure, and moisture content. Furthermore, satellite technology and geographic information systems allow the integration of spatial data layers for the analysis of spatial patterns of wildfire occurrence and the wildfire risk at different scales. Dynamic digital maps have become an important tool to present risks, vulnerability, exposure, and risks. The maps greatly help all participants involved in the assessment work, facilitate the presentation of results, assist in understanding the risks, and visualise risk levels (Servidoni, *et al*. 2021). The following maps can be made to assess the risk of wildfires: 1. Hazard maps, 2. Maps of exposure of the population, critical infrastructure, facilities, etc.; 3. Capacity and capability maps (resources, equipment, roads, etc.); 4. Other information, such as administrative borders, roads, settlements, railways, bridges, other critical infrastructure, etc.; 5. Forest vegetation, protected areas, hydrographic network, basins, topsoil, etc. According to Watts (2002), decisions concerning wildfire risk not only require challenging technical steps to assess the risk of wildfire but, at the same time, require identification of an acceptable risk level, which is more of a task for society than for an engineer.

The wildfire risk assessment is based on the scenario when the wildfire is started, where it will occur, and how it will propagate. The assessment system consists of indices describing the state of the basic hazard components. Since 1947, when the Angstrom Index was established in Sweden, several fire hazard indices have been developed worldwide. Comparison of characteristics of 11 indices (Hahamed *et al*., 2017): Angstrom, Nesterov (N), M-Nesterov (M-N), Keetch-Byram Drought Index (KBDI), modified KBDI, Baumgartner, Canadian Fire Weather Index (FWI), Simple Fire Danger (F), Czech Fire Danger Index (FD), Lebanese Fire Danger (L), shows that the most widely used index is FWI, also used in the Western Balkan region. Furthermore, the modified Angstrom Index is in use in Serbia (Ratknić Tatjana, 2017). In 2004 and 2008, the Institute of Hydrometeorology and Seismology of Montenegro (IHSM), in cooperation with the Sector for Emergency Management and Civil Protection Montenegro, applied the FWI (Fire Weather Index). This method is based on the assessment of the forest fuel flammability index depending on past and current weather conditions. The meteorological elements that affect the hazard are: air temperature, relative air humidity, wind speed, and precipitation in the previous 24 hours. The forecast results were extremely good; however, further work on the forecast was suspended due to a lack of funds.

Such monitoring, risk assessment, and early warning from the meteorological viewpoint are already widely used in practice. At the global level, it is the World Meteorological Organization (WMO), through the World Weather Watch Programme - WWWP and the World Weather Research Programme WWRP, and others. The European Organisation for the Exploitation of Meteorological Satellites - EUMETSAT is an intergovernmental organisation providing its users with weather and climate-related satellite data, images, and products 24 hours a day, 365 days a year. From the aspect of wildfires, the European Commission's (EC) Joint Research Center (JRC), while working to develop and implement advanced methods for assessing wildfire hazards and mapping the burnt areas at the European level, developed the European Forest Fire Information System (EFFIS), which is part of the EU Copernicus programme, under the Emergency Management Service (EMS). EFFIS publishes two indicators providing information on the FWI local/time variability compared to the historical series of approximately 30 years. The EFFIS fire hazard forecast module currently provides access to fire hazard indices using numerical weather forecasts from two deterministic models, i.e. km spatial resolution. EFFIS generally serves the needs of the EU Member States, but non-EU countries can also obtain certain information and services. There is also an initiative to establish a Global Wildfire Information System (GWIS).

In almost all European countries, there are national wildfire information systems. With support from the Japan International Cooperation Agency (JICA), RN Macedonia developed the MKFFIS, which has been functioning successfully for years. Furthermore, most countries have established fire surveillance systems, which include different types of fire detection sensors, CCD smoke detection cameras, infrared (IR) radiometers that detect heat radiating from the fire, IR spectrometers for identification of the spectral characteristics of smoke gases, as well as laser detection systems (LIDAR) that determine the three-dimensional position of the smoke particles with a laser beam, etc.

Numerous analyses and reports (*Izvještaj DRI o reviziji, 2019*) on wildfires in Montenegro show insufficient efficiency of the system and limited capacity in terms of lack of coordination, lack of knowledge of probability assessment, and consequences of the potential hazard, with the emphasis on the fact that the system is not supported by an appropriate information service and database, for the necessary risk assessments, mapping and hazard mapping, and the absence of supervision of the execution of tasks. Accordingly, the DRI's assessment is that Montenegro does not have in place a sufficiently efficient system of protection against wildfires (*Izvještaj DRI o reviziji, 2019*). In this regard, the Government of Montenegro and JICA launched in 2021 the NFFIS project for Montenegro, modelled after the MKFFIS.

The aim of this paper is to explore the existing national information capacities for wildfire risk management, databases, information capacities, coordination, risk assessment procedures, and early warning for wildfire risks in Montenegro.

MATERIAL AND METHODS

Since "MKFFIS is intended as a possible prototype or model for the system whose functions should be achieved by establishing an NFFIS in Montenegro" for this purpose, the research started with the analysis of the content of the online materials available for the MKFFIS (http://mkffis.cuk.gov.mk/broshura/MKFFIS-en.pdf). Since the MKFFIS is a prevention and early warning system for wildfires, it integrates 4 (four) basic modules: (1) assessment of forest fire hazards; (2) assessment of exposure; (3) assessment of vulnerability and losses;

and, (4) assessment of capacity/inventory. In order to gain an understanding of the methodological basis of the MKNFFIS basic modules, a detailed analysis of the material referred to in Chapter 5 was performed, notably item 5.1 "The Methodological setting of the Integrated System for Prevention and Early Warning –of Forest Fires - MKFFIS, Table A) Forest fire risk elements and risk assessment tools and Table C) Data necessary for the creation of tools for the forest fires risk assessment. The results and features of the MKFFIS are presented in Chapter 6 of the MKFFIS brochure. As regards the research of the forest fire surveillance system and early warning system, research and practices in the application of these systems were considered with a focus on the development project, analyses (Stipaničev *et al.*, 2010), and reports on the application of the Integral Forest fire Monitoring System – (in Croatian IPNAS) in the Republic of Croatia.

In order to look at the possibilities for establishing an NFFIS in Montenegro, an analysis of the situation related to forest fire was carried out in three key sectors involved in the NFFIS establishment, which are the Rescue and Protection Directorate as the leading organisation in the disaster risk reduction, forestry institutions responsible for forest management and the IHSM in terms of early warning for potential hazards, as well as an appropriate general analysis of the situation regarding forest fires in Montenegro, including causes, hot spots, damage, history, monitoring, and imaging, etc.

The following methods were used in the research: content analysis, statistical method, and the comparative method. The content analysis method was applied during the analysis of national *(Izvještaj o realizaciji programa gazdovanja šumama, 2011,…; Izvještaj o stanju sistema zaštite, 2010,...)* and international reports (JRC Forest Fires, annual reports) on Forest Fires, climate change, conceptual-normative and other documents (Strategija DRR, 2017). The statistical method was applied to explore the trends of individual risk elements, such as climate change (Pavićević, 2012). The comparative method was applied primarily for the comparison of data obtained by content analysis and statistical method on the forest fire risk elements and the features of the risk assessment and early warning system.

The data sources were publicly available legal normative documents and annual reports of the institutions mentioned above; some data were obtained through a questionnaire - survey in these institutions. In preparing this paper, analysis was carried out with respect to each wildfire risk element and the possibilities of developing appropriate risk assessment tools for the purpose of setting up an NFFIS in Montenegro.

RESULTS AND DISCUSSION

The research showed that the MKFFIS functions as an integrated web platform for communication and information exchange among all relevant actors involved in wildfire prevention and early warning of wildfire hazards. Guided by the risk concept, the methodological setting of the integrated wildfire prevention and early warning system – MKFFIS - provides the designed wildfire risk elements and risk assessment tools, as follows:

1) Wildfires hazard: hot spots map and wildfire history map;

2) Exposure: forest vegetation map and map of forest damage values;

3) Vulnerability: vegetation map and a wildfire weather index map;

4) Capacity: all necessary topographic and other basic maps and data on the resources for the control.

In view of the tools and risk assessment function of the MKFFIS and the data necessary for their creation, the following requirements may be listed for the NFFIS of Montenegro:

1) For the creation of the Hot Spot Map and the Vegetation Dryness Map data from the publicly available or licensed sources through the providers mentioned above, such as EUMESAT with additional engagement or NASA's Fire Information for Rescue Management System (FIRMS) indicating global hot spots in easy-to-use formats;

2) Establish a Fire Weather Index Map; a precondition is a sufficiently dense automated weather stations (AWS) network managed by the IHSM, which will be able to automatically (at certain time intervals) send data on key weather parameters measured (temperature, humidity, wind speed and direction, precipitation) to the central NFFIS (RPD) unit;

3) For the Forest Vegetation Map, the key data supplier should be the forest sector entities, mainly the Forest Administration of Montenegro (FA) and others, as necessary. A precondition for providing quality data on forest vegetation (species, age, diameter, wood volume, slope, etc.) is the existence of a quality National Forest Inventory (NFI), i.e. digitized forestry data, in a specific format and standards;

4) In order to introduce a Fire History Map in the NFFIS Montenegro, there is a need for a consistent process and procedures for preparing fire reports by the Forestry Sector and RPD, and accordingly, this needs to be developed during the NFFIS development process;

5) The existence of a Topographic Map and other basic maps in the appropriate format and quality is also a precondition from a technical point of view, given that NFFIS should be established as an integrated GIS platform. In terms of providing continuous services to the NFFIS in relation to basic maps and other digital base layers, the main source of data should be the Cadastre and State Property Administration (CaSPA) of Montenegro. The CaSPA has recently worked on the development of a digital topographic map at a 1:25 000 scale in collaboration with JICA. Based on this project, a digital topographic map at a 1:25 000 scale was prepared for 70% of the territory of Montenegro, after which the CSPA completed the rest on its own. The following data are maintained on the CaSPA website: Orthophoto for the entire territory of Montenegro (imaging date 2007. pixel size 0.5 m), digital map of Montenegro at a 1:25 000 scale for the entire territory, thematic data including road network, railway network,

watercourses, settlements, facilities, digital terrain model, relief, administrative boundaries, cadastral unit boundaries. The CaSPA Geoportal (www.geoportaluzn.me) was implemented with the following services - view, download, transformation, and invoke;

6) A Map of Forest fire control resources can be a very useful tool to support Montenegro's national forest fire management system. If providers under the MKFFIS are taken as a starting point contributing to the establishment of this tool, it can be concluded that it is a complex function that depends on several factors, highlighting the need for the establishment of resources databases from several national institutions. This model should be a challenge for the RPD and a roadmap for the establishment of a similar system during the NFFIS implementation project in Montenegro.

7) The implementation of the damaged forests value table depends mostly on the available data of the Forest Administration of Montenegro. In other words, the basic precondition for this tool is established procedures and a price list set for all parameters in accordance with the forestry legislation.

Some key findings of the research, which are essential for the establishment of basic NFFIS functions and products in Montenegro, are as follows:

1) Forestry Sector, from a strategic point of view, is governed by the Law on Forests (Zakon o šumama, 2010), the National Forest and Forestland Management Policy *(Nacionalna šumska politika, 2008; Godišnji program gazdovanja šumama, 2013)*, and the Strategy with the Forestry Development Plan for the period 2014-2023 *(Nacionalna šumska strategija, 2014)*, on the basis of which the legal framework and forestry policies were implemented by the competent institutions in this period. The First National Forest Inventory (NFI) was completed in 2011 *(Prva nacionalna inventura šuma Crne Gore, 2013)*, and as regards the methodology, the NFI complies with the EU standards (European glossary for Wildfires, 2012; Council Directive (ECC) no. 2158/92; Risk Assessment and Mapping Guidelines, 2010,) and is compatible with national inventories implemented in Europe. It uses the elements of the systematic sample in cluster form. The distribution of clusters and sample plots is based on a rectangular grid 2 km x 2 km (basic grid), determined by Gauss-Kruger coordinate system, zone 6. For data processing within the FA, an "NFI Analysis Software" was put in place. The NFI program was developed according to the NFI assessment methodology; the program can be used as a standalone application to work with the MS database access platform or to work with the central database and the MS SQL server database. The program also allows connection to GIS platforms to link the NFI data to digital maps. A more detailed technical analysis of this software script should be considered in order to determine the possibility of connecting to the NFFIS as such (source) or with some adaptation/adjustment;

The research has shown differences in the various data records, such as the percentage of forest and forestland using different criteria (Figure 3). As regards the "Forest fire damage and historical records", the FA has so far used a classic method of assessing burnt areas - in field visits, using GPS, it followed the boundaries of the burnt area, and eventually, a model was created where the burnt area in hectares is automatically calculated and shown on the map. Discrepancies are evident in the information from the annual reports of the FA and EFFIS (Table 1).

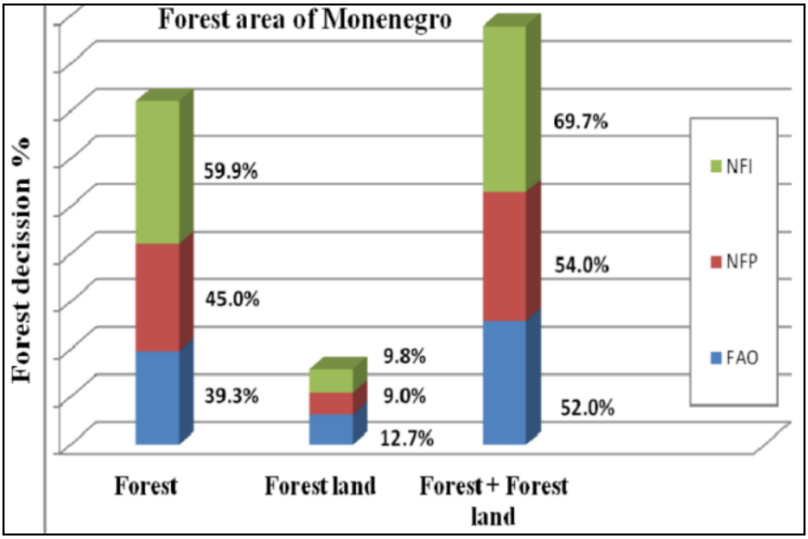

Figure 3. Montenegro's forest cover according to the NFI, NFP and FAO sources

Table 1. Comparative overview of forest fires (2010-2020)

Year	Surface/ha		Difference
	Source EFFIS	Source MFA	
2010	No data	695	/
2011	10 798	49 009	38 211
2012	23 872	11 858	12 287
2013	1 043	171	872
2014	No data	62	/
2015	7 388	3 124	4 264
2016	3 238	1 099	2 139
2017	35 969	21 215	14 754
2018	2 339	3 416	1 077
2019	9 284	1 170	4 641
2020	25 812	4 643	21 169

Source: The authors' own calculations based on the data from the reports of the organisations mentioned above

Despite the significant steps forward it has made thus far, Montenegro lacks a single and well-organised system to monitor and prevent the wildfire risk.

It is necessary to establish a more efficient system of fire protection, monitoring, as well as efficient remediation (Curovic *et al*. 2021).

Setting up the NFFIS would be a great opportunity to increase the overall capacity of relevant stakeholders to effectively manage the wildfire risk, and the NFI provides an excellent basis for this. Further analysis of the FA capacities is needed in terms of their readiness to achieve the necessary preconditions for establishing the process of assessing forest fire damage and losses (clarification of the price list, forest fire recording procedures, method for assessing damage and losses from forest fires, burnt areas, wood volume, etc.).

2) The Institute of Hydrometeorology and Seismology of Montenegro (IHSM), in order to provide the metrological data for the NFFIS functions, currently disposes of 55 meteorological stations, of which 33 automated (AMSs), transmitting the measured data automatically from the field to the central server and 22 classical meteorological stations (CMSs). The automated and classical meteorological stations, operated by the IHSM, measure the meteorological parameters, such as: air temperature, relative humidity, wind (direction and speed), and precipitation, and can be used to create FWI, etc.

Table 2. Overview of the numerical models used by IHMS

	Model 1	**Model 2**	**Model 3**	**Model 4**
Model	Oper 1 WRF-NMM Input data from ECMWF Oper11 WRF-NMM Downscale from oper 1	Oper0, oper2, Oper 22, drownscale from oper 2.	WRFChem v4.1.2 Input data from WCMWF.	NMME-DREAM1 Input data from ECMWF NMME-DREAM11 Downscale from NMME-DREAM1
Resolution (km)	3km; 1km; 0,5km	12km; 9km; 3km	6km; 2km	5km; 2km
Results availability time	00 UTC initialization 8:00UTC, 13:00 UTC 12 UTC initialization 20:00 UTC, 24:00 UTC	00 UTC initialization 5:44 UTC, 4:57 UTC 6:48 UTC, 12 UTC initialization 17:45 UTC, 16:58 UTC, 18:53 UTC	Initialization 00 UTC available: 10:40 initialization 12 UTC, 22:40	NMME-DREAM1 – 10:42 UTC NMME-DREAM11- 15:40 UTC
Max. Forecasted Period (days)	5 days	5 days	3 days	3 days

Source: The authors' own creation based on the data from the reports of the IHMS

The IHSM applies the computer-based forecast and the corresponding numerical models. The computer-based forecast is a direct result of numerical modelling, and forecasters have no subjective influence on it. There are two models of computer-based forecasts in use; input data for Model 1 originate from the NCEP/USA global model, and for Model 2 from the ECMVF global model, as follows: model1 WRF NMM v3.9.1 and model2 WRF NMM v3.9.1. Whereas numerical modelling, or numerical weather forecast, starts from the viewpoint that, knowing the current weather situation, the development of the process can be presented through mathematical formulas and the logical laws of physics. For 20 years, the IHSM has been continuously using the latest numerical models for the weather forecast, the NCEP/USA by Prof. Zaviša Janjić and Prof. Slobodan Ničković, (Eta, NMM-E, VRFNMM, NMMB, EtaDREAM, NMME-DREAM). The characteristics of these "numerical modelling" models can be seen in the Table 2.

The IHSM, in accordance with the Law on Hydro meteorological Affairs in the process of daily (24.7.365) data dissemination from global world meteorological centres, has taken the following:

-6.5 GB k 2 (00.12) + 1.2 GBk2 (06.18) = 15.2 GB data grib1 from ECMVF Reading

-3.2 GB k (00,06,12,18) = 15.2 GB data grib2 from NCEP / USA Washington

-7 GB k 4 (00,06,12,18) = 24 GB grib2 data with ICON DVD Offenbach

These data are extracted from global forecasting models on a daily basis and are used to launch the high-resolution model. High-resolution models WRF NMM a9km, WRF NMM a3km, WRF NMM e3km, WRF NMM e3km, WRF NMM e1km, WAM, Eta-DREAM are being launched daily (24/7/365). The products of these models were available on the IHMS web servers on a daily basis.

At present, the IHMS does not use satellite data to produce products similar to those produced by the MKFFIS. Regarding the NFFIS establishment objectives in Montenegro and the need to access certain products serviced by the EUMETSAT, it is important to note that Montenegro is not yet a full or associated EUMETSAT member. Therefore, Montenegro has only limited access to the EUMESAT products and services based on the DAWBEE project. The research showed that for some time, the IHMS was calculating FWI, but not currently, which is why it is necessary to take measures to establish this function.

3) Rescue and Protection Directorate (RPD), as the main pillar of the national disaster risk mitigation system, should have a central position within the NFFIS Montenegro, which means that the PRD would be the location of the NFISS central server unit and the institution that will assume responsibility for the administration and maintenance of the entire system. The research on the RPD organisation and capacity showed that in its current organisational structure, the RPD has a 112 Unit or an Operational Communication Centre (OCC) within which there are certain capacities in terms of server installations and other IT equipment, but of course, the NFFIS' needs have to be assessed in a comprehensive manner, as well as human resources and technical strengthening.

Therefore, as regards the introduction of some functions in the NFFIS, from a technical point of view, it is recommended that for some products, it would be best to take the same approach/concept used in the MKFFIS, such as the technology of publishing the hot spots map and the vegetation dryness map, using the channels of the EUMETSAT network and other satellite channels. To establish a sustainable and operational NFFIS, it is essential that this system is included in the appropriate regulatory framework of the institutions, which are the key JICA project partners (RPD, IHSM, and FA).

Over the past few years, the early warning systems for forest fires in the Mediterranean region, but also further, have been increasingly relying on technical and electronic surveillance from the ground, which is already showing a significant improvement in the early warning system. In the forest fire seasons in 1999 and 2000, Germany tested the “Autonomous Early Warning System For Forest Fires” (AVFS). In a test area of about 800 km^2, 45 forest and field fires occurred, all detected and identified by the AVFS within the prescribed deadline, even earlier than by experienced observation staff, and the software false alarm rate was below 1%, the operator can deal with easily (Kührt E., Knollenberg J., Mertens V., 2001). Croatia has developed its own Integral Forest fire Monitoring System – the IPNAS, which is an integrated and intelligent forest fire monitoring and observation system based on video cameras in the visible and/or infra-red part of the spectrum. The IPNAS is a modular system in terms of both hardware and software. Hardware modularity allows it to easily add new camera observation locations. Software modularity allows it to easily add completely new functionalities. The IPNAS is not only a fire detector but an advanced, integrated and intelligent fire monitoring and observation system that can be used as a fire detector system but also as an advanced system for remote video presence. It is an integrated system because it is based on the fusion of different data types (video signals, weather data, and GIS information), and intelligent because it is designed on the knowledge of artificial and computer intelligence.

Table 3. Overview of wildfire damage for the period 2016-2020

	Burnt area (ha)	**Number of wildfires**	**Wood volume burnt (m3)**	**Crops burnt (plantings)**	**Damage (€)**	**Fire extinguishing costs (€)**
2016	1 100	73	24 334	/	66 834	1 560
2017	21 216	154	142 629	/	1 794 553	3 440
2018	3 417	18	132	6 200	3 660	760
2019	1 170	82	26 738	68 260	329 307	8 920
2020	4 644	220	39 013	0	1 434 870	1 220
TOTAL	31 547	547	232 846	74 460	3 629 224	15 900

Source: The authors' calculations based on annual reports from the Forest Directorate

The financial aspect is also important for the establishment of such systems. The cost of the entire system of 56 observation stations and 10 operating centres, which are being implemented in several stages throughout the Split Dalmatia County, amounts to around €2.1 million, which is only 2.5% of the officially estimated damage from wildfires in 2003 in this County (about €66 million), so investing in such systems, though they cannot reduce the number of fires, but can significantly reduce the fire damage, is justified and useful (Stipaničev, D. *et al*., 2010).

The French project PRODALIS (Motorola Case Study, 2008), implemented in 2008 on the Atlantic coast of France, showed that a system of 14 firefighting video observation units weekly detected more than 90 burn-offs that were illegal in the fire season, so in this way, the firefighting video surveillance system provides a direct weekly income of more than €8 000. (Motorola Case Study, 2008). The official data from the Forest Directorate of Montenegro show that direct damage from wildfires for the period 2016 to 2020 was €3 629 224 (Table 1), while the damage for 2012 alone on 11 858 hectares of burnt area was €4 268 099, and in 2011, as many as 49 009 hectares of burnt areas, but financial indicators were not available. There are also the costs for the engagement of observers of EUR 18 000 only for August each year (annual management programme of the FA).

CONCLUSIONS

The practice and numerous analyses after the fire seasons have shown that Montenegro still lacks an efficient system of protection against wildfires, which primarily relies on its fire response ability. The research has shown that the development of information technologies has significantly improved the capabilities of the early warning system and efficient wildfire risk management. The efficiency of numerous national and global systems has already been confirmed, which imposes the need to pay particular attention to this issue in Montenegro.

The research showed very high possibilities for software solutions for numerical and mapped MKFFIS products for efficient wildfire risk management. The analysis of the capabilities and capacities in three key institutions in Montenegro for the NFFIS establishment showed that certain information segments for automated risk assessment were developed but were not systematised or sufficiently supported by IT, and the capabilities and capacities could be considered underdeveloped. With a systematic approach, most of the tools could be developed realistically and other MKFFIS tools could be developed under additional projects, which would significantly improve the system of protection against wildfires. The cost-effectiveness and efficiency of the systems for the early detection of wildfires, such as the IPNAS, are realistically applicable in Montenegro, considering its geographical and climatic characteristics. As these systems are modular in terms of software and hardware, they can be combined and complemented. Montenegro's accession to the European Union and other forms of cooperation also impose the compliance of this system, so the pilot projects implemented should not be in collision with the NFFIS but complementary to it. The cost analysis showed that for some years (2012), direct financial damages were higher than the price of such systems for the whole of Montenegro.

With the current issues of unsystematised data, procedures, risk assessments, and early warning, it is unlikely to expect more effective prevention of wildfires. On the contrary, they will become increasingly frequent due to current climate trends and cause more damage, especially in marginalised and inaccessible areas. Without a decisive policy shift and clearly defined objectives to improve the risk management system and its use, significant progress in preventing forest fires can hardly be expected. The establishment of NFFIS, whose significance is becoming increasingly apparent, could provide a solution to many problems in mitigating the risk of disasters in the forest sector, i.e. in the protection against wildfires in Montenegro.

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