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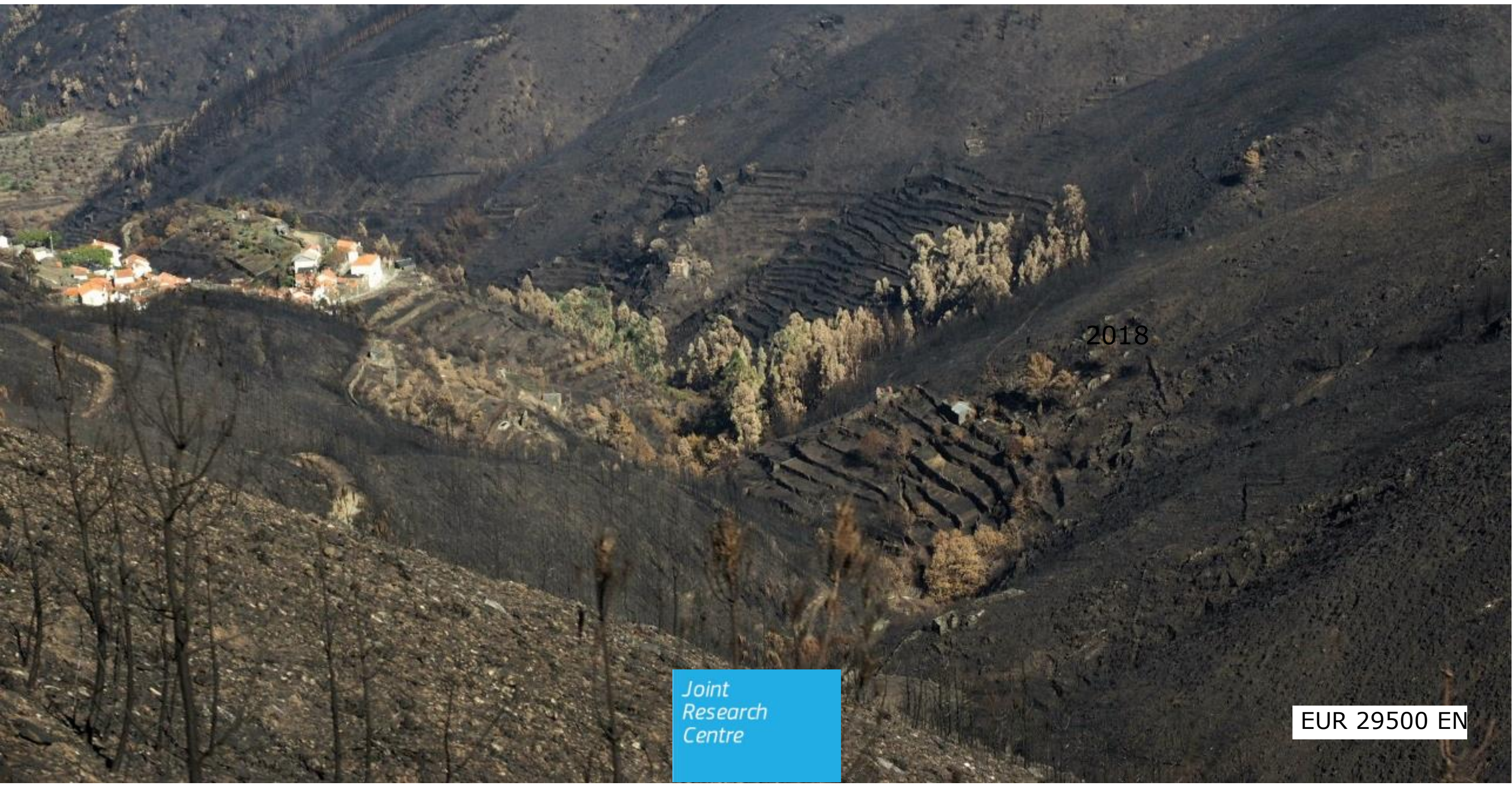
Basic criteria to assess wildfire risk at the pan-European level



2018

Joint Research Centre

EUR 29500 EN

"Basic criteria to assess wildfire risk at the pan-European level" is a report published by the Joint Research Centre in collaboration with other Directorate Generals of the European Commission, including DG ENV, and the national wildfire administrations of the countries in the Expert Group on Forest Fires (see list of contributors).

Contact information

Address: Joint Research Centre, Via Enrico Fermi 2749, TP 261, 21027 Ispra (VA), Italy
Email: JRC-EFFIS@ec.europa.eu
Tel.: +39 0332 78 6138

JRC Science Hub
https://ec.europa.eu/jrc

EUR 29500 EN
PUBSY No. JRC113923

Print	ISBN 978-92-79-98201-9	ISSN 1018-5593	doi:10.2760/228736
PDF	ISBN 978-92-79-98200-2	ISSN 1831-9424	doi:10.2760/052345

How to cite this report: Jesús San-Miguel-Ayanz, Hugo Costa, Daniele de Rigo, Giorgio Libertà, Tomàs Artés Vivancos, Tracy Durrant, Daniel Nuijten, Peterl Löffler, Peter Moore *et al*. 2018, Basic criteria to assess wildfire risk at the Pan-European level. EUR 29500 EN, ISBN 978-92-79-98200-2, doi:10.2760/052345

Title Basic criteria to assess wildfire risk at the pan-European level

Abstract

This report present basic criteria that could be used for the estimation of wildfire risk at the pan-European level. The report has been elaborated in consultation with the national experts in the Expert Group on Forest Fires and represents a first attempt on establishing critical variables that may help in characterizing areas in the pan-European region on the basis of their susceptibility to suffer damage caused by wildfires.

Authors – European Commission & International Organizations

DIRECTORATE GENERAL JOINT RESEARCH CENTRE

Directorate E: Space, Security & Migration
Disaster Risk Management

Jesús San-Miguel-Ayanz[1]

Hugo Costa[1]

Daniele de Rigo[2]

Giorgio Libertá[1]

Tomas Artés Vivancos[1]

Tracy Durrant[3]

DIRECTORATE GENERAL ENVIRONMENT

Directorate D1: Natural Capital
Land Use & Management

Daniel Nuijten[4]

Peter Löffler[4]

UNITED NATIONS FOOD AND AGRICULTURE ORGANIZATION (FAO)

Peter Moore[5]

1 European Commission, Joint Research Centre (JRC),
Ispra (VA), Italy

2 External consultant for the European Commission
ARCADIA SIT s.r.l, Vigevano (PV), Italy

3. External consultant for the European Commission
GFT Italia s.r.l, Milan (MI), Italy

4. European Commission, Directorate General Environment,
Directorate D: Natural Capital, Land–Use and Management
Brussels, Belgium

5. Forest Fire Management & Disaster Risk Reduction
FAO-Forestry Department, Rome, Italy

Authors – Expert Group on Forest Fires

Belgium	Jan BAETENS	Ghent University
Bulgaria	Vladimir KONSTANTINOV	Executive Forest Agency
France	Yvon DUCHE	Organization National d'Foret
	Philippe JOANNELLE	Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, DGPAAT
Hungary	Peter DEBRECENI	National Food Chain Safety Office, Forestry Directorate
	Dániel NAGY	
Israel	Avi Ben ZAKEN	Fire and Rescue Commission
		Ministry of Public Security
Lebanon	George MITRI	University of Balamand
Morocco	Fouad ASSALI	Service de la protection des forêts (Haut-Commissariat aux Eaux et
	Hicham MHARZI ALAOUI	Forêts et à la Lutte Contre la Désertification)
Poland	Joseph PIWNICKI	Forest Research Institute
	Ryszard SZCZYGIEŁ	Forest Fire Protection Department
Portugal	Rui ALMEIDA	Instituto. de Conservaçao da Natureza e das Florestas
	Miguel CRUZ	Civil Protection Authority
Romania	Septimius MARA	Ministry of Waters and Forests
Russia	Andrey ERITSOV	Russian Aviation Agency
Sweden	Leif SANDAHL	Swedish Civil Contingencies Agency (MSB)
		Resilience Development and Analysis Department
UK	Andy MOFFAT	Forest Research UK
	Robert GAZZARD	Forestry Commission, UK

Reviewers – Expert Group on Forest Fires

Algeria	Abdelhafid BENCHIKHA	Direction Générale de la Protection Civile
	Mohamed ABBAS	Direction Générale des Forêts
Cyprus	Kostas PAPAGEORGIOU	Ministry of Agriculture, Rural Development and Environment
	Ioannis TOUMASIS	Department of Forests
Greece	Kleanthi PAVLIDOU	Ministry of Environment and Energy; Directorate General for the Development and Protection of Forests and the Rural Environment
Ireland	Ciaran NUGENT	Forest service, Department of Agriculture, Food and the Marine (DAFM)
Italy	Marco di FONZO	CUTFAA Comando Carabinieri per la Tutela Forestale
Norway	Dag BOTNEN	The Norwegian Directorate for Civil Protection (DSB)
Spain	Elsa ENRIQUEZ	Ministry of Agriculture and Fisheries, Food and Environment
	Antonio LOPEZ	Forest Fire Spanish Service
Turkey	Kamil Tolgay DURSUN	General Directorate of Forestry In TURKEY
	Ugur BALTACI	

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2 Introduction

Wildfire risk assessment is fundamental for developing prevention, mitigation and preparedness plans. Every country has a customized approach to assess wildfire risk, which varies widely among them (San-Miguel-Ayanz *et al*. 2003). Normally those countries more often confronted with wildfire events are better prepared, and elaborate wildfire risk maps. However, harmonized procedures for wildfire risk assessment are needed in the context of the pan-European region to better coordinate actions to alleviate the damaging effects of wildfires. The main objective of this report is to describe available datasets that may be used to have a standardized approach to assess wildfire risk at the pan-European level.

2.1 Work on forest fires in the context of EFFIS

The work of the Commission of forest fires started many years ago, in the context of Reg. 2158/92.

The European Forest Fire Information System (EFFIS) was established jointly by the European Commission services (DG ENV and JRC), the relevant fire services in the EU Member States, other non-EU European countries and Middle East and North African countries (Forest Services and Civil Protection services). In 1998, the Expert Group on Forest Fires (EGFF) was established in connection with the development of the European Forest Fire Information System (San-Miguel-Ayanz *et al*. 2013b). Research activities for the development of the system initiated at JRC in 1998 and the first EFFIS operations were in the year 2000.

In 2003, EFFIS was embedded in the new Regulation (EC) No 2152/2003 (Forest Focus) of the European Council and Parliament on monitoring of forests and environmental interactions until it expired in 2006. Since then, EFFIS has operated as a voluntary system of information on wildfires until 2015, when it became part of the EU Copernicus program, under the Emergency Management Services. Currently there is no EU legislation regarding forest fire protection.

Acting as the focal point of information on forest fires, EFFIS supports the national services in charge of wildfire management. Currently, the EFFIS network is made up of 41 countries in Europe, Middle East and North Africa. EFFIS provides specific support to the Emergency Response Centre (ERCC, formerly Monitoring and Information Centre: MIC) of Civil Protection as regards near-real time information on wildfires during the fire campaigns, and assists other DGs through the provision of both pre-fire and post-fire information on wildfire regimes and impacts. It provides information that supports the needs of the European Parliament with regards to wildfire management, impact in natural protected areas and harmonized information on forest fires in the EU.

EFFIS also centralizes the national fire data that the countries collect through their national forest fire programs in the so-called EFFIS Fire Database (Camia *et al.* 2014). The EFFIS web services[1] allow users to access near-real time and historical information on wildfires in Europe, Middle East and North Africa.

EFFIS provides a continuous monitoring of the fire situation in Europe and the Mediterranean area (San-Miguel-Ayanz *et al*. 2012), and regularly sends updates to EC services during the main fire season. The information about the on-going fire season is continuously updated on the EFFIS web site (up to 6 times, daily), which can be interactively queried[2]. EFFIS provides daily fire danger maps and forecasts of fire danger for up to 10 days in advance, updated maps of the latest active fires, wildfire perimeters and post-fire evaluation of damage.

Every year, an annual report on "Forest Fires in Europe, Middle East and North Africa" is published by the JRC and authored by Commission services and the experts in the Expert Group on Forest Fires (EGFF). The latest of these reports is the "Forest Fires in Europe, Middle East and North Africa 2017" (San-Miguel-Ayanz *et al*. 2018).

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[1] http://effis.jrc.ec.europa.eu
[2] see http://effis.jrc.ec.europa.eu/current-situation

2.2 The Expert Group on Forest Fires: role and components

The Expert Group on Forest Fires (EGFF) was set up in 1998 in relation to the initial activities on the establishment of a European Forest Fire Information System (EFFIS) coordinated by DG ENV and JRC. It is now established as a sub-group of a wider Commission Expert Group on Forest Information and is co-financed by ENV/JRC/GROW as part of the EFFIS Work Program under Copernicus. The EGFF is managed by DG ENV and co-chaired by DG ENV/JRC.

The EGFF has several advising roles as regards forest fires in cooperation with the European Commission. In a nutshell, the EGFF role is:

- Contribution to the conception and development of the European Forest Fire Information System (EFFIS).
- Contribution to the harmonization of data/information in the EFFIS fire database (fire event information reported by the countries – over 2 million records from 26 countries).
- Contribution to sustainable forest management and exchange of information to increase forest resilience
- Contribution to the design and usage of EFFIS information, exchange of information on lessons learned on the entire fire cycle, from prevention to restoration, and discussion and posting of good forest fire prevention practices.
- Contribution and drafting of a yearly report on forest fires in Europe, Middle East and North Africa (2000-2016).
- Contribution to the development of the Forest Information System for Europe (FISE) through the development and maintenance of the European Forest Fires Information System (EFFIS).

The EGFF includes not only EU countries, but also other European non-EU countries, and countries in the Middle East and North Africa. The extension of the EGFF to Middle East and North African countries was implemented in collaboration with the United Nations Food and Agriculture Organization (UN FAO) Silva Mediterranea network. Figure 1 shows the countries that are in the EGFF. In blue are the EU countries, in green are the non-EU European countries and in red the countries in Middle East and North Africa.

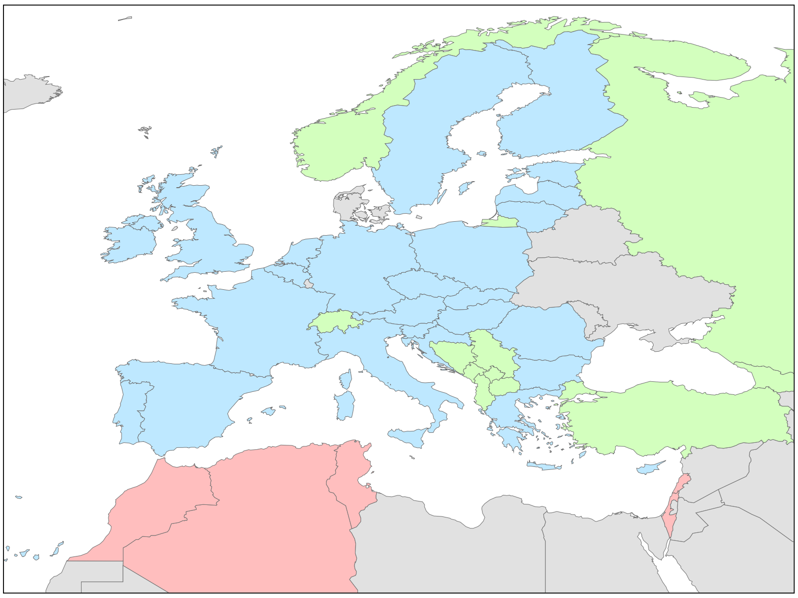

Figure 1. Map of countries in the EGFF – EFFIS Network

Currently, the EFFIS network constitutes 41 countries, including 25 EU Member States (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, the Netherlands and the United Kingdom), 10 European non-EU countries (Albania, Bosnia & Herzegovina, former Yugoslavian Republic of Macedonia, Georgia, Kosovo, Montenegro, Norway, Russia, Serbia, Switzerland and Turkey), and 5 MENA countries (Algeria, Israel, Lebanon, Morocco and Tunisia).

The EGFF meets normally twice every year, in Spring for the preparation of activities related to the forthcoming wildfire season and in Autumn, for the evaluation of the fire campaign and the analysis of the actions taken on fire prevention and fire fighting in the year. In particular, the tasks assigned to the EGFF are to:

- Provide annual fire event data to the European Forest Fire Information System (EFFIS)
- Contribute to 'Forest Fires in Europe, Middle East and North Africa' report
- Provide an annual ex-post review of forest fire season during the autumn meeting
- Work on common criteria/ harmonized approaches for forest fire risk assessment (2018) following ECA's 2014 report.
- Provide recommendations for EU support for effective forest management and land use measures for fire prevention (2018).

2.3 Steps in producing this report

The first consultation with EGFF on wildfire risk assessment at the pan-European scale took place at the 36th meeting of the EGFF, on October 2017. At that occasion, the JRC presented a basic approach that could eventually be used for that purposed on the basis of the recently published chapter on Wildfires (San-Miguel-Ayanz *et al*. 2017), within the Science for Disaster Risk Management 2017 report (Poljanšek *et al*. 2017).

The next consultation occurred at the 37th EGFF meeting, on April 2018. At this meeting, it was decided to organize sub-groups on the EGFF to work on two important topics for both the countries and the European Commission. One sub-group would work on the potential elaboration of wildfire risk assessment at the pan-European scale, while a second sub-group would focus on providing guidance for wildfire prevention activities.

A dedicated meeting of the EGFF subgroup on wildfire risk assessment took place at JRC on June 2018. The results of this meeting were presented and discussed at the 38th EGFF meeting on November 2018. The current report represents the agreement on basic criteria for wildfire risk assessment reached at this meeting.

3 Wildfire risk assessment

3.1 Examples of national wildfire risk assessments

National risk assessment is conducted in many countries in the world using different variables and diverse methodologies (San-Miguel-Ayanz *et al*. 2004). The approaches used in this process differ among countries and are fitted to the specific conditions and data availability in each country. Often wildfire risk assessment is conducted at sub-country level, as in the case of countries with disaggregated administrations such as Germany, Spain, Italy.

3.2 A pan-European approach to wildfire risk assessment

Existing literature in the assessment of wildfire risk at national or European level reveals that the number and type of variables that can be included in this assessment is very broad (Sebastian-Lopez *et al*. 2008). Some attempts to estimate wildfire risk were conducted by the JRC in the past, on a research basis (Sebastian-Lopez *et al*. 2002).

The JRC published in 2017 the Science for Disaster Risk Management 2017 report, which includes a specific chapter on the discussion of wildfires and the assessment of wildfire risk. The approach used in this report follows the recommendations in the previous report (San-Miguel-Ayanz *et al*. 2017), which defines wildfire fire risk as the combination of wildfire danger and vulnerability. The proposed approach further simplifies some of the variables in the model to accommodate them to the available information at the pan-European level.

The following sections describe the different datasets that can be considered as basic criteria for wildfire risk assessment at the pan-European level. A pre-requisite for the data is the availability of the data for the pan-European region. In some cases, the data covered most of the region of interest and may be complemented by national datasets that are assimilated to the European dataset in terms of format and information content. The scheme proposed in terms of data structure contributing to the assessment of wildfire risk analysis is presented in Figure 2.

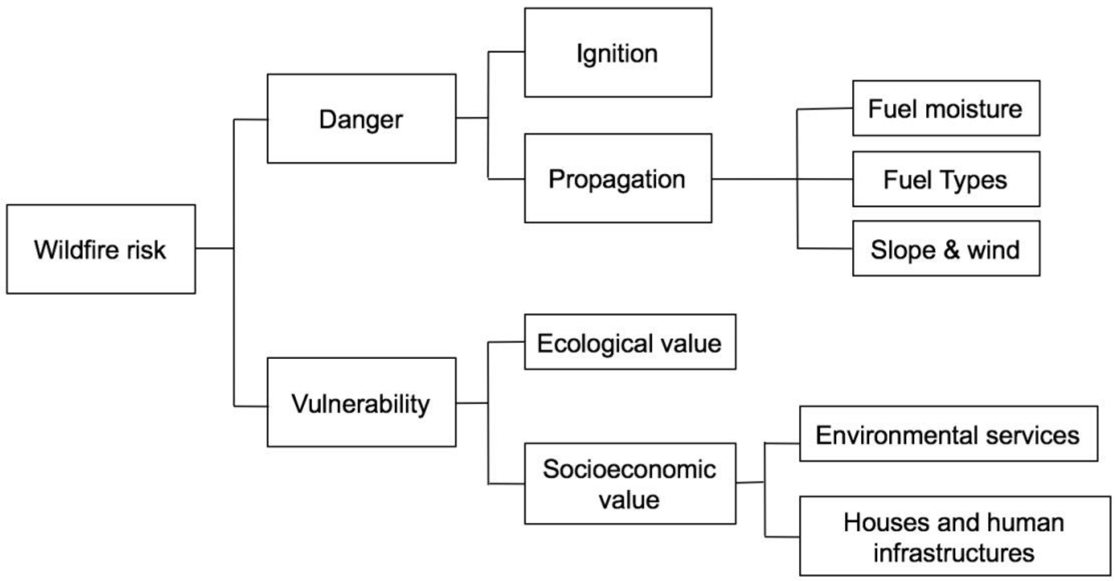

Figure 2. Basic components of wildfire risk assessment.

3.3 Wildfire danger

Often, wildfire danger is understood as the assessment of the conditions under which a fire can be ignited and would spread. Sometimes this is also referred to as fire hazard. There are indices, such as the Fire Weather Index (FWI), that provide a direct assessment of fire danger due to weather conditions. Long-term series of FWI data can be used as an explanatory variable in the assessment of wildfire risk assessment at the pan-European level. Figure 3 shows areas in which high FWI conditions are frequent in the region.

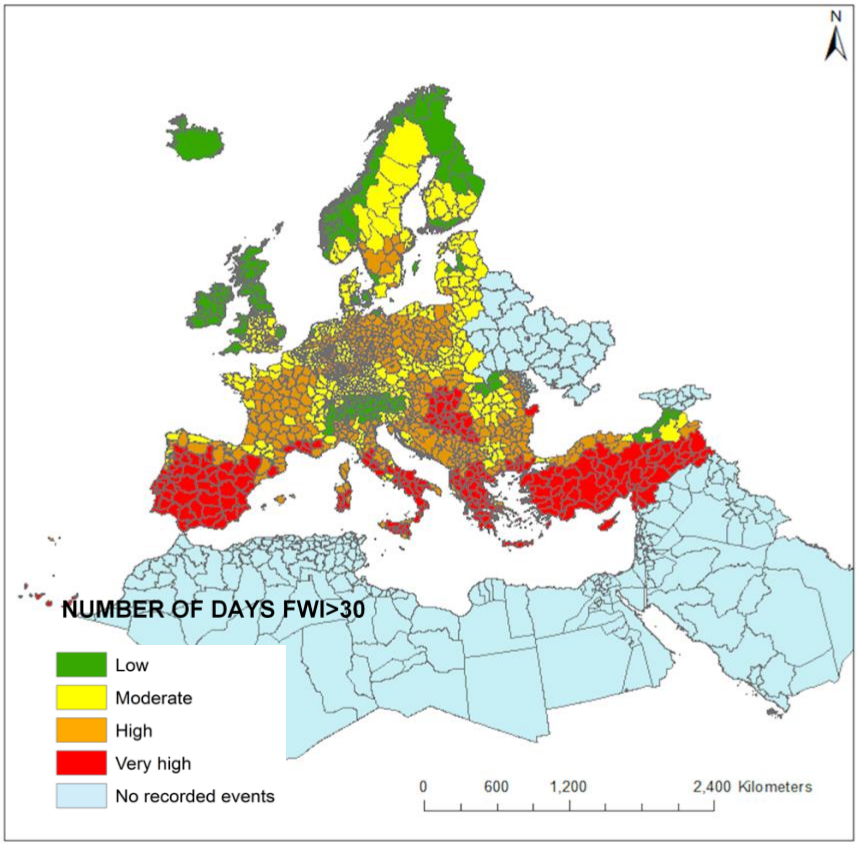

Figure 3. Frequency of days with high fire danger (Fire Weather Index greater than 30: ERA-Interim reanalysis).

3.3.1 Wildfire ignition

An increase in fire ignitions may lead to the simultaneity of many fire events and increase the likelihood of fires to spread and to become uncontrolled fires, which can cause substantial damage under favorable environmental conditions for fire growth. Historical records on the number of fires may be used to assess the contribution of fire ignition to fire risk. The number of ignitions, next to other key factors such as fuels, weather, are used to characterize fire behavior and thus fire danger (Finney, 2005)

Historical records of number of fires are available through the EFFIS Fire Database (Camia *et al*. 2014) for 26 countries in Europe, Middle East and North Africa. In addition, the 18-years of records on the number of fires of approximately 30 ha or larger derived from satellite imagery are available in EFFIS and can be used as a complementary database.

Previous studies have considered the causes of fire ignition as a relevant factor for fire risk assessment (Figure 2), namely anthropogenic (e.g. accident, arson), and natural (lighting). However, approximately 95% of the fires in Europe are human-caused (Ganteaume *et al* 2013), and hence the importance of knowing or modelling the causes of fire ignition fades in the context a large-scale assessment. Furthermore, information of fire causes does not exist for many countries. In view of the overall scope of the present study, causes have been excluded as one of the explanatory variable for a pan-European risk assessment.

An example of the number of fires in EFFIS for the period 2000-2017 is presented in Figure 4.

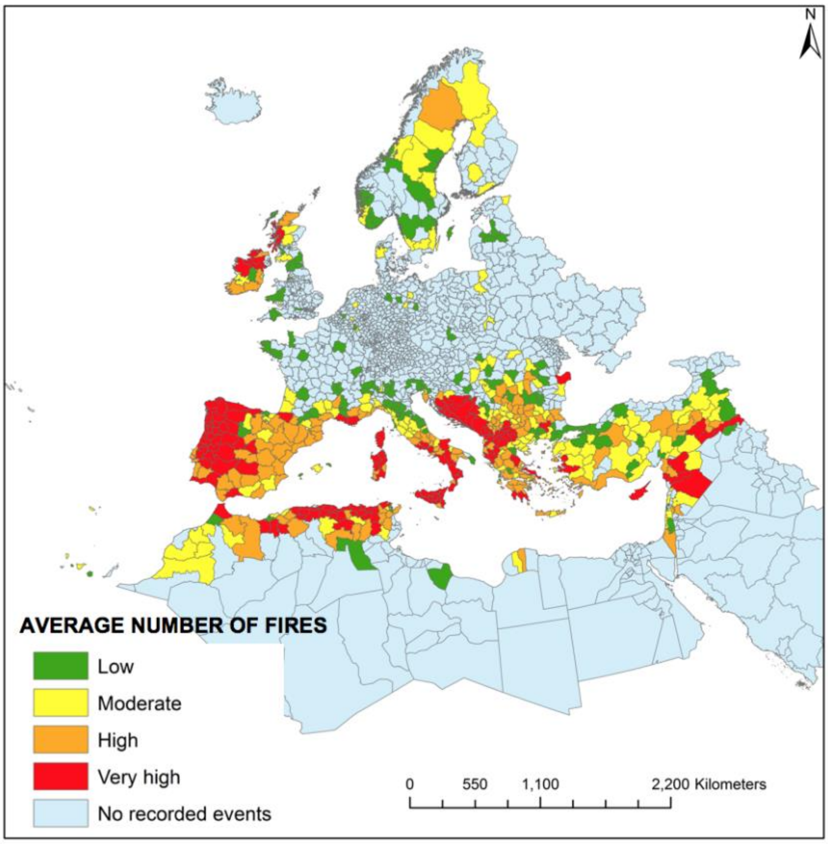

Figure 4. Average number of fires mapped in EFFIS, classified in 4 categories, for the period 2000-2017.

3.3.2 Wildfire propagation

3.3.2.1 Fuel Moisture content

Moisture content of fuel is a fundamental element for wildfire spread, as dry fuels burn easily and provide favorable conditions for wildfire propagation (Van Wagner, 1987; Yebra *et al*. 2013) The fuel moisture content fluctuates in time and space and is highly dependent on weather conditions.

Measuring vegetation moisture content is not possible in practice over large areas. However, fuel moisture can be modelled via fuel moisture indexes derived from weather data. Such an approach is common practice in fire-related fields, such as wildfire research and management. Common indices used for assessing vegetation moisture content are the components of the Fire Weather Index (FWI). The FWI was developed in Canada (Van Wagener, 1987) but has been proven suitable for European conditions (Viegas *et al*. 1999). The FWI is made of a set of components derived from weather data such as temperature, wind speed, relative humidity, and precipitation. The various components are used to derive the 3 sub-indices of the FWI-system, which are aggregated into a single index, the Fire Weather Index (FWI) (Figure 5). The FWI is currently used in the European Forest Fire Information System and has been widely adopted by many European countries as a best approach to assess wildfire danger (San-Miguel-Ayanz *et al*. 2018). FWI are computed from numerical weather predictions from the European Center for Medium-Range Weather Predictions (ECMWF) at a spatial resolution of ~9 km.

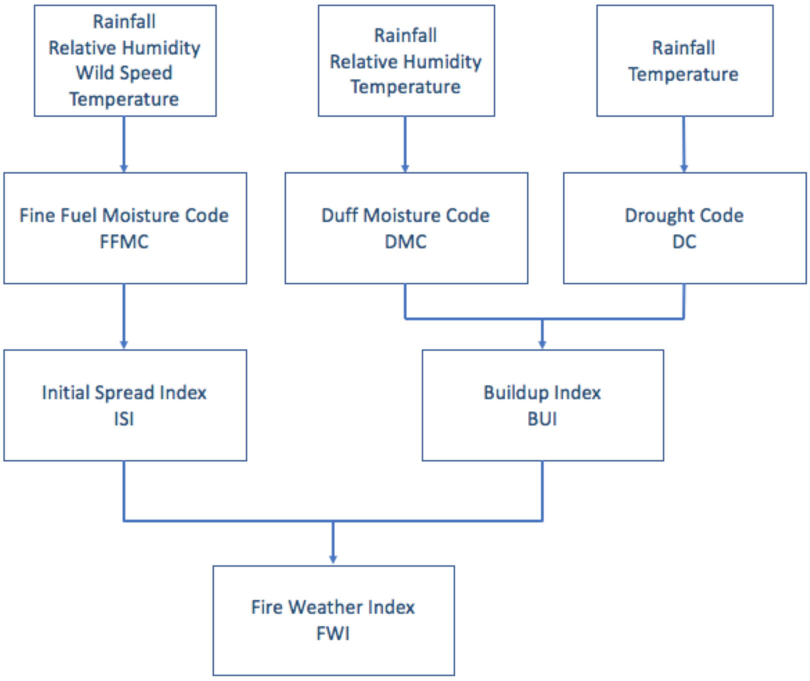

Figure 5. Canadian Forest Fire Weather Index (FWI) system

Within the FWI-system, there are three components of fuel moisture, related to the moisture content of three classes of forest fuel of different drying rates. These are: (1) the Fine Fuel Moisture Code (FFMC), related to the moisture content of litter and other fine fuels (Figure 6), (2) the Duff Moisture Code (DMC) (Figure 7), which represents the moisture content of loosely compacted organic matter in the soil representing medium-size fuels, and (3) The Drought Code (DC) (Figure 8) linked to the compact organic matter layer, representing the moisture content of thicker fuels that have a longer drying rate.

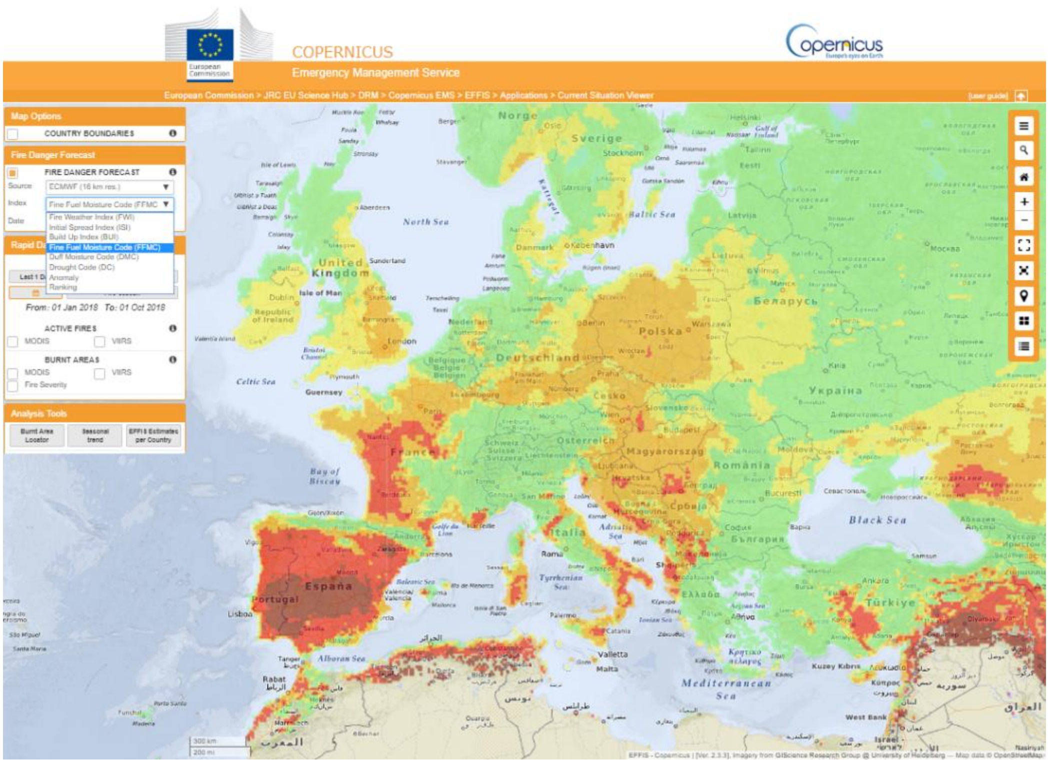

Figure 6. Example of the Fine Fuel Moisture Content in EFFIS (conditions on October 1st 2018).

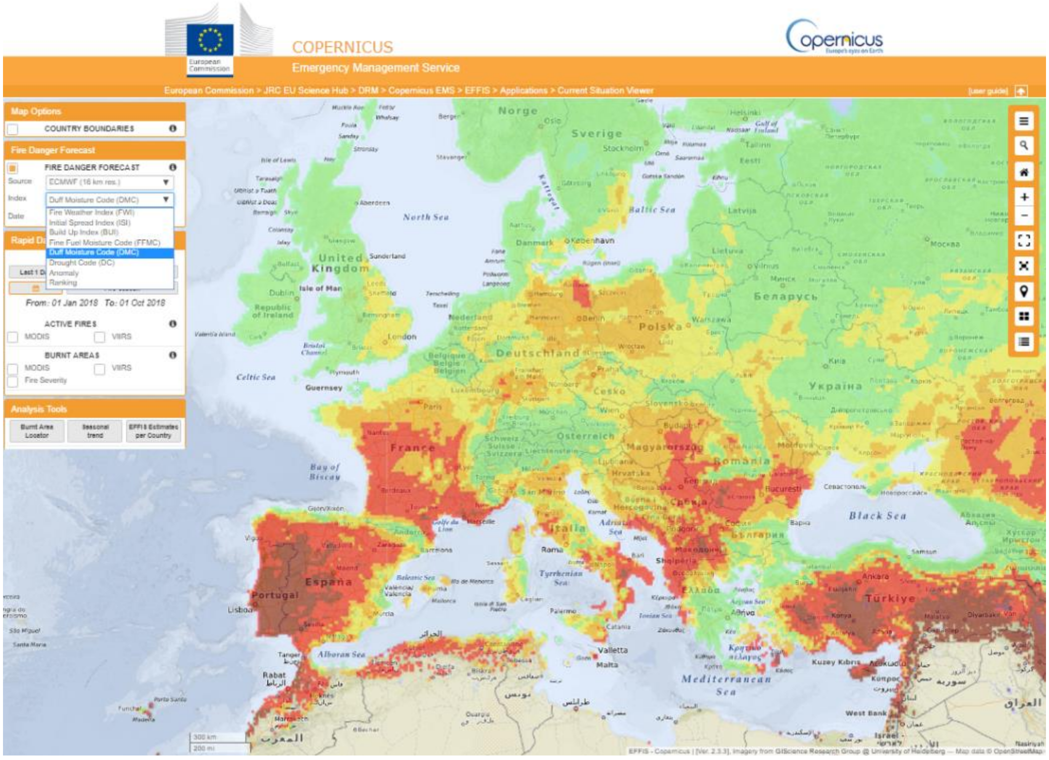

Figure 7. Example of the Duff Moisture Code in EFFIS (conditions on October 1st 2018).

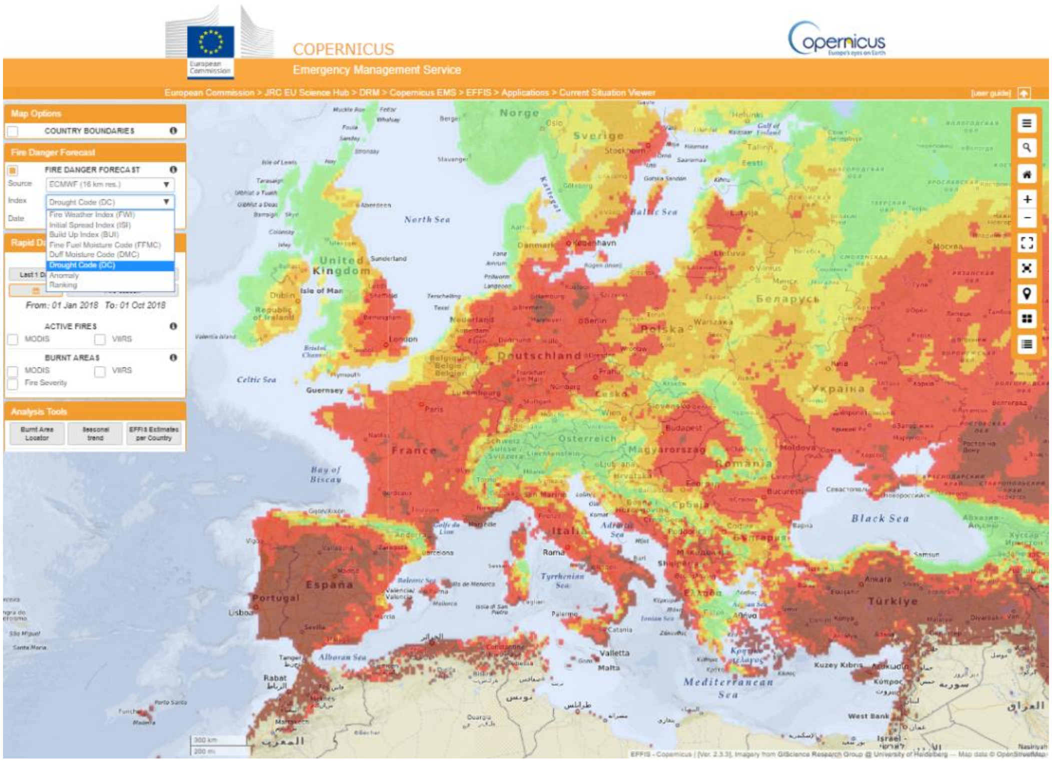

Figure 8. Example of the Drought Code in EFFIS (conditions on October 1st 2018).

3.3.2.2 Fuel Types

Wildfire propagation depends of the type of fuel available to burn, which may include tree crowns, shrubs, duff, *etc*. Each type of fuel may hamper or facilitate fire propagation because of its characteristics. However, wildfire behavior is highly dependent on the horizontal and vertical structure of the fuels and the inter-connection among them (Scott and Burgan, 2005).

Determination of fuel types in practice is a very complex process (Keane *et al*. 2001) and, at the European scale, can only be done using indirect measurements or modelling technologies such as remote sensing. A European data set that is already available and useful to address fuel types as a criterion of wildfire risk assessment is the Fuel Map of Europe (JRC, 2010). This data set (Figure 9) maps 42 fuel types organized in 9 groups (Table 1).

Table 1. Fuel types of the Fuel map of Europe.

Group	Fuel type
Grassland	Pastures
	Sparse grassland
	Mediterranean grassland and steppes
	Temperate, Alpine and Northern grassland
Shrubland	Mediterranean moors and heathlands
	Temperate, Alpine and Northern moors and heathland
	Mediterranean open shrublands (sclerophylous)
	Mediterranean shrublands (sclerophylous)
	Deciduous broadleaved shrublands (thermophilous)
	Alpine open shrublands (conifers)
Transitional shrubland/ forest	Shrublands in Mediterranean conifer forests
	Shrublands in Mediterranean sclerophylous forest
	Shrublands in Mediterranean montane conifer forest
	Shrublands in termophylous broadleaved forest
	Shrublands in beech and mesophytic broadleaved forest
	Northern open shrublands in broadleaved forest
	Shrublands in Alpine and Northern conifer forest
Conifer forest	Mediterranean long needled conifer forest (Mediterranean pines)
	Mediterranean scale-needled open woodlands (juniperus, cupressus)
	Mediterranean montane long needled conifer forest (black and scots pines)
	Mediterranean montane short needed conifer forest (firs, cedar)
	Temperate conifer pantation
	Alpine long needled conifer forest (pines)
	Alpine short needled conifer forest (fir, alp. spruce)
	Northern long needled conifer forest (scots pine)
	Northern short needled conifer forest (spruce)
Broadleaved forest	Mediterranean evergreen broadleaved forest
	Thermophilous broadleaved forest
	Mesophytic broadleaved forest
	Beech forest
	Montane beech forest
	White birch boreal forest
Mixed forest	Mixed Mediterranean evergreen broadleaved with conifers forest
	Mixed termophylous broadleaved with conifer forest
	Mixed mesophytic broadleaved with conifer forest
	Mixed beech with conifers forest
Aquatic vegetation	Riparian vegetation
	Coastal and inland halophytic vegetation and dunes
	Aquatic marches
Agro-forestry areas	Agro-forestry areas
Peat bogs	Peat bogs
	Wooded peat bogs

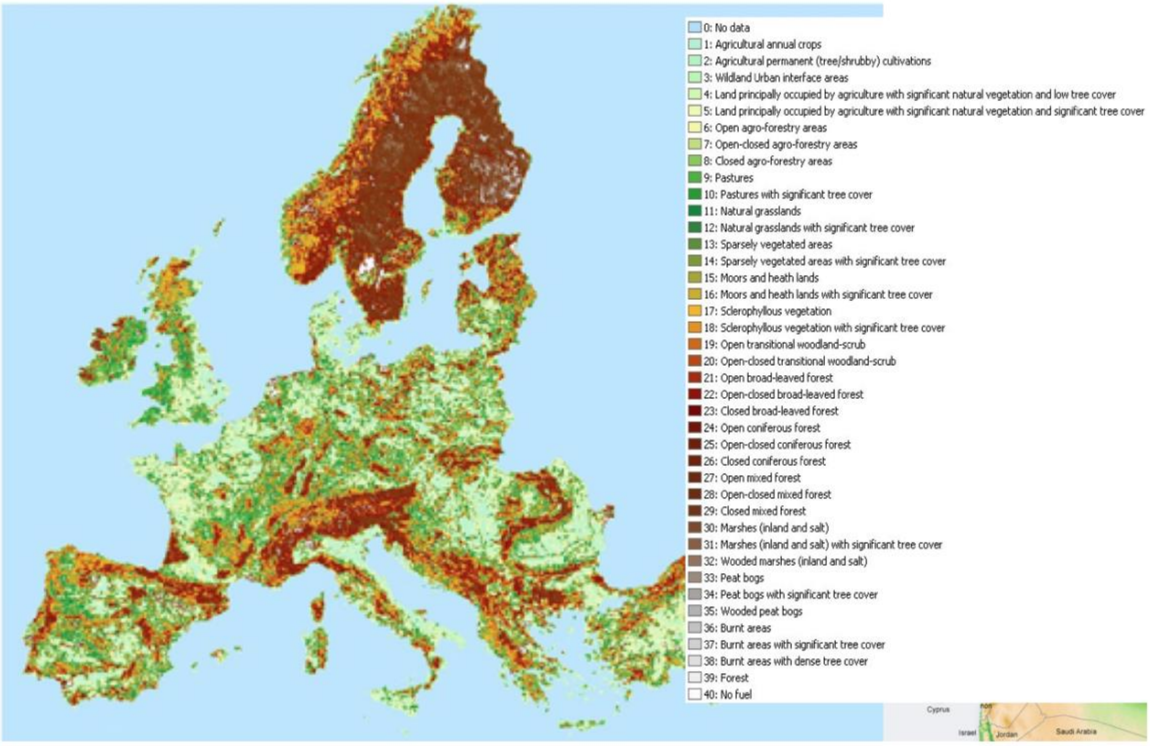

Figure 9. Fuel Map of Europe.

3.3.2.3 Slope and winds

Topography is related to local conditions with relevance for wildfire propagation. For example, steep slopes may facilitate fire spread, and southern facing slopes are likely to be hotter and drier, and hence prone to fire ignition and propagation. Winds are also a local condition affecting wildfires. Weather conditions and topography are the main drivers of fire propagation: in areas subject to frequent fire occurrence, even the local soil and vegetation composition may differ depending on the orography (Sharples, 2008; Hernandez *et al*., 2005; de Rigo *et al.*, 2017). Figure 10 shows the topography for the pan-European region.

Figure 10. Topography of the pan-European region.

Digital Elevation Models (DEM) can be used to evaluate local and broader topographic conditions, and nowadays there are available several data sets covering Europe, such as the ASTER Global DEM (Abrams *et al*. 2010), the Shuttle Radar Topography Mission (SRTM) (Farr *et al*. 2007) and the MERIT DEM (Yamazaki *et al.*, 2017). These products are available with 3- and 1-arc-second pixel size (~90 and ~30 m).

Winds can be considered for wildfire risk assessment through the Initial Spread Index (ISI) (Figure 11) of the Canadian FWI-system. ISI considers the combined effects of wind and the Fine Fuel Moisture Code (FFMC) (Figure 6), and represents the expected rate of fire spread.

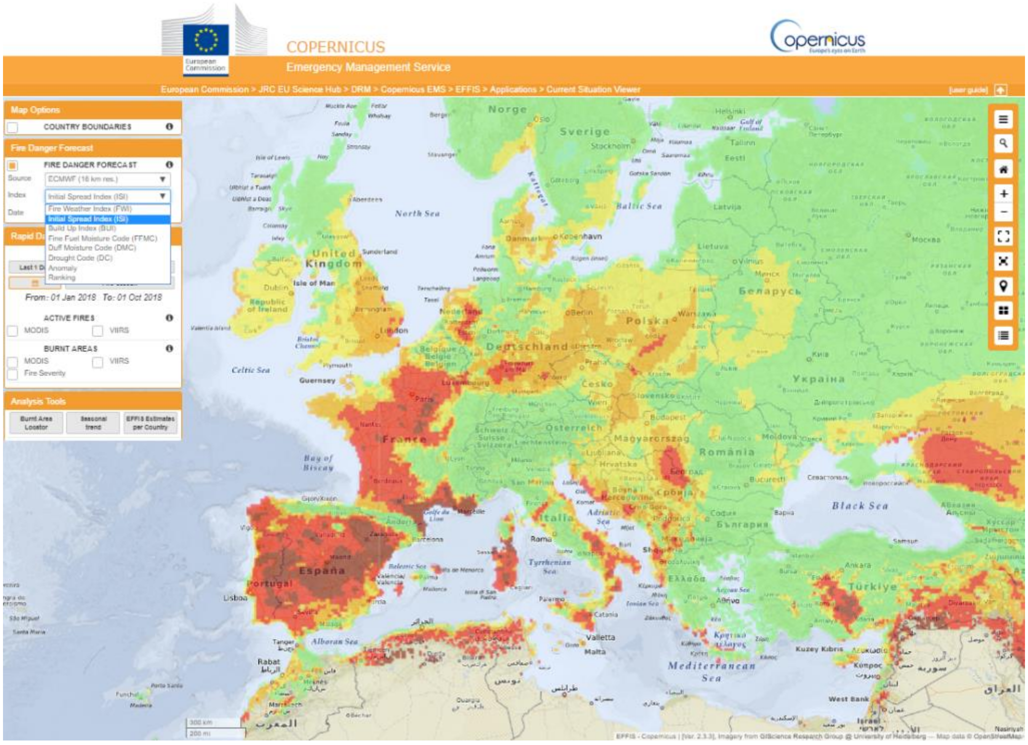

Figure 11. Example of Initial Spread Index in EFFIS (conditions on October 1st 2018).

3.4 Vulnerability

3.4.1 Ecological value

Global anthropogenic disturbance of ecological equilibrium has reached an unprecedented magnitude and consequences in this century. Countries in Europe are committed to the protection of the environment, and shape their policies according to the pursuit of sustainable development. Ecological values, however, are difficult to measure as they are often intangible, but their protection is fundamental for all forms of life, including humans.

Calculating ecological value in quantitative terms is very complex, and a qualitative approach should be adopted. In the European context, harmonized criteria have long been used for defining protected areas, namely the Natura 2000 network of sites, which can be used to emphasize the special ecological values of a territory. Natura 2000 identifies the most valuable and threatened species and habitats in Europe, whose damage from wildfires represent great loss, in some cases potentially not recoverable in the worst case scenario. Natura 2000 sites include several different types of protected areas, such as Bird Directive Sites (SPA), and Habitats Directive Sites, which are defined with different motivations and can be used to refine levels of wildfire risk.

National Designated Protected Areas must also be considered when assessing wildfire risk. They include over 1.1 million km^2 in 39 European countries in 2014[3] ranging from national parks to forest reserves and from strict nature reserves to resource reserves. National authorities report the protected areas to the European Environmental Agency (EEA) clustering the different designation-types according to three main categories[4]:

[3] https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas/nationally-designated-protected-areas-assessment-3

[4] https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas

a) Designation types used with the intention to protect fauna, flora, habitats and landscapes, b) statutes under sectoral, particularly forestry, legislative and administrative acts providing an adequate protection relevant for fauna, flora and habitat conservation, and c) private statute providing durable protection for fauna, flora or habitats. However, the national designated protected areas include sites that may not meet internationally adopted definitions of protected areas.

3.4.2 Socioeconomic value

Environment provides fundamental services, such as water flow regularization and erosion control, and are often categorized in provisioning, supporting and regulating services on which humans depend (Maes *et al.*, 2013; de Rigo *et al.*, 2016). Damage by wildfire can thus have not only ecological, but also socioeconomic consequences affecting people's livelihood, safety, health, *etc*.

A practical approach to address this criterion is to estimate the damage of wildfires in terms of costs. The latter is the cost of restoring land cover to its state previous to a potential wildfire. Wildfire damage costs have been estimated for Europe based on the CORINE Land Cover (Oehler *et al*. 2012, Camia *et al*. 2017). These authors established a restoration cost for each land cover class at country level, and an average restoration time was defined according to the recovery capacity of the land cover. The damage caused by wildfire was estimated by discounting the cost of restoring the land cover over a restoration period. Different estimates were produced for three different vulnerability scenarios in which different levels of damage could be caused by low, medium and high wildfire severity.

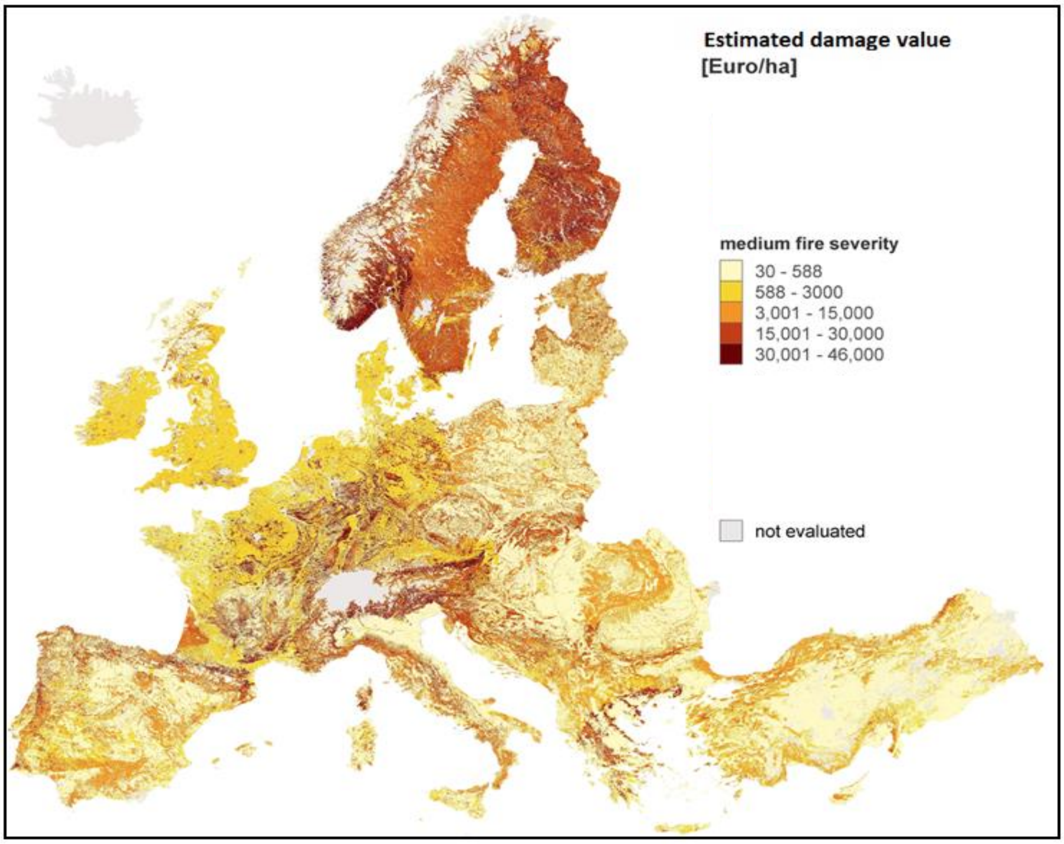

Figure 12. Socio-economic value (reconstruction cost of different land cover types).

This practical approach can eventually evolve and include indicators of the ecosystem's conditions and the services they provide. Indicators have been proposed at the European level in the framework of the EU Biodiversity Strategy to 2020, namely those described in the fifth report (Maes *et al*., 2018) of the Mapping and Assessment of Ecosystem and Their Services (MAES). This report includes a set of spatially-explicit indicators for assessment of ecosystem condition per ecosystem type, and the underpinning data can be organized in a natural capital accounting framework. The indicators address ecosystem conditions such as biomass volume, and pressures such as wildfires for forests and woodlands. Considering such indicators can be useful for fine mapping the vulnerability of ecosystem services to wildfires from a socioeconomic point of view.

Socioeconomic value can also be considered in particular areas where wild vegetation and people co-exist, which normally is referred to as the Wildland-Urban Interface (WUI). Particular attention has been given all over the world to the WUI for research, management and prevention of wildfires (Stewart *et al.*, 2007; Syphard *et al.*, 2007; Vilar del Hoyo *et al.*, 2011; Gallardo *et al.*, 2016; Fox *et al.*, 2018; Kaim *et al.*, 2018) because of its large risk of wildfires. Currently, the JRC is producing what will be the first harmonized WUI layer at the 100 m resolution for Europe (39 countries). This product is scheduled for 2019 and can be integrated in wildfire risk assessment.

The WUI layer can be used together with additional data sets, such as spatial data on critical infrastructures. The latter is defined in the EU (Council Directive 2008/114/EC) as any "asset, system or part thereof, which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions". For these reasons, critical infrastructures at risk of wildfires should be highlighted in a risk assessment. The JRC has collected European data on critical infrastructures from a range of sources and harmonized and stored them in a geographical database (Herrera *et al*. 2015). Alternatively, a database maintained by KPMG (https://home.kpmg.com/it/it/home.html), the International Development Assistance Services (IDAS), is a potential source on spatial data on critical infrastructures.

4 Towards the implementation of a pan-European wildfire risk assessment

The above sections set the basic criteria for the assessment of wildfire risk at the pan-European level. The next step in the process is the implementation of the basic criteria and the testing and validation of the resulting wildfire risk map at the pan-European level. This work will be undertaken in close collaboration with the Expert Group on Forest Fires in the near future.

However, the effects of climate change must be taken into account in the implementation (de Rigo *et al*. 2017; Amatulli *et al*. 2013). Also, lessons learned from previous critical fires must be taken into consideration (San-Miguel-Ayanz *et al*. 2013a), as these episodes are becoming more frequent in Europe and worldwide.

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doi:10.2760/052345

ISBN 978-92-79-98200-2