FIREURISK - DEVELOPING A HOLISTIC, RISK-WISE STRATEGY FOR EUROPEAN WILDFIRE MANAGEMENT

Grant Agreement Number: 101003890 **Call identifier:** H2020-LC-CLA-2018-2019-2020	
Topic:	LC-CLA-15-2020 Forest Fires risk reduction: towards an integrated fire management approach in the E.U.
Instrument:	RIA

D5.11 – Report of FirEUrisk Pilot Site 6 Demonstration

Deliverable Identifier:	D5.11
Deliverable Due Date:	30/11/2024
Deliverable Submission Date:	17/12/2024
Deliverable Version:	Final version
Lead partner:	UAH
Authors:	M. Lucrecia Pettinari (UAH), Javier Salas Rey (UAH), Emilio Chuvieco (UAH)
Work Package:	WP5 - Pilot Sites and Demonstration Areas
Task:	Task 5.2 Management of study cases
Dissemination Level:	☒PU: Public ☐ CO: Confidential, only for members of the Consortium (including the Commission Services)

Revision History

Version	Date	Edited by	Description
v.0.1	25/11/2024	M. Lucrecia Pettinari, Javier Salas Rey	Document draft writing and formatting.
v.0.2	26/11/2024	Emilio Chuvieco	Draft review by UAH coordinator and FirEUrisk Science Leader
v.0.3	16/12/2024	Cristina Vega García, Kirsten Thonicke, Vasileios Kazoukas, Juli Pausas	Internal approval review by the QRB
V1.0	17/12/2024	M. Lucrecia Pettinari	Final version submitted

Quality Control

Type	Date	Reviewed by	Approved/Comment
Internal review	30/11/2024	Cristina Vega García, Kirsten Thonicke	Approved
Security issues	16/12/2024	Vasileios Kazoukas	Approved
QRB	16/12/2024	Juli Pausas	Approved

Executive Summary

General information about the event

- The project's sixth Pilot Site Demonstration Event (DE) was organized by UAH and took place in Milan, Italy, on 16 September 2024. This Demonstration Event was hosted by the Consiglio Nazionale delle Ricerche (CNR), at their headquarters of Milan, and took place in a hybrid format, including online connection for remote attendees.
- The recording of the DE, as well as the slides and a document with the product cards demonstrated are available in the FirEUrisk website, allowing other interested stakeholders to get information on the products presented in an asynchronous way.

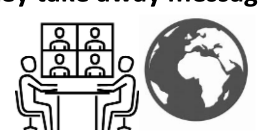
Objectives and methodology

This demonstration event comprised the European Territory as a pilot site. It's main objectives were:

- Publicly disseminating the project and the products developed, with a particular focus on the products developed at ET scale.
- Evaluating the quality of the FirEUrisk products in terms of the level of interest they generate among potential users, and determine the appropriateness of the methods used for the development of the different products.
- Obtaining feedback regarding possible improvements in the development of FirEUrisk products.

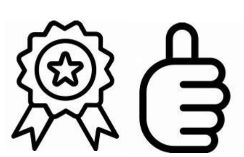
During the event, 15 FirEUrisk products generated at European scale were presented, including the Integrated fire Risk Index (IRI). The presentations were grouped in three blocks, corresponding to the assessment of fire danger components, the assessment of the vulnerability components, and the assessment of the fire risk integration and the mitigation and adaptation components. After each block, a survey was given to the attendees to gather their feedback on the products presented.

Key take away messages



35 in-person attendees plus 144 participants online. Attendees from 35 different countries.

Diverse professional activities of participants: principally working on national or regional Governmental Organizations and the Academia, but also a significant participation from members of private companies, NGOs and research institutions. 10 participants belonged to European Commission Organizations, mostly the Joint Research Centre, but also different Directorate Generals.



Overall, the answers reflected the extensive agreement of the participants who answered the survey with the approaches and methods used by FirEUrisk. For the questions punctuating the agreement in a scale 1 to 5, the options "4 - Mostly agree" or "5 - Totally agree" were selected by between 73.33 and 90.54% of the surveys, with a mean for all these sort of questions of 83.78%.

Disclaimer

Copyright message

Table of Contents

List of Figures

List of tables

List of Acronyms

Table 1: List of Acronyms

ALS	Airborne Laser Scanning
AUC	Area Under the Curve
BASE	Burnt Area Simulator for Europe
BD	Biological Distinctiveness
CBD	Canopy Bulk Density
CBH	Canopy Base Height
CC	Canopy Cover
CFA	Crown Fire Activity
CFB	Crown Fraction Burned
CFL	Canopy Fuel Load
CH	Canopy Height
CNR	Consiglio Nazionale delle Richerche
CR	Climatic Region
D	Danger
DG	Directorate General
DGVM	Dynamic Global Vegetation Model
DE	Demonstration Event
E	Exposure
ECHO	European Civil Protection and Humanitarian Aid Operations
EC	European Commission
ECMWF	European Centre for Medium-range Weather Forecast
EFFIS	European Forest Fire Information System
ERA5	ECMWF Reanalysis v.5
EST	Ecosystem service value
ET	European Territory
EU	European Union
EVa	Ecological value
EVA	Ecological Values Assessment
FFM	Fire Forecasting Model
FI	Fireline Intensity
FL	Flame length
FMC	Fuel moisture content
FRLMS	Fire Reduction Land Management Strategies
FRP	Fire Radiative Power
FT	Fuel Type
GEDI	Global Ecosystem Dynamics Investigation
GLM	Generalised Linear Model
GR	Growth Rate
HILDA+	HIstoric Land Dynamics Assessment+
IFS	Integrated Forecast System
IP	Ignition probability
IRI	Integrated fire Risk Index
ISS	International Space Station
JRC	Joint Research Centre
LEV	Potential loss of Ecological values
LFMC	Live fuel moisture content
LiDAR	Light Detection and Ranging
LUCAS	Land Use and Coverage Area frame Survey
LUT	Look-up Table
MODIS	Moderate Resolution Imaging Spectroradiometer
NGO	Non-Governmental Organization
PALSAR	Phased Array L-band Synthetic Aperture Radar sensor
PBD	Prescribed burn days
PCA	Principal Component Analysis
PHI	Probability of human ignition
PIK	Potsdam Institute for Climate Impact Research
PNI	Probability of natural ignition
Pp	Precipitation
PUM	Product User Manual
RF	Random Forest
RH	Relative Humidity
RI	Reaction Intensity
RST	Recovery Start Time
RT	Recovery Time
RTM	Radiative Transfer Model
SAR	Synthetic Aperture *Radar*
SSP	Shared Socioeconomic Pathways
TP	Temperature
UAH	University of Alcalá
V	Vulnerability
WDTA	Wildfire Danger by Thermal Anomaly
WP	Work Package
WS	Wind speed
WUI	Wildland-urban interface

1 Introduction

1.1 European Territory (ET) Demonstration Event objectives

The main objectives of the Demonstration Event consisted on presenting and evaluating the FirEUrisk products at European scale, as well as gathering feedback of the participants on any potential improvement proposals, namely:

- Publicly disseminating the project and the products developed, with a particular focus on the products developed at ET scale.
- Evaluating the quality of the FirEUrisk products:
  - Assessing the level of interest they generate among potential users.
  - Determining the appropriateness of the methods used for the development of the different products.
- Obtaining feedback regarding possible improvements in the development of FirEUrisk products.

1.2 Purpose and structure of the document

This document presents an analysis of the European Territory Demonstration Event, reporting on the participation, products presented and evaluated, and the result of the products' evaluation by the participants.
The document is structured to facilitate a clear understanding of the key outcomes and insights gathered during the DE. It begins with a short description of the European Territory Pilot Site, followed by the agenda and characteristics of the event (Section 2). Then, the characteristics of the attendees is presented. Section 3 includes a summary of the different products showcased during the DE, while Section 4 presents the validation and protocol and results. Finally, Section 5 describes the conclusions and lessons learned. The Annex includes a copy of the questionnaire completed by the attendees.

2 Implementation of the ET Demonstration Event

2.1 Description of the European Territory Pilot Site

The ET Pilot Site covers the whole area of Europe that was selected for the processing of the different products at ET scale. It corresponds to continental Europe plus the Mediterranean islands that are within the boundaries of the continental region. The area excludes the islands that are outside the continental boundaries, i.e. Iceland, Cyprus, Canary Islands and the Azores. This area covers the Mediterranean countries in the south, temperate regions in Central Europe, and reaches the boreal regions in northern Norway.
Figure 1 shows the area corresponding to the European Territory, displaying an example of the Integrated fire Risk Index for a day in July 2024.

2.2 Demonstration Event highlights

The Demonstration Event took place at the CNR offices in Milan. The in-person meeting took place in a meeting room that could accommodate a maximum of 50 participants. Key European stakeholders were invited by e-mail to attend the meeting, particularly those who are part of European organizations such as the Joint Research Centre (JRC), DG-ECHO, or the European Environmental Agency. Invitations were also sent to partners of other European projects related to fire, and dissemination of the activity was also performed using social media channels such as X and LinkedIn. Around 300 initial registrations were received. Of those, 135 persons attended in person, and 148 persons attended online (see Section 2.4). Since the DE was covering the European territory and not a specific country, the event took place in English. For the online attendees, a Zoom webinar was organized, and the participants could follow the presentations, ask questions that were answered either orally or in writing, and participate in the surveys to gather feedback on the products presented.

The recording of the demonstration event, as well as the slides presented, are available at the FirEUrisk website (https://fireurisk.eu/european-territory/).

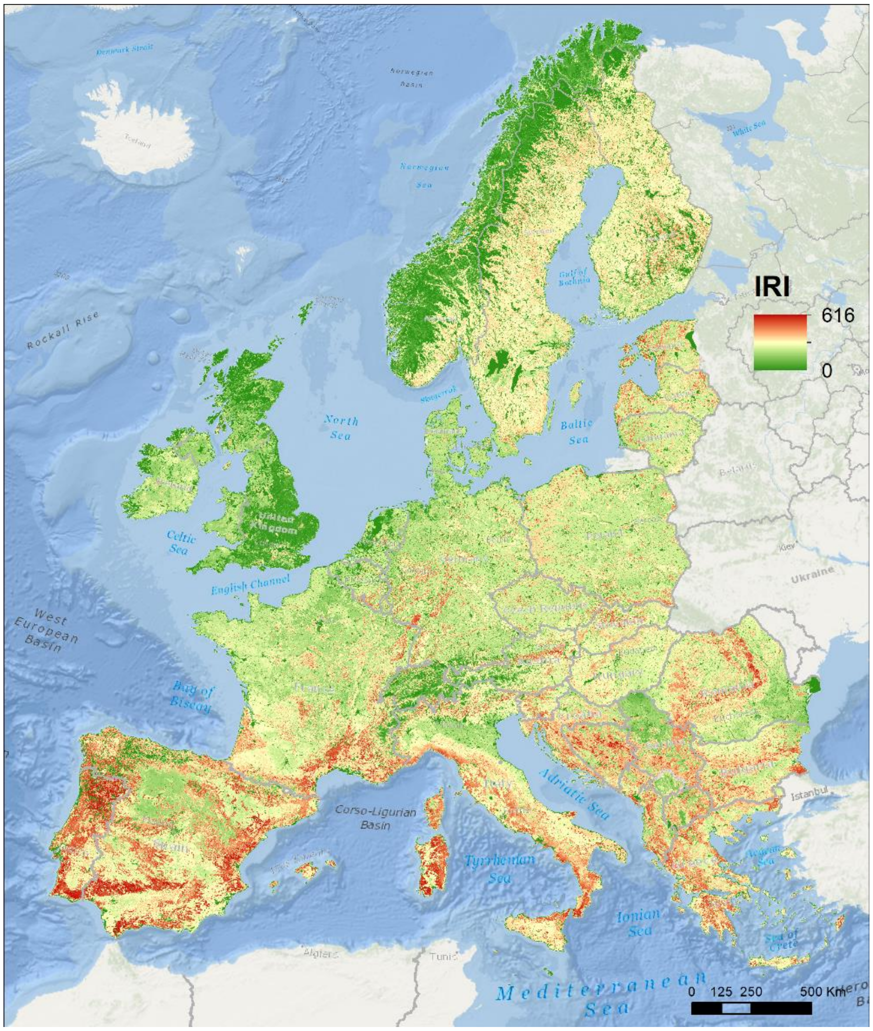


Figure 1: European Territory Pilot Site, showing the Integrated fire Risk Index (IRI) corresponding to 04/07/2024.

2.3 Meeting Agenda

The agenda of the meeting (Table 2) was designed to showcase the FirEUrisk products that were integrated at European scale into the IRI (corresponding to WP1), plus presenting fire mitigation (WP2) and adaptation (WP3) research performed at European level.

After the introductory session by Domingos Viegas and Emilio Chuvieco, a first section on fire Danger components was presented, followed by a dedicated survey to gather feedback from the participants on the products presented. This occupied the morning part of the event. After lunch, the Vulnerability component products were presented, as well as the methods for the integration of the different components to obtain the IRI, after which some additional questions were asked in a dedicated survey. The last section of the event presented the products pertaining to fire mitigation, and fire adaptation and climate scenarios.

At the end of each presentation, the participants (both in person and online) could ask questions to the presenters, which were answered orally in most cases, and in a few cases in writing in the Zoom platform.

Table 2: Agenda of the Demonstration Event

Time allocated	Fire risk components	WP task	Presenter
9.15 – 9-30	Registration		
9.30 – 9.45	Project presentation	7	Domingos Viegas
9.45 – 10.00	FirEUrisk risk framework	4	Emilio Chuvieco
10.00 – 10.15	Human ignition	113	Clara Ochoa
10.15 – 10.30	Natural ignition	112	Evgeni Kadantsev
10.30 – 10.45	Live FMC	111	Valerio Pampanoni
10.45 – 11.15	**Coffee break**		
11.15 – 11.30	Fuel types	114	Elena Aragoneses
11.30 – 11.45	Propagation	115	Darko Stipanicev
11.45 – 12.30	Assessment of fire danger components		ET end-users
12.30 – 13.30	**Lunch**		
13.30 – 13-45	Ecological values	123	Fatima Arrogante
13.45 – 14.00	Coping capacity / Recovery time	122	Florent Mouillot
14.00 – 14.15	Ecosystem services	124	Simone Martino
14.15 – 15.15	Assessment of fire vulnerability components		ET end-users
15.15 – 15.45	**Coffee break**		
15.45 – 16.15	Risk integration and validation	131	Emilio Chuvieco
16.15 – 16.45	Fire mitigation	2	Domingos Viegas
16.45 – 17.15	Fire adaptation & climate scenarios	3	Kirsten Thonicke
17.15 – 18.00	Assessment of fire risk integration, mitigation and adaptation components		ET end-users

2.4 Attendance characterization

As mentioned before, this was a hybrid event. Due to the European scope of the DE, the interested parties were located in different countries, so the online participation was higher than the in-person participation, thus reducing travel costs and environmental footprint. The characteristics of each of the audiences are described below.

2.4.1 In-person audience

A total of 35 persons attended the Demonstration Event at CNR, and their country of origin is indicated in Figure 2. Not surprisingly, being the event held in Italy, the majority of the participants were Italian (17), followed by Spanish (7) and Portuguese (4). These numbers include the members of the FirEUrisk consortium.

In terms of their professional activity, most of the participants worked either at universities (12 participants) or at National Governmental Organizations (10 participants). In particular, as part of these national organizations, 6 participants are part of the Corpo Nazionale Vigili del Fuoco (Italian National Fire and Rescue Service). It is also important to highlight that 5 participants are employees of the European Commission Joint Research Centre, one of the main targets of the DE. A summary of the affiliation of the participants is shown in Figure 3.

Finally, when registering to the DE, the participants were asked to indicate the spatial scale in which they were interested: European, National or Regional. Participants could select one or several scales, depending on the kind of work they do. The results of this selection is show in Figure 4. A total of 59 options were selected, with 18 participants selecting more than one option. Of the participants that selected only one spatial scale of interest, almost everyone selected the European Scale; this was also the spatial scale most selected, 27 times, followed by the National Scale (18) and the Regional (14). Those who selected the National and/or Regional scales work mostly in National Governmental Institutions

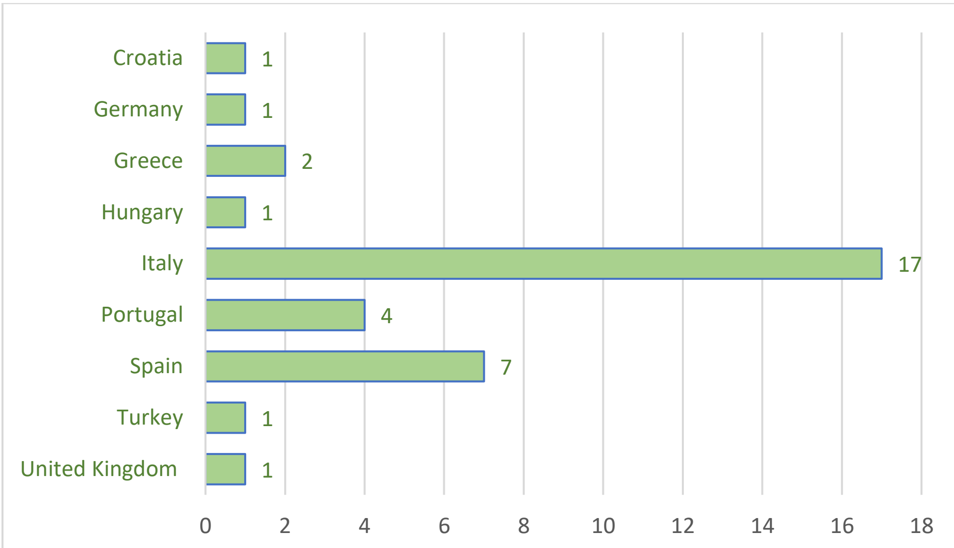


Figure 2: Country of DE in-person participants

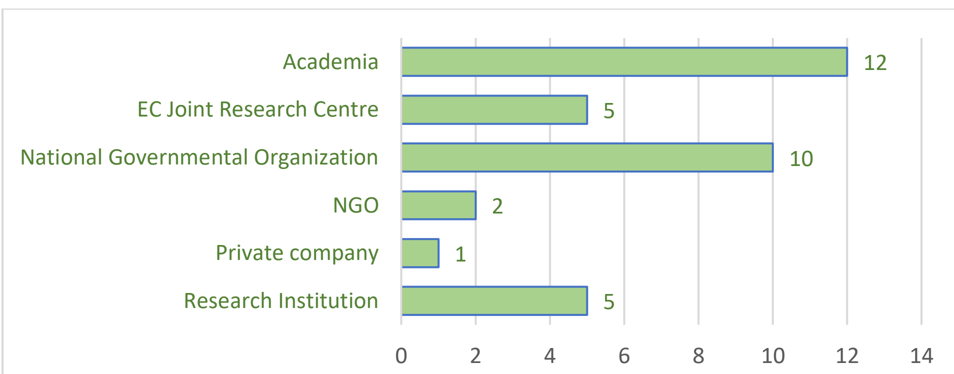


Figure 3: Distribution of in-person participants by professional activity

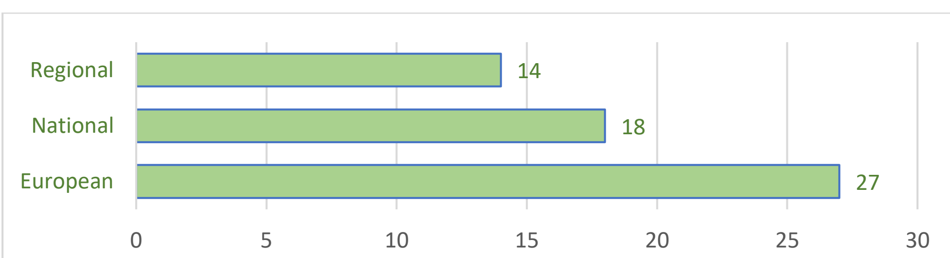
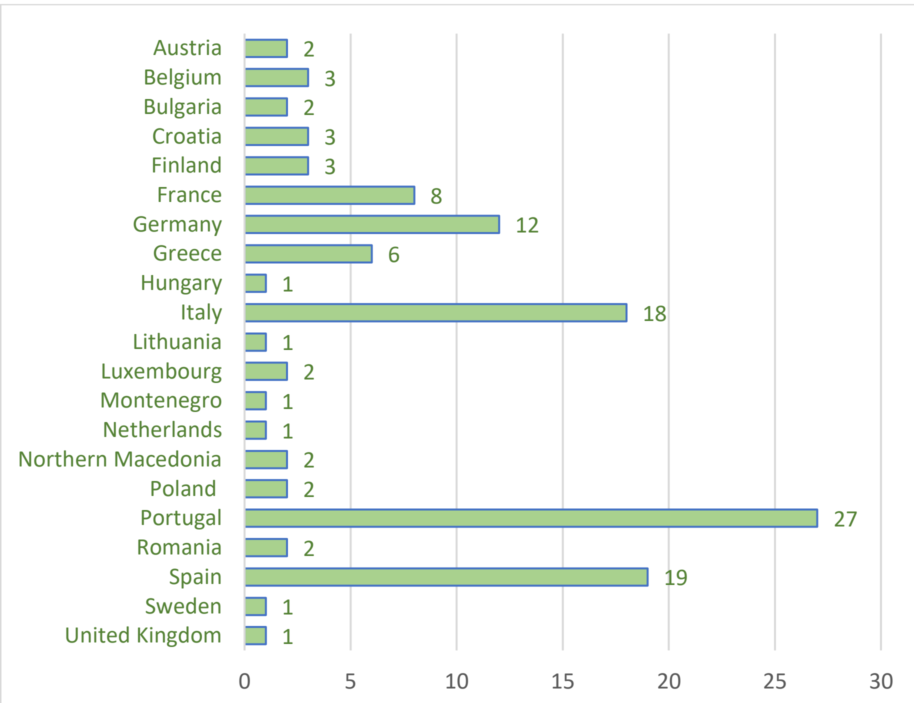


Figure 4: Spatial scale of interest of the participants

2.4.2 Remote audience (Zoom webinar)

The number of online participants was much higher than the in-person ones, with 144 attendees via de Zoom webinar application. Figure 5 shows the number of attendees per country, divided between the countries which are included in the ET pilot site (117 participants in total from 21 countries), and the ones outside it (25 participant in total from 14 countries, including 5 participants who did not indicate their country of origin). Within the attendees from the ET, the most numerous were from Portugal, Spain, Italy and Germany, in that order.



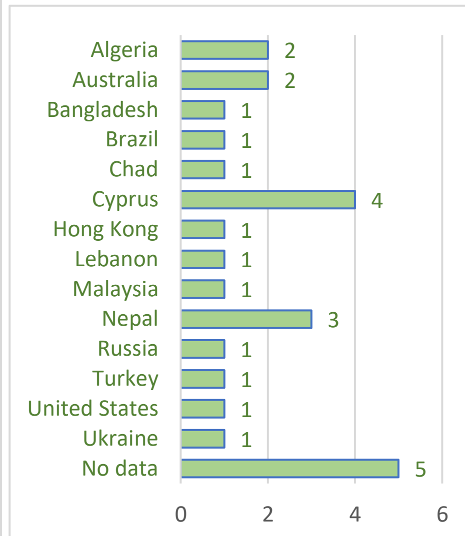


Figure 5: Number of online attendees per country. Left: countries within the pilot site. Right: countries outside the pilot site.

Regarding the professional activity of the participants (see Figure 6), the majority (40) belong to Regional or National Governmental Organizations, such as different Fire Departments, firefighter-training organizations, personnel of governmental administration offices, national parks, or Civil Protection organizations, amongst others. The second most frequent activity was Academia (31 attendees), represented by different universities from countries both inside and outside the ET. 26 participants work in private companies, such as Insurance companies, companies that provide solutions based on geospatial information, or companies that provide technology for firefighting. The 23 attendees from Research Institutions belong to National Research Councils (from Italy, Spain, France, Greece) or other institutes (public or private) dedicated to topics such as forests, environment, geophysics or meteorological research. The NGOs represented in the DE (14) are mostly related to fire prevention and monitoring in different countries. It is also important to highlight the participation online of 5 members of the European Commission, including personnel of the Joint Research Centre and DG-ECHO. Finally, 5 attendees did not indicate their affiliation.

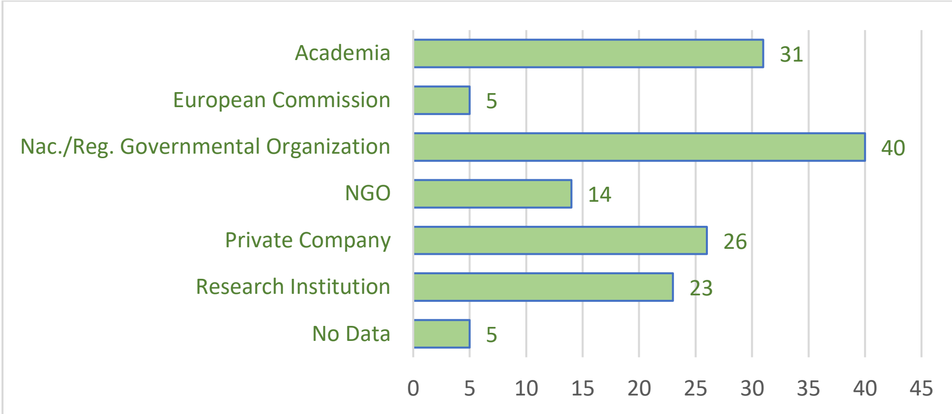


Figure 6: Distribution of online participants by professional activity

Taking into consideration the spatial scale of interest of the online participants, 213 answers were received, which are summarized in Figure 7. Practically the same number of participants selected the Regional or National scale, which was the option most selected, while in this case, contrary to the in-person attendees, the European scale was least represented. 43 participants selected more than one spatial scale of interest.

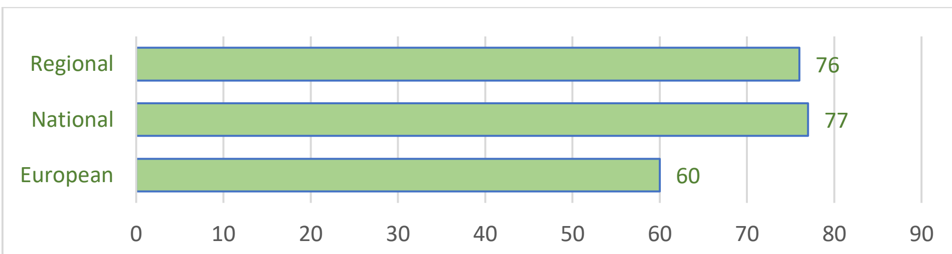


Figure 7: Spatial scale of interest of the online participants

3 Products Description

In this chapter, we present a description of the products showcased at the Demonstration Event. Each product is associated with a reference assigned to all FirEUrisk products. The following sections follow the order of presentation in the agenda and not the product reference number.

The description provided for each product was written by those responsible for each product's development. During the meeting, a link in the form of a QR code was provided several times, so that the participants could download a document with the product cards to help them follow the presentations, or to have more information about the products during the meeting. This document is available in the FirEUrisk website (https://fireurisk.eu/wp-content/uploads/2024/11/European-Territory-Product-Cards.pdf) where the participants of the event and the people who watch the DE in an asynchronous way can access this data. The following sections reproduce the information provided to the participants in that file.

3.1 Danger Products

3.1.1 Human ignition probability

3.1.1.1 Description

Brief description of the content: It's a probabilistic map estimated from a random forest model using human and climate variables. The likelihood of ignitions map (scale 0 to 1) has a spatial resolution of 1 km2.
Task in which it was carried out: The product developed within the Activity "A1.1.3 Human ignition drivers".
Fire risk component: Danger
Contact details of the developer: Clara Ochoa, University of Alcalá.
Is it publicly available? Only the paper (Ochoa et al., 2024)

3.1.1.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units (if categorical data, include the description of each category):	Probability scale 0 to 1
Update Frequency:	Static layer
Estimated Accuracy:	80%
Output Format:	.tif
Temporal coverage:	2001-2019
Spatial resolution:	1 km^2

3.1.1.3 Methodology

The product estimates the probability that a human caused fire will be ignited. The product was developed using Random Forest algorithm based on socio-economic and climatic drivers (Table 3) of ignition from geospatial indicators and demographic databases. The model obtained a performance of 80% estimated by the area under the curve (AUC). The model uses all ignitions that generated burned areas > 100 ha for a total of 33,388 ignitions. In addition, different data balancing methods were tested for the training, the stratified method being the most suitable for this model. This method consists of using a descriptive layer of European ecological regions to obtain a more representative sample of absence points. The results of the climate model showed that the probability of ignition in northern Europe is masked, the human models encountered challenges with classification accuracy, suggesting that the Random Forest (RF) algorithm struggled to make accurate predictions based solely on human variables. These findings imply that predicting large fires initiations across broad geographic extents may not be feasible with human variables alone, highlighting the necessity of including climatic variables. This limitation depends on the scale of the analysis, as it dictates the magnitude of potential environmental gradients that drive initiation patterns. Whereas the mixed model proved to be the best candidate to represent the probability at the European scale. This might be because climatic variables help the model to differentiate between northern and southern Europe and thus find patterns in the data. It is important to note that by using the mixed models, areas of high probability are seen in northern Europe, which would otherwise be masked. Because of the results, we suggest the use of mixed models for global studies.

Table 3: Human and climatic components

Variable	Source	Year	Publication
1. Distance to roads	Meijer et al 2018 (GLOBIO)	2018	2018
2. Forest-Agricultural Interface (FAI)	From Fuel Map (see section 3.1.4.5)	2019	2023

3. Wildland- Urban Interface (WUI)	(Bar-Massada et al., 2013)	2022	2023
4. Wildland- Agricultural Interface (WAI)	From Fuel Map (see section 3.1.4.5)	2019	2023
5. Wildland- Forest Interface (WFI)	From Fuel Map (see section 3.1.4.5)	2019	2023
6. Forest-Urban Interface (FUI)	From Fuel Map (see section 3.1.4.5)	2019	2023
7. Land change	Corine Land Cover	2000 and 2018	-
8. Cattle / km^2	FAO	2010	2014
9. Goats / km^2	FAO	2010	2014
10. Sheep / Km^2	FAO	2010	2014
11. GDP (2011, USD millions)	Aalto University, Helsinki	2015	2020
12. Population > 65 years	SEDAC-CIENSIN (Warszawski et al., 2017)	2010	2010
13. Population density	GEOSTAT 2018, GISCO. (Batista e Silva et al., 2021)	2018	-
14. Evapotranspiration	Antonio Trabucco, Robert Zomer (2019)	2018	2019
15. Aridity Index	Antonio Trabucco, Robert Zomer (2019)	2018	2019
16. Bioclimates	European Commission and the University of Edinburgh	2000	2018
17. Ecological Regions	FAO	2000-2010	2013

3.1.1.4 Data display

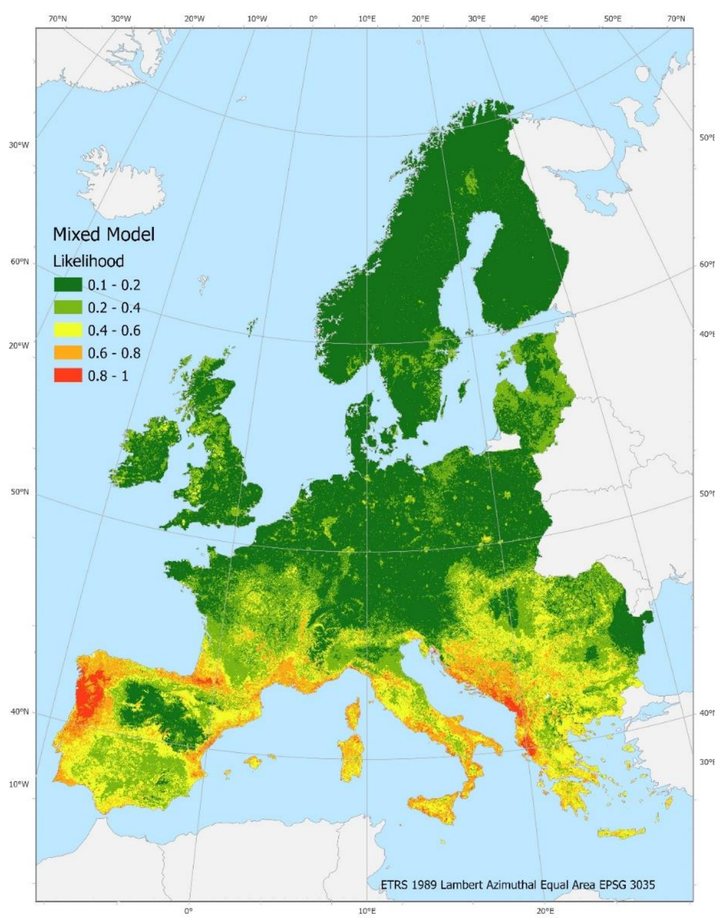


Figure 8: Human ignition probability map

3.1.1.5 References

Ochoa, C., Bar-Massada, A., & Chuvieco, E. (2024). A European-scale analysis reveals the complex roles of anthropogenic and climatic factors in driving the initiation of large wildfires. Science of the total environment, 170443. https://doi.org/10.1016/j.scitotenv.2024.170443

3.1.2 Natural ignition probability

3.1.2.1 Description

The Fire Forecasting Model (FFM, Sofiev et al, in prep.)-based Natural Ignition Probability product predicts the wildfires ignition probability by natural causes through basic meteorological parameters provided by Numerical Weather Predicting models.

The product was developed within the Activity "A1.1.2 Natural fire ignitions: Lightning".

Fire risk component: Ignition

Contact details of the developer: Evgeny Kadantsev

The product validation is still ongoing, the historical reanalysis and operational forecast will be publicly available through https://silam.fmi.fi/ website and FirEUrisk project platform.

3.1.2.2 Technical components

Characteristics	Description
Type of products:	Geospatial Product
Units (if categorical data, include the description of each category):	Probability on 0 to 1000 scale
Update Frequency:	Daily
Estimated Accuracy:	50%
Output Format:	.nc4
Temporal coverage:	06.06.2018 – today
Spatial resolution:	~9 km

3.1.2.3 Methodology

FFM employs a multi-step machine learning procedure to construct a statistical model that predicts Fire Radiative Power (FRP) based on global ERA5 reanalysis (https://www.ecmwf.int/en/forecasts/ dataset/ecmwf-reanalysis-v5), ERA5-Land reanalysis (https://www.ecmwf.int/en/era5-land), the Integrated Forecast System (IFS) operational forecast (https://www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model), and Terra's Moderate Resolution Imaging Spectroradiometer (MODIS, MOD14/MYD14, collection 6, https://www.earthdata.nasa.gov/learn/find-data/near-real-time/firms). The model utilizes various meteorological parameters, including Cloud-to-Ground Lightning Flash Density and Fire Danger Indices, as predictors for training and making predictions by calculating their respective contributions to total FRP. The contribution of cloud-to-ground lightning flash density to FRP is then used as a proxy for natural ignition probability.

3.1.2.4 Data display

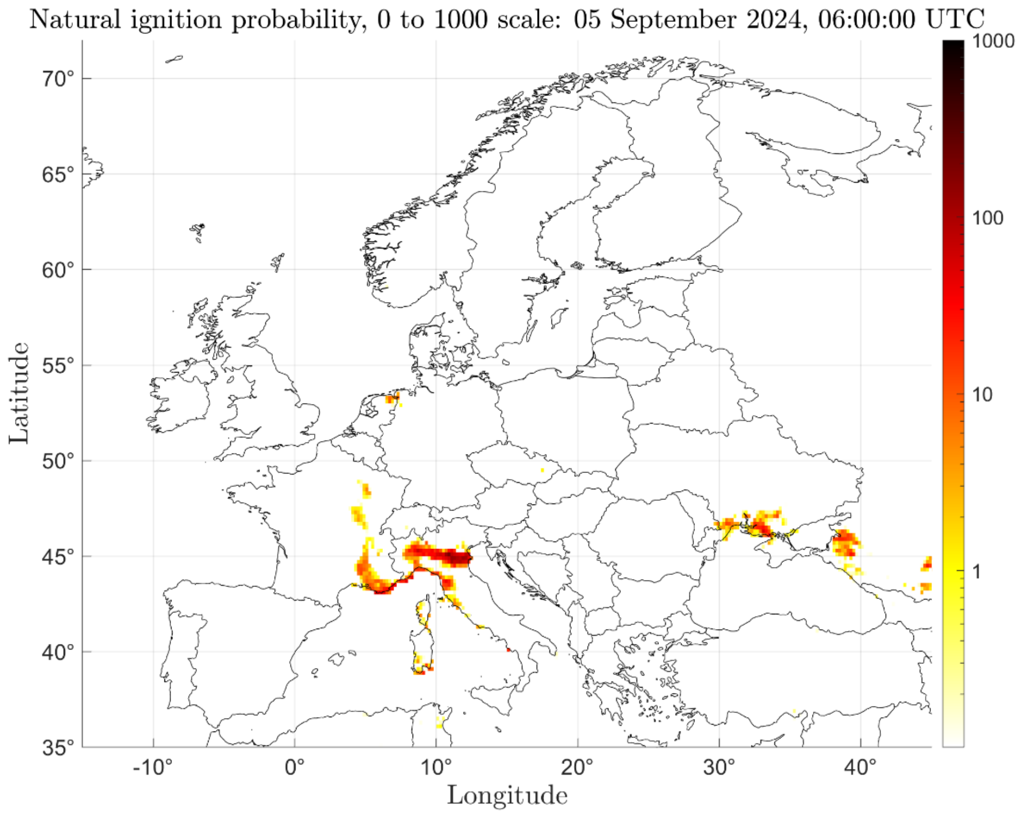


Figure 9: Example of product output on the European Territory

3.1.3 Live Fuel Moisture Content

3.1.3.1 Description

Radiative Transfer Model (RTM)-based Live Fuel Moisture Content (LFMC) product based on the Sentinel-3 Synergy and Sentinel-2 L2A surface reflectance product and a Look-Up Table (LUT)-based inversion procedure. The product was developed within the Activity "A1.1.1. Fire weather and fuel status prevention".

Fire risk component: Fuels

Contact details of the developer: Valerio Pampanoni

The product validation is still ongoing, and as such the database is not publicly available yet.

3.1.3.2 Technical components

Characteristics	Description
Type of products:	Geospatial Product
Units:	% moisture content
Update Frequency:	~Daily (Sentinel 3), ~Weekly (Sentinel 2)
Estimated Accuracy:	80-90%
Output Format:	.tiff, .nc
Temporal coverage:	2018-today (S3 Synergy) 2017-today (S2 L2A)
Spatial resolution:	300m (S3 Synergy), 10-20m (S2 L2A)

3.1.3.3 Methodology

This product is based on the inversion of Look-Up Tables (LUT) created using a combination of the PROSPECT-D, 4SAIL Radiative Transfer Models (RTMs) and a modified version of Huemmrich's GeoSail, and convolving the calculated reflectances in the Sentinel-3 SYNERGY and Sentinel-2 MSI channels. The LUTs change depending on the land cover type: PROSPECT-D and 4SAIL are used for grasslands and shrublands, while for forests the 4SAIL output is fed into the Geo component to simulate discontinuous vegetation. The LUT inversion is performed using Random Forest Regression algorithms.

3.1.3.4 Data Display

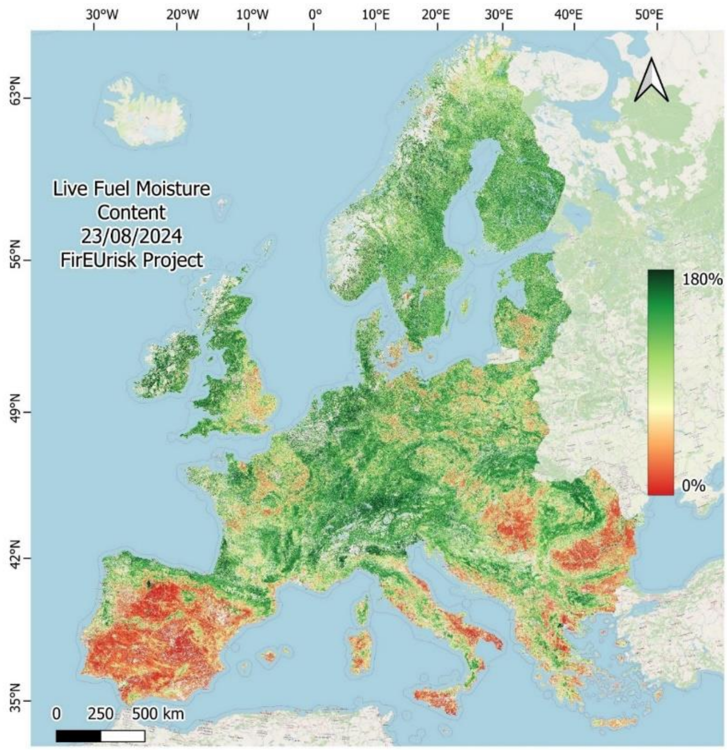


Figure 10: Example of product output on the European Territory on the 23rd of August 2024.

3.1.3.5 References

Pampanoni, V., Laneve, G., & Santilli, G. (2022). Evaluating Sentinel-3 Viability for Vegetation Canopy Monitoring and Fuel Moisture Content Estimation. In, IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium (pp. 5634-5637). Kuala Lumpur, Malasya: IEEE.

Pampanoni, Valerio, et al. (2023) "Early Validation of A Live Fuel Moisture Content Product Based on Sentinel-2 and Sentinel-3 Images." IGARSS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium. IEEE. https://doi.org/10.1109/IGARSS52108.2023.10281970.

Yebra, M., Dennison, P., Chuvieco, E., Riaño, D., Zylstra, P., Hunt, E.R., Danson, F.M., Qi, Y., & Jurdao, S. (2013). A global review of remote sensing of live fuel moisture content for fire danger assessment: moving towards operational products Remote Sensing of Environment 136, 455-468.

3.1.4 Fuel classification and map

3.1.4.1 Description

The European fuel map is a raster layer representing the first-level fuel types of the FirEUrisk fuel classification system for the continental scale. It was generated through the integration of existing land cover datasets and bioclimatic modelling. Then, it was smoothed and resampled to the target spatial resolution (1 km). Finally, it was validated using LUCAS (Land Use and Coverage Area frame Survey), Google data, and the GlobeLand30 map. Further information can be found in the Product User Manual (PUM).

The European fuel map is part of the FirEUrisk project, which pretends to create a European integrated strategy for fire danger assessment, reduction, and adaptation.

Task in which it was carried out: A1.1.4

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses, University of Alcalá (UAH)

Is it publicly available? (Yes/No): Yes

If the affirmative case, include downloading address: https://doi.org/10.21950/YABYCN

3.1.4.2 Technical components

Characteristics	Description
Type of products:	Geospatial layer / document (Product User Manual)
Units (if categorical data, include the description of each category):	Forest 1121 Deciduous broad leaf open forest 1122 Deciduous broad leaf closed forest 1211 Needleleaf Evergreen Open 1212 Needleleaf Evergreen Closed 1301 Mixed Open Forest 1302 Mixed Closed forest Shrub 21 low 22 medium 23 high Grass 31 Low 32 Medium 33 High Crop 41 Herbaceous 42 Woody Wetland 51 Tree 52 Shrubland 53 Grassland Urban 61 Continuous urban fabric 62 Discontinuous urban fabric
Update Frequency:	No update
Estimated Accuracy:	81%
Output Format:	.tif
Temporal coverage:	Circa 2019
Spatial resolution:	1 km

3.1.4.3 Methodology

The European fuel map was generated through the integration of existing land cover datasets and bioclimatic modelling. Then, it was smoothed and resampled to the target spatial resolution (1 km). Finally, it was validated using

LUCAS (Land Use and Coverage Area frame Survey), Google data, and the GlobeLand30 map. Further information can be found in the Product User Manual (PUM).

3.1.4.4 Data display

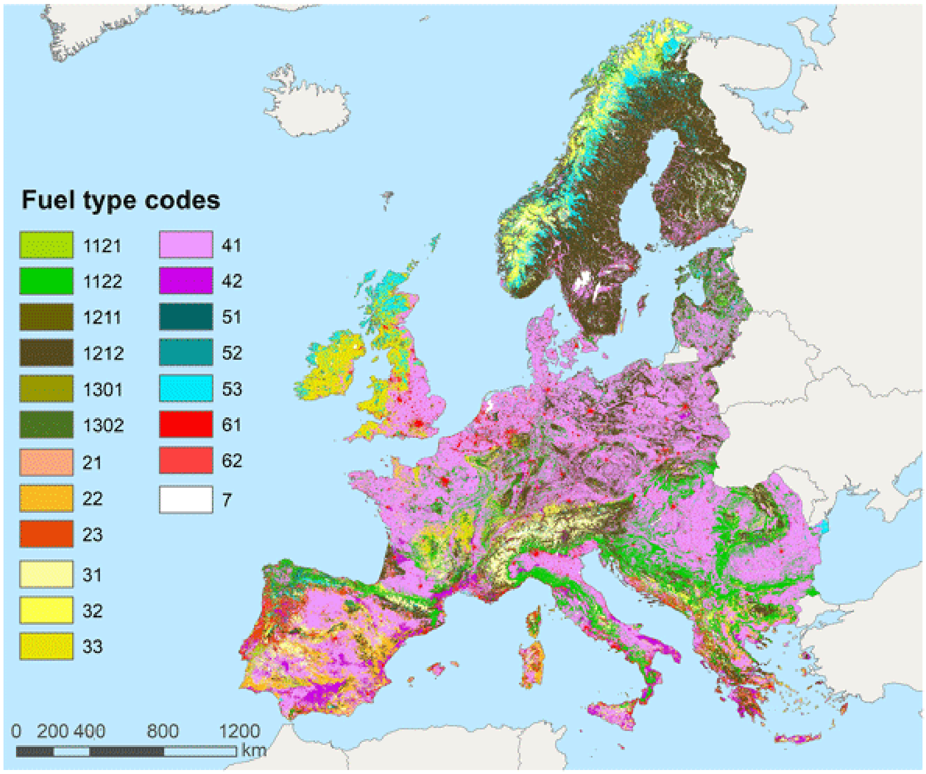


Figure 11: European Fuel Map

3.1.4.5 References

Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E. (2023) Classification and mapping of European fuels using a hierarchical, multipurpose fuel classification system, Earth System Science Data, 15, 1287–1315, https://doi.org/10.5194/essd-15-1287-2023.

3.1.5 Canopy fuel parameters

3.1.5.1 Description

The dataset of European canopy fuel parameters, at 1 km spatial resolution, encompasses a total of 6 maps including: forest canopy height, canopy cover and canopy base height, along with their associated uncertainties. They have been generated by integrating the Global Ecosystem Dynamics Investigation sensor (GEDI) with other sensors. Further details about the generation of these maps can be read in Aragoneses et al. (2024). These maps complement the categorical information of the FirEUrisk European fuel type map for the forest fuel types of Aragoneses et al. (2023).

Task in which it was carried out: A1.1.4

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses, University of Alcalá (UAH)

Is it publicly available? (Yes/No): Yes

If the affirmative case, include downloading address: https://doi.org/10.21950/KTALA8

3.1.5.2 Technical components

Characteristics	Description
Type of products:	6 Geospatial layers
Units (if categorical data, include the description of each category):	Canopy height and its uncertainty: metres Canopy cover and its uncertainty: Parts per unit (which is the same as percentage expressed as decimal) Canopy base height and its uncertainty: metres.
Update Frequency:	No update
Estimated Accuracy:	The GEDI RH80 metric had the strongest correlation with Canopy height for all fuel types (r = 0.96-0.97, Bias = -0.16-0.30 m, RMSE = 1.53-2.52 m, rRMSE = 13.23-19.75 %). A strong correlation was also observed between ALS-canopy cover and GEDI-canopy cover (r = 0.94, Bias = -0.02, RMSE = 0.09, rRMSE = 16.26 %), whereas weaker correlations were obtained for canopy base height estimations based on forest inventory data (r = 0.46, Bias = 0 m, RMSE = 0.89 m, rRMSE = 39.80 %). Spatial extrapolation (r = 0.72-0.82, Bias = -0.18-0.29 m, RMSE = 3.63-4.18 m and rRMSE = 28.43-30.66 % for canopy height; r = 0.82-0.91, Bias = 0, RMSE = 0.07-0.09 and rRMSE = 10.65-14.42 % for canopy cover; r = 0.62-0.75, Bias = 0.01-0.02 m, RMSE = 0.60-0.74 m and rRMSE = 19.16-22.93 % for canopy base height).
Output Format:	.tif
Temporal coverage:	Circa 2020
Spatial resolution:	1 km

3.1.5.3 Methodology

Spatially explicit data on forest canopy fuel parameters provide critical information for wildfire propagation modelling, emission estimations and risk assessment. We developed a two-step, easily replicable methodology to estimate forest canopy fuel parameters (canopy height, canopy cover and canopy base height) for the entire European territory, based on data from the GEDI sensor, onboard the International Space Station (ISS). First, we simulated GEDI pseudo-waveforms from discrete airborne laser scanning (ALS) data over forest plots. We then used metrics derived from the GEDI pseudo-waveforms to estimate mean canopy height, canopy cover and canopy base height, for which we used national forest inventory and airborne Light Detection and Ranging (LiDAR) as reference data. The second stage was to generate wall-to-wall maps of canopy fuel parameters at 1 km resolution using a spatial interpolation of GEDI-based estimates for polygons with GEDI footprints within. For those polygons for which GEDI observations were not available (mainly Northern latitudes, above 51.6ºN), the parameters were estimated using random forest regression models based on multispectral and SAR imagery and biophysical variables. Uncertainty maps for the estimated parameters were provided at the grid level, considering the propagation of individual errors for each step in the methodology. The final outputs provide a wall-to-wall estimation for the continent of Europe of three critical parameters for modelling crown fire propagation potential and demonstrate the capacity of GEDI observations to improve the characterisation of fuel models.

3.1.5.4 Data display

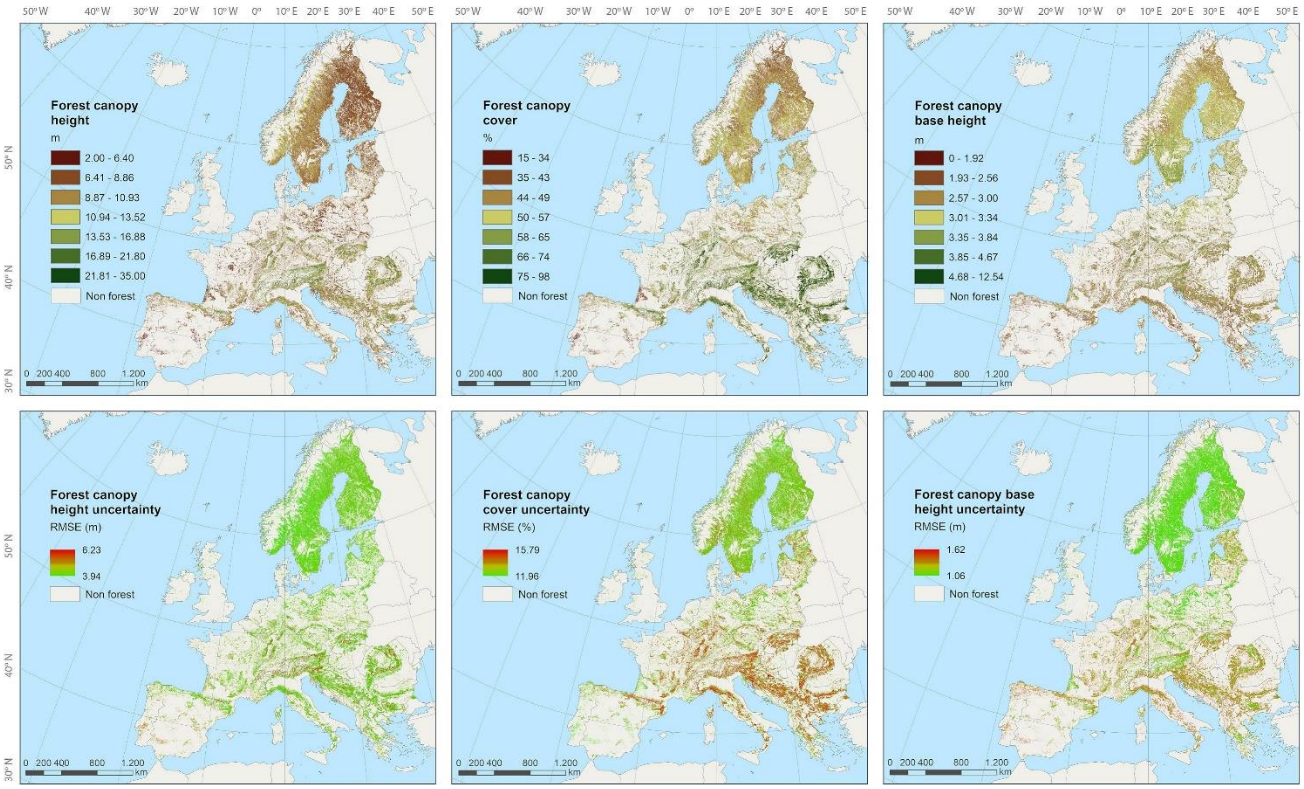


Figure 12: Maps of forest canopy height, canopy cover and canopy base height (above) with their corresponding uncertainty (below).

3.1.5.5 References

Aragoneses, E., García, M., Ruiz-Benito, P., and Chuvieco, E. (2024) Mapping forest canopy fuel parameters at European scale using spaceborne LiDAR and satellite data, Remote Sensing of Environment, 303, 114005.

Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E. (2023) Classification and mapping of European fuels using a hierarchical, multipurpose fuel classification system, Earth System Science Data, 15, 1287–1315, https://doi.org/10.5194/essd-15-1287-2023.

3.1.6 Canopy fuel load and canopy bulk density

3.1.6.1 Description

The dataset of European canopy fuel parameters, at 1 km spatial resolution, encompasses a total of 4 maps including: forest canopy fuel load and canopy bulk density, along with their associated uncertainties. They have been generated by integrating GEDI with other sensors. Further details about the generation of these maps can be read in Aragoneses et al. (2024, in review). These maps complement the categorical information of the FirEUrisk European fuel type map for the forest fuel types in Aragoneses et al. (2023) and the European maps of forest canopy height, canopy cover and canopy base height in Aragoneses et al. (2024).

Task in which it was carried out: A1.1.4

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses, University of Alcalá (UAH)

Is it publicly available? (Yes/No): Not yet (after the publication is accepted, it will be)

3.1.6.3 Technical components

Characteristics	Description
Type of products:	4 Geospatial layers
Units (if categorical data, include the description of each category):	Canopy fuel load and its uncertainty: kg/m^2 Canopy bulk density its uncertainty: kg/m^3
Update Frequency:	No update
Estimated Accuracy:	Estimation of CFL and CBD at the footprint level (CBD r = 0.6 – 0.86 and RMSE = 33.1 – 59-6 %) Spatial extrapolation (CFL r = 0.85 and RMSE = 12.98 %; CBD r = 0.75 and RMSE = 21 %)
Output Format:	.tif
Temporal coverage:	Circa 2020
Spatial resolution:	1 km

3.1.6.4 Methodology

We integrate satellite LiDAR observations of the GEDI sensor, with multispectral (Landsat 8) and radar (Phased Array L-band Synthetic Aperture Radar sensor – PALSAR) images, and biophysical data to provide spatially-explicit estimates of two key descriptors of crown fire behaviour – canopy fuel load (CFL) and canopy bulk density (CBD) – covering the whole European territory at 1 km^2 grid resolution. GEDI L1B and L2A level footprints were used to estimate Leaf Area Density, from which CFL and CBD were subsequently derived. We then extrapolated the estimates to European areas not covered by GEDI using machine learning models with multispectral and radar imagery and biophysical variables. Pixel-level uncertainty for the spatial extrapolation was also estimated by modelling the root mean squared error of the spatial extrapolation models.

3.1.6.5 Data display

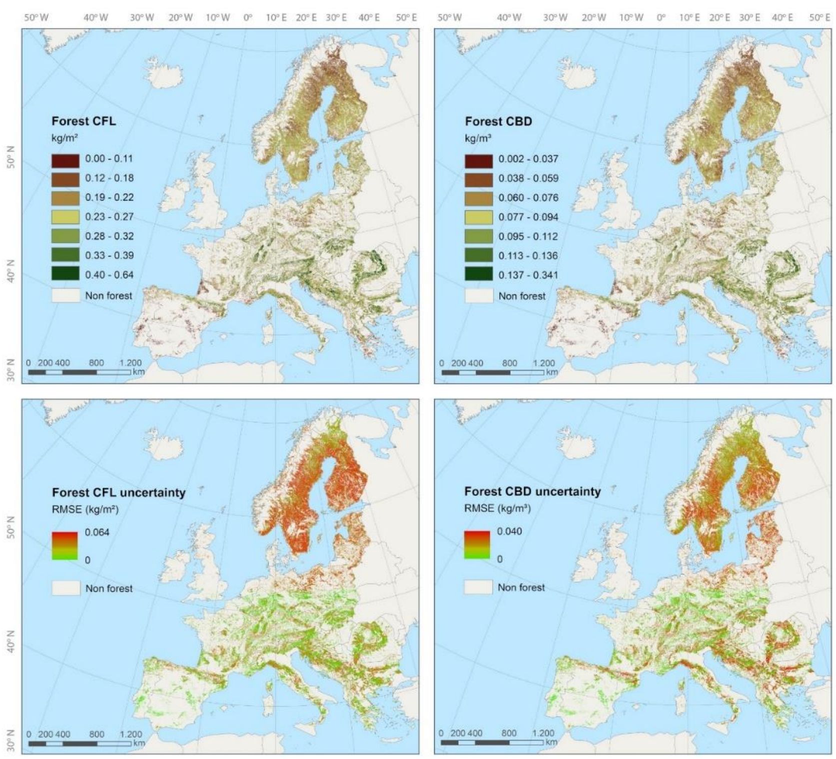


Figure 13: Maps of forest canopy fuel load (CFL) and canopy bulk density (CBD) (above) with their corresponding uncertainty (below).

3.1.6.6 References

Aragoneses, E., García, M., Ruiz-Benito, P., and Chuvieco, E. (2024) Mapping forest canopy fuel parameters at European scale using spaceborne LiDAR and satellite data, Remote Sensing of Environment, 303, 114005.

Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E. (2023) Classification and mapping of European fuels using a hierarchical, multipurpose fuel classification system, Earth System Science Data, 15, 1287–1315, https://doi.org/10.5194/essd-15-1287-2023.

Aragoneses, E., García, M.; Tang, H. and Chuvieco, E. (2024) A multi-sensor approach allows confident mapping of forest canopy fuel load and canopy bulk density to assess wildfire risk at the European scale, Remote Sensing of Environment. (in review)

3.1.7 Propagation potential indicators

3.1.7.1 Description

This product includes GeoTIFF raster maps of propagation potential indicators for European Territory, as well as reports with detail description of methodology and obtained results. Propagation potential for EU territory is calculated in 1 km^2 resolution, based on past fires on EU territory from Jan 1st, 2001 to Dec 31st, 2019; fires larger than 2000 ha were selected. Outputs are typical surface fire propagation potential indicators, as well as crown fire propagation potential indicators.

Task in which it was carried out: A1.1.5, *Analysis of fire propagation, fuel consumption and smoke emission as risk factors*

Fire risk component: Fuel

Contact details of the developer: FESB SPLIT

Is it publicly available? (Yes/No): Yes

3.1.7.2 Technical components

Characteristics	Description
Type of products:	Geospatial product
Units:	Not applicable
Update Frequency:	If needed
Accuracy:	To be defined
Output Format:	.tiff
Fire risk component (accordingly to the Integrated Scheme of the FirEUrisk project):	Propagation / Vulnerability
Temporal coverage:	Static layers
Spatial resolution:	1 km x 1 km
Availability on FirEUrisk platform:	Yes in FirEUrisk DataHub.

3.1.7.3 Methodology

Propagation potential for EU territory is calculated in 1 km2 resolution, based on custom implementation of Rothermel's surface fire model and various crown fire models (in Python) for cell-based wildland landscape fire growth simulations. From the list of past fires on EU territory from Jan 1st, 2001, to Dec 31st, 2019, fires larger than 2000 ha were selected. There were 403 of such fires. For their dates, maps of meteorological parameters were extracted from ERA5 and resampled to 1 km resolution. 10h Fuel Moisture Content and wind speed were calculated for each date, based on two weather scenarios: average weather conditions (50th percentile) and extreme weather conditions (5th percentile for fuel moisture and 95th percentile for wind speed). Input maps were wind speed and direction, 10h dead fuel moisture, slope, aspect, fuel models, Canopy Cover (CC), Canopy Height (CH), Canopy Base Height (CBH) and Canopy Bulk Density (CBD). Outputs are typical surface propagation potential indicators: Rate of Spread – R [m/s], Reaction intensity – RI [kW/m2], Fireline Intensity – FI [kW/m] and Flame Length – FL [m] and crown fire propagation potential indicators: Crown Fraction Burned (CFB) [fraction], Crown Fire Activity (CFA), Crown Fire Rate of Spread [m/s], Crown Fire Heat per Unit Area [kJ/m^2], Crown Fire Flame Length (m) and Crown Fire Fireline Intensity [kW/m].

3.1.7.4 Proved accuracy at European Territory

The same as accuracy of input maps (fuel maps, weather data maps).

3.1.7.5 Validation/testimonial of local end-users

Internal Quality Control: Internal validation by historical fires. External stakeholder validation: Firefighters of Dalmatia Counties that use wildfire surveillance and monitoring system.
Satisfaction questionnaires on product usability filled in by the stakeholder.

3.2 Vulnerability Products

3.2.1 Ecological values

3.2.1.1 Description

The product is a raster TIFF layer with a spatial resolution of 1 km, providing current ecological value data across Europe. This dataset offers up-to-date information, making it suitable for contemporary environmental analyses and applications.
Task in which it was carried out: Task 1.2.
Fire risk component: The ecological values are part of the ecological vulnerability to wildfires.
Contact details of the developer: Fátima Arrogante Funes
Is it publicly available? (**Yes**/No)
If the affirmative case, include downloading address: It is available for download upon request by contacting us.

3.2.1.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units	0-1000, from low ecological values to high ecological values
Update Frequency:	10 years
Estimated Accuracy:	NA
Output Format:	GeoTIFF
Temporal coverage:	2020
Spatial resolution:	1km

3.2.1.3 Methodology

The methodology used for ecological values assessment (EVA) is based on characterising the ecosystems' biological distinctiveness (BD) and conservation status (CS) (Figure 14) based on the methodology scheme proposed by Dinerstein et al., (1995). We stated that ecosystems hosting high taxonomic richness (Brun et al., 2019) or rare plant communities, or habitats of endangered species highly contribute to their value through their enhanced functioning. The destruction or degradation of these valued ecological components, notably by fires, can have long-term implications for ecosystem health and conservation (Sritharan et al., 2022).

The previously described indicators (from BD and CS) were introduced in the Principal Components Analyses (PCA) model (Andersen et al., 2009), taking the positive direction for values close to 1000 and negative for those close to 0. Species richness, forest productivity, density of habitat, key biodiversity areas, exceptional forest, unique habitat preservation and places of special conservation conserve the original direction. In contrast, the human pressure and loss of forest indicators inverse the direction, taking values close to 1000 where human pressure and loss of forest values were low. Regarding the previous explanation, we selected the first PCA because it represents the synergies between conservation status and biological distinctiveness. For example, zones with fewer roads and railways and a loss of forest cover conserve better ecological values.

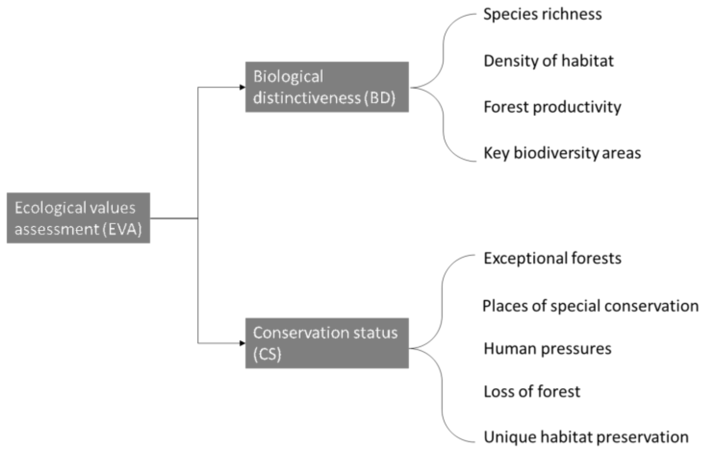


Figure 14: Components of the estimation of ecological values

3.2.1.4 Data display

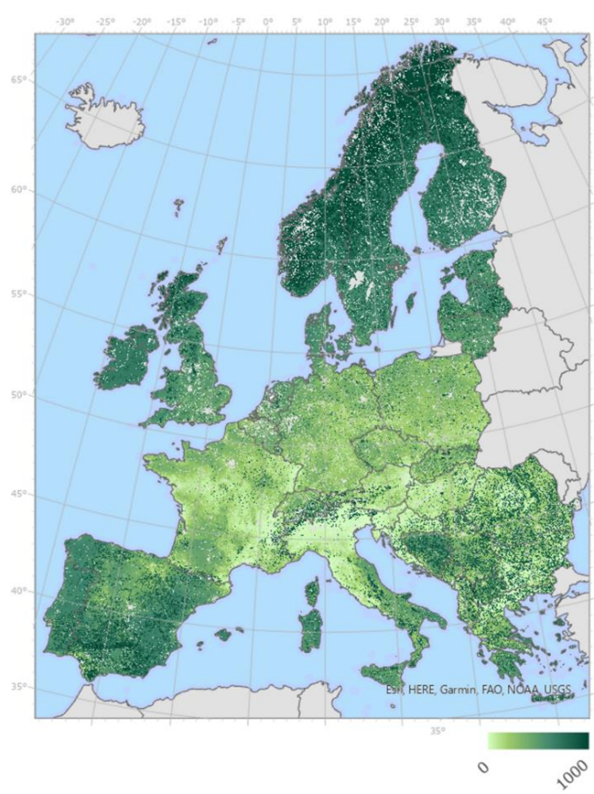


Figure 15: Map of ecological value assessment (EVA) in Europe, scaled from 0 (low value) to 1000 (maximum value). Zones with 0 values were related to areas not considered in this study, such as crops or urban areas.

3.2.1.5 References

Andersen, T., Carstensen, J., & Hernandez-Garcia, E., Duarte, C. M. (2009). Ecological thresholds and regime shifts: approaches to identification. Trends in Ecology & Evolution, 24(1), 49–57.

Arrogante-Funes, F., Aguado, I., & Chuvieco, E. (2022). Global assessment and mapping of ecological vulnerability to wildfires. Natural Hazards Earth Systems Sciences, 22, 2981-3003.

Arrogante-Funes, F., Mouillot, F., Moreira, B., Aguado, I. & Chuvieco, E. (2024). Mapping and assessment of ecological vulnerability to wildifres in Europe. Fire Ecology (in press).

Brun, P., Zimmermann, N. E., Graham, C. H., Lavergne, S., Pellissier, L., Münkemüller, T., & Thuiller, W. (2019). The productivity-biodiversity relationship varies across diversity dimensions. Nature Communications, 10(1), 5691. https://doi.org/10.1038/s41467-019-13678-1

Dinerstein, E., Olson, D., Graham, D., Webster, A., Pimm, S., Bookbinder, M., & Ledec, G. (1995). A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean. World Bank.

Sritharan, M. S., Scheele, B. C., Blanchard, W., Foster, C. N., Werner, P. A., & Lindenmayer, D. B. (2022). Plant rarity in fire-prone dry sclerophyll communities. Scientific Reports, 12(1), 1–10. https://doi.org/10.1038/s41598-022-15927-8

3.2.2 Recovery time

3.2.2.1 Description

Ecosystem recovery time (RT) refers to the time (in years) needed for the vegetation component of the ecosystem (dominant tree species present within pixels referenced as forests, or vegetation types for shrubland, grasslands and croplands) to fully recover from a fire event. RT includes both the recovery starting time (RST) and growth rate (GR). RST is the time needed for a species to get the sufficient seed bank to start germination and grow and can be slightly negative for species resprouting from the basal root system to highly negative for species resprouting from apical buds. RST was locally modified with management strategies and climate. GR was derived from standard forest growth models locally modified with climate.

Task in which it was carried out: Task 1.2 Exposure and vulnerability

Fire risk component: Ecological Vulnerability

Contact details of the developer: Florent MOUILLOT, IRD

Is it publicly available? (Yes/No) Yes

If the affirmative case, include downloading address: upon request to the developer.

3.2.2.2 Technical components

Characteristics	Description
Type of products:	Geospatial / document
Units (if categorical data, include the description of each category):	Years
Update Frequency:	No
Estimated Accuracy:	NA
Output Format:	Geotiff
Temporal coverage:	NA
Spatial resolution:	1km

3.2.2.3 Methodology

The EU scale recovery time (RT) at 1km resolution, was generated from Corine Land cover identifying forests, shrublands, grasslands, croplands and other areas (non-burnable), potential tree species distribution, and their functional traits related to post-fire regeneration strategy and growth rate. RT was decomposed into regeneration starting time (RST) and growth rate (GR).

For RST, we collected information on tree species vegetative (resprouting) or seedling emergence (serotiny, seed dispersal) response strategies (Archibald et al. 2019). We attributed an RST value of -25 years for **fire-tolerant** species regenerating from trunk buds and -10 years for **fire-tolerant** species resprouting from belowground material. For species regenerating from the seed bank surviving the fire, we attributed an RST value of 0. Finally, for species without resprouting ability nor post-fire germination from the seed bank, we considered a colonisation delay (0 to 20 years) as the time needed for seeds to be dispersed from neighbouring unaffected ecosystems. Dispersal efficiency was related to seed mass, dispersal strategies and maximum distances (Vargas et al., 2023, Table A2). For species carrying multiple strategies, we kept the lowest RST between the strategies. RST was locally modified by climate, soil erosion, forest management potentialities, and topography.

For GR, we used each species' yearly growth rate (GR, m.year-1) and maximum tree height (THMAX, m) from forest growth models (Schworer et al. 2014) to derive the Relative Growth Rate RGR (%HMAX.year-1), and derive the time needed for a species to reach its maximum height (RT in years = 1/RGR). GR was locally modified by environmental constraints of Mean Annual Temperature, Mean Annual Precipitation and Soil available water Capacity.

3.2.2.4 Data display

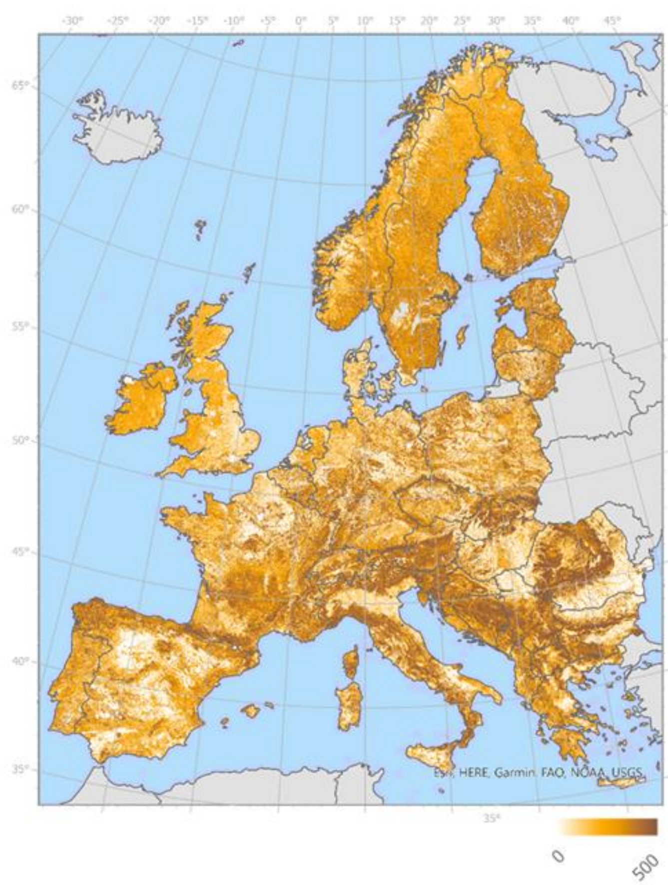


Figure 16: Map of Recovery Time (in years after fire) over Europe

3.2.2.5 References

Archibald, S., Archibald, S., Hempson, G. P., & Lehmann, C. (2019). Research review A unified framework for plant life-history strategies shaped by fire and herbivory. https://doi.org/10.1111/nph.15986

Schwrorer C., Henne PD, Tinner W. (2014). A model-data comparison of Holocene timberline changes in the Swiss Alps reveals past and future drivers of mountain forest dynamics. Gobal change biology, 20 (5) : 1512-1526. https://doi.org/10.1111/gcb.12456

Vargas, P., Heleno, R., & Costa, J. M. (2023). EuDiS - A comprehensive database of the seed dispersal syndromes of the European flora. Biodiversity Data Journal, 11. https://doi.org/10.3897/BDJ.11.E104079

3.2.3 Coping Capacity

3.2.3.1 Description

Ecosystem Coping Capacity refers to the ability of the vegetation component of the ecosystem (dominant tree species present within pixels referenced as forests, or vegetation types for shrubland, grasslands and croplands) to resist a fire event. Values vary between 0 for fully killed individuals to 1 for fully resistant species not affected by the fire.

Task in which it was carried out: Task 1.2 Exposure and vulnerability

Fire risk component: Ecological Vulnerability

Contact details of the developer: Florent MOUILLOT, IRD

Is it publicly available? (Yes/No) Yes

If the affirmative case, include downloading address: Upon request to the developer

3.2.3.2 Technical components

Characteristics	Description
Type of products:	Geospatial / document
Units (if categorical data, include the description of each category):	Fraction (0-1)
Update Frequency:	No
Estimated Accuracy:	NA
Output Format:	Geotiff
Temporal coverage:	NA
Spatial resolution:	1km

3.2.3.3 Methodology

The EU scale coping capacity at 1km resolution, was generated from Corine Land cover identifying forests, shrublands, grasslands, croplands and other areas (non-burnable), potential tree species distribution, and their functional traits acknowledged as contributing to fire survival (bark thickness, tree height, basal crown height) (Stevens et al. 2020). Pixel's coping capacity resulted from the mean of the specific coping capacities of species present in the pixel. Grasslands, croplands and shrublands/heathlands were assumed as fully burned (coping capacity = 0) during fire events, Species coping capacity was finally linearly reduced according to higher fire intensity.

3.2.3.4 Data display

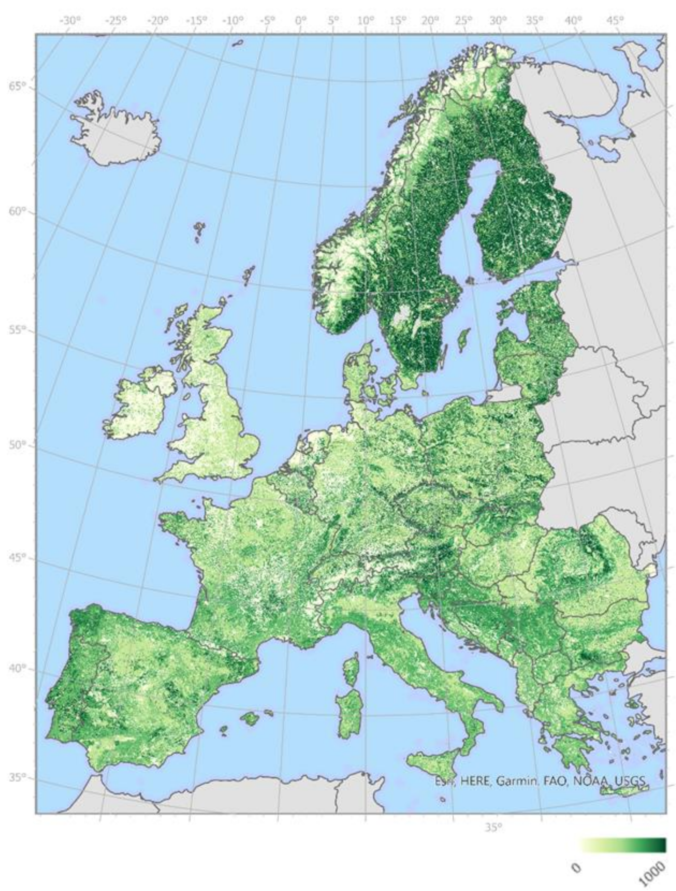


Figure 17: Map of the ecosystems' Coping Capacity to fire over Europe (0 non-resistance, 1000 high resistance).

3.2.3.5 References

Stevens J.T., Klinh M.M., Schwilk D.W., Varner J.M., Kane J.M. 2020. Biogeography of fire regimes in western U.S. conifer forests: A trait-based approach. Global Ecology and Biogeography 29(5):944-955.

3.2.4 Ecosystem services

3.2.4.1 Description

This product is about economic values of expected damages by wildfires for the European Territory assessed for different assets (some provisioning services such as agricultural and forestry goods; regulating ecosystem services such as pollination, carbon sequestration and soil erosion; and manufactured capital such as properties). Values are mapped and reported at a resolution of 1 km^2 for the year 2021.

Task in which it was carried out: The product was made within the WP1 task 1.2.4.

Fire risk component: Vulnerability

Contact details of the developer: Simone Martino and Clara Ochoa

Is it publicly available? (Yes/No): not yet. When the maps will be finalised, they will be made available.

3.2.4.2 Technical components

Characteristics	Description
Type of products:	Geospatial / document
Units (if categorical data, include the description of each category):	Euros per hectare
Update Frequency:	not decided yet
Estimated Accuracy:	NA
Output Format:	Geotiff
Temporal coverage:	2021
Spatial resolution:	1 km2

3.2.4.3 Methodology

The approach used for the assessment of the potential damage of wildfires is based on the correction of the economic value of natural capital by a loss coefficient (ranging 0 to 1), function of the intensity of fire (Castillo et al., 2017) and the time of recovery of the asset (Roman et al., 2013). Coefficients of loss are measured in Spanish Mediterranean forests for timber (Molina et al, 2011; Rodríguez-Silva et al., 2012), carbon sequestration (Molina et al., 2019) and soil erosion (Gomez et al., 2009), and adapted to other assets (agricultural perennial crops) according to the judgement of the research team.

Economic values of natural capital (agricultural and forestry assets) are assessed by market-based approach (Martino et al., 2023). The values of regulating ecosystem services are taken by the INCA project (Vallecillo et al., 2018), while the value of properties is made by correcting national prices provided by *Numbeo*[1] by the local GDP per capita (Kummu et al., 2018). Details are provided by Martino et al. (2023).

We derived maps of damage for timber, livestock, fruit trees, olive groves and vineyards, assuming that the value of natural capital asset is lost for the time necessary for a specific asset to recover from wildfires. Recovery time for trees is variable from 50 to 200 years (Adámek et al. 2016). We have assumed 50 years as a reasonable time to assess the damage of timber. There is no information in the literature about the recovery time of fruit trees, olive groves and vineyards, therefore the choice of recovery time (5 years) was guided only by judgement of the research team. Recovery time for the damage of ecosystem services such as soil retention are measured assuming values proposed by Milazzo et al. (2022), ranging from 6 to 20 years. Adámek et al. (2016) is used to consider the recovery time of shrublands (6 years) as a proxy for pollination recovery, because shrubs are important habitats which pollinators depend on.

These damages are assessed as the present value of the future losses, assumed constant until the natural asset has fully recovered (Roman et al., 2013). A social discount rate of 3.5% is used (UK Gov, 2024).

Values of carbon sequestration are generated with an approach that considers the recovery of vegetation following a logistic curve (Mouillot et al., 2023; Chuvieco et al 2023). The parameters of the logistic curve are not empirically estimated, nor deduced from the literature, but proposed by the research team to test their sensitivity on the expected damage.

Damage to properties is assessed by correcting the property values by a coefficient of loss, which is function of the material of the property (concrete or wood) and the intensity of fire. These coefficients of loss are proposed by the research team but not yet validated.

All these damages are mapped at the scale of 1km^2 for the European Territory.

---

[1] https://www.numbeo.com/cost-of-living/

3.2.4.4 Data display

The map proposed (Figure 18) refers to the total damage of several natural capital assets (timber, livestock, fruit trees, olive groves, vineyards). Values are expressed in 2021 euros per hectare. The histogram of these values (Figure 19) shows that the average damage is just a few euros per hectare; however, the distribution of these values is skewed to the right with just a few pixels reporting vales from 20 to 30 thousand euros per hectare. The map shows that areas of particular damage are central Europe, the Alps, the Apennines, the Pyrenees, northern Portugal, Southern Spain and the Balkan Peninsula.

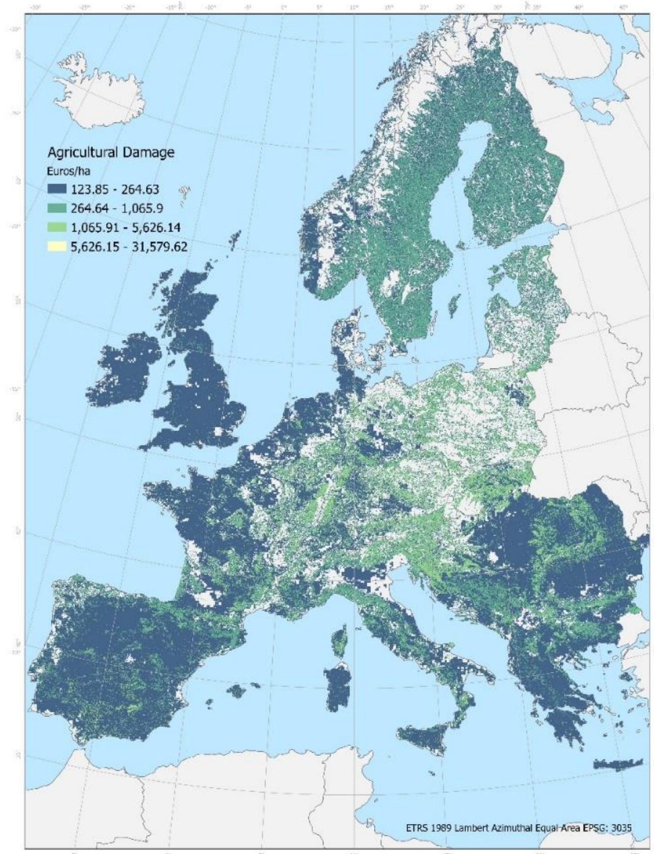


Figure 18: Map of the total damage of the agro-forestry values

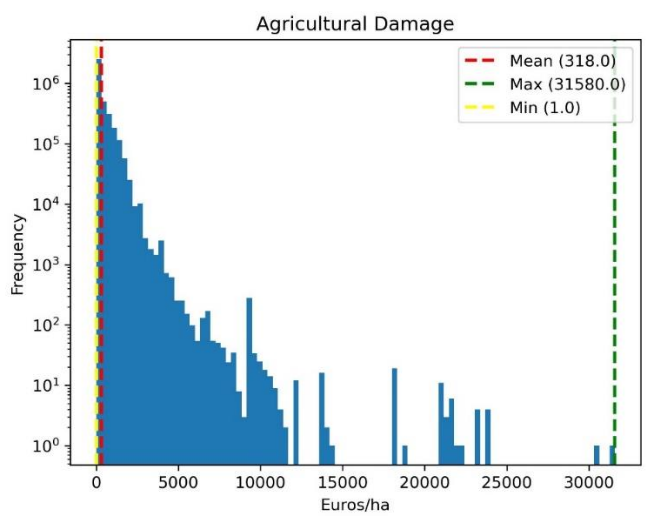


Figure 19: Histogram of the distribution of the damages reported in Figure 18

3.2.4.5 References

Adámek, M., Hadincová, V. and Wild, J., 2016. Long-term effect of wildfires on temperate Pinus sylvestris forests: Vegetation dynamics and ecosystem resilience. Forest Ecology and Management, 380, pp.285-295. La Notte, A. et al., 2021. Ecosystem Services Accounting – Part III - Pilot accounts for habitat and species maintenance, on-site soil retention and water purification Available at https://publications.jrc.ec.europa.eu/repository/handle/JRC126566.

Castillo, M.E., Molina, J.R., y Silva, F.R., García-Chevesich, P. and Garfias, R., 2017. A system to evaluate fire impacts from simulated fire behavior in Mediterranean areas of Central Chile. Science of the total environment, 579, pp.1410-1418.

Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Ramona Velea, Florent Mouillot, Juan R. Molina, Ana I. Miranda, Diogo Lopes, Michele Salis, Marin Bugaric, Mikhail Sofiev, Evgeny Kadantsev, Ioannis Gitas, Dimitris Stavrakoudis, George Eftychidis, Bar-Massada, A., Alex Neidermeier, Valerio Pampanoni, Pettinari, M.L., Arrogante, F., Ochoa, C., Moreira, B., & Viegas, D. (2023). Towards an integrated approach to wildfire risk assessment: when, where, what and how may the landscapes burn. Fire, 6, 215, https://doi.org/10.3390/fire6050215.

Gomez, E. and Alvarez, K., 2009. Forest fires: detection, suppression and prevention. Nova Science Publishers.

Kummu, M., Taka, M. and Guillaume, J.H., 2018. Gridded global datasets for gross domestic product and Human Development Index over 1990–2015. Scientific data, 5(1), pp.1-15.

Martino, S. et al. 2023. Economic Impacts of Fire – A Focus on Analysis of Economic Vulnerability of Natural and Human Capitals and proposal of an Integrated Capitals Approach to wildfire vulnerability. Chapter 7. Deliverable D1.4- Report on Methodological frameworks for vulnerability assessment. Available at https://fireurisk.eu/wp-content/uploads/2024/05/D1.4_FirEUrisk_ReportMethodologicalFrameworksVulnerability_V1.pdf.

Milazzo, F., P. Fernández, A. Peña, and T. Vanwalleghem. "The resilience of soil erosion rates under historical land use change in agroecosystems of Southern Spain." Science of The Total Environment 822, 153672.

Molina, J.R., Herrera, M.A., Zamora, R., Rodríguez y Silva, F., González-Cabán, A., 2011. Economic losses to Iberian swine production from forest fires. Forest Policy Econ. 13, 614–621.

Molina, J.R., Herrera, M.A. and y Silva, F.R., 2019. Wildfire-induced reduction in the carbon storage of Mediterranean ecosystems: An application to brush and forest fires impacts assessment. Environmental Impact Assessment Review, 76, pp.88-97.

Mouillot et at., 2023. Environmental Vulnerability and Resilience Assessment – A Focus on Ecological Vulnerability. Chapter 6. Deliverable D1.4- Report on Methodological frameworks for vulnerability assessment. Available at https://fireurisk.eu/wp-content/uploads/2024/05/D1.4_FirEUrisk_ReportMethodologicalFrameworksVulnerability_V1.pdf.

Rodríguez-Silva, F, Molina, J.R., González-Cabán, A. and Machuca, M.Á.H., 2012. Economic vulnerability of timber resources to forest fires. Journal of Environmental management, 100, pp.16-21.

Román, M.V., Azqueta, D. and Rodrígues, M., 2013. Methodological approach to assess the socio-economic vulnerability to wildfires in Spain. Forest Ecology and Management, 294, pp.158-165.

UK Gov. 2024. The green book 2022. Available at https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020#

Vallecillo, S., et al. 2018. Ecosystem services accounting. Part I Outdoor recreation and crop pollination. JRC technical reports. Available at https://publications.jrc.ec.europa.eu/repository/handle/JRC110321.

3.3 Integration of components

3.3.1 Integrated fire risk index (IRI)

3.3.1.1 Description

Brief description of the content: Includes the different components of fire risk developed within the project, integrating Danger, Exposure and Vulnerability.
Task in which it was carried out: The product developed within the Activity "A1.3 1: Integration of fire risk assessment".
Fire risk component: All
Contact details of the developer: Emilio Chuvieco, University of Alcalá.
Is it publicly available? Only prototype

3.3.1.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units (if categorical data, include the description of each category):	Probability scale 0 to 1000
Update Frequency:	Daily
Estimated Accuracy:	Unknown
Output Format:	.tif
Temporal coverage:	Tested in the summer of 2024
Spatial resolution:	1 km^2

3.3.1.3 Methodology

The product integrates the different components of risk developed within FirEUrisk to give a synthetic view of fire risk conditions for a specific moment and area. The input data includes static data (human ignition, exposure…) and dynamic components (weather conditions, fuel moisture…). Table 4 includes a list of inputs, which can be further documented with their respective products' cards. Figure 20 includes a graphical representation of the different components of risk considered in FirEUrisk.
The integration of the different components was based on quantitative weighting, considering the relative importance of each component in terms of extreme fire risk assessment. The integrated fire risk index (IRI), was computed by combining the Danger (D), Exposure (E) and Vulnerability (V), with the following formula:

$$IRI = (0.6*D + 0.4*V)*E$$

Danger was derived from Probability of Ignition and Propagation Potential. Vulnerability was derived from estimated social damages (including housing and ecosystem services) and ecological damages (including the coping capacity of plants and their recovery potential), by estimating the reduction of values (both ecosystem services and ecological values) that would occur in case the area is burned. The conditions of that burning depend on propagation estimates, considering weather conditions and fuel characteristics, particularly on Fire Line Intensity and Flame Length, which affect the degree of estimated post-fire severity. Exposure was estimated by considering burnable covers (weight 0.8), with an additional weight for those areas with Wildland-urban interface (weight 1), having a value of 0 the unburnable areas.

Table 4: Inputs to compute the Integrated Risk Index (IRI)

Variable	Units	Sources
TP, Temperature	º C	DWD-ICON7 data
Pp, Precipitation	mm	DWD-ICON7 data
WS, Wind speed	m/s	DWD-ICON7 data

Variable	Units	Sources
RH, Relative Humidity	%	DWD-ICON7 data
FT, Fuel types	Fuel classes	FirEUrisk fuel map
PNI, Probability of natural ignition	0/1000	Weather data and lightning
PHI, Probability of human ignition	0/1000	Human and biophysical factors
LFMC, Live fuel moisture content	% DW	Satellite data
E, Exposure	0, 0.8, 1	WUI, land cover
SEV, Value of Houses and Infrastructures	€/ha	Statistics
CL, Climatic regions	1-2 / No-Yes Med	Proxy of building materials
EST, Ecosystem service values	€/ha/year	Statistics
EVa, Ecological values	0/1000	Cartographic & vegetation databases
LEV, Potential loss of Ecological values	0/1000	Coping capacity, resistance
RT, Recovery time	years	Several species

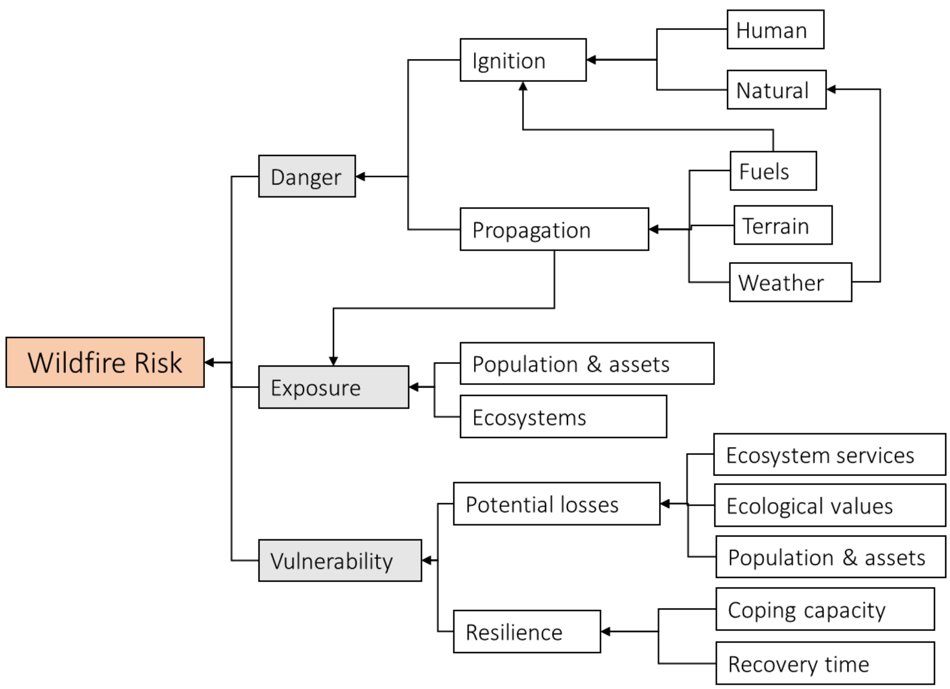


Figure 20: Conceptual integration of wildfire risk assessment components within the FirEUrisk project (after Chuvieco et al., 2023).

3.3.1.5 Data display

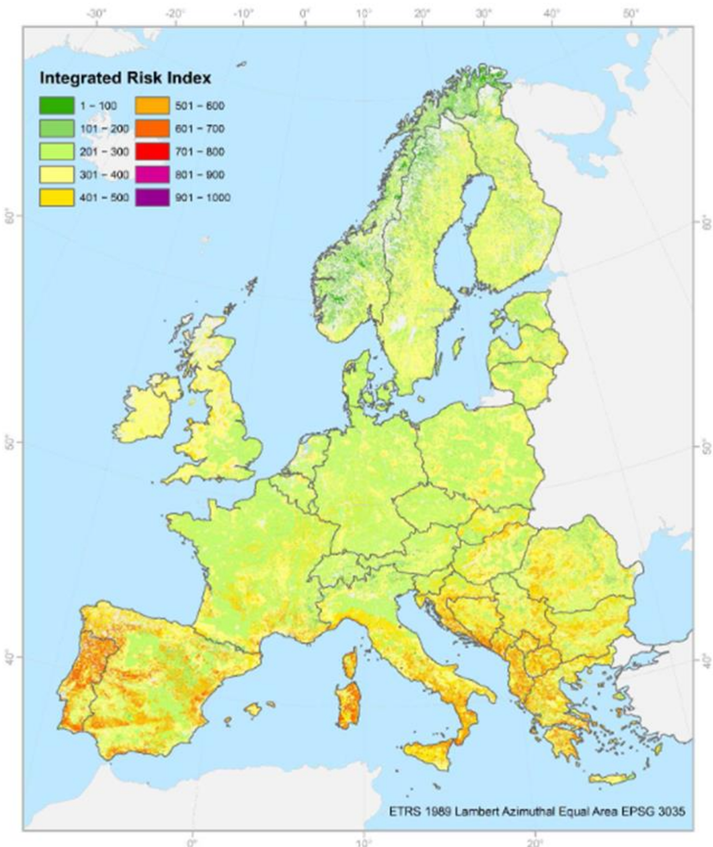


Figure 21: Example of IRI values for the extreme fire weather scenario

3.3.1.6 References

Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Ramona Velea, Florent Mouillot, Juan R. Molina, Ana I. Miranda, Diogo Lopes, Michele Salis, Marin Bugaric, Mikhail Sofiev, Evgeny Kadantsev, Ioannis Gitas, Dimitris Stavrakoudis, George Eftychidis, Bar-Massada, A., Alex Neidermeier, Valerio Pampanoni, Pettinari, M.L., Arrogante, F., Ochoa, C., Moreira, B., & Viegas, D. (2023). Towards an integrated approach to wildfire risk assessment: when, where, what and how may the landscapes burn. Fire, 6, 215, https://doi.org/10.3390/fire6050215.

3.4 Mitigation Products

3.4.1 Maps of Suitability of Fuel-Relevant Land Management Strategies in Europe

3.4.1.1 Description

This product includes a set of maps which summarize suitable areas for the use of three relevant fire reduction land management strategies (FRLMS) aimed to reduce fuel cover and fuel load —herbivory, mechanical removal, and prescribed burn—at the landscape-scale in Europe as part of WP2, Task 2.2, Deliverable 2.4, under the risk reduction activity, oriented to the components of Danger-> Propagation-> Fuels, fire risk component of the integrated project strategy. Full details on the biophysical, socioeconomic, and environmental factors which can contribute to the uptake and success of the FRLMS, including a summary of the methodology; decision trees for choosing suitable FRLMS; maps of FRLMS-suitable areas (as published in Neidermeier et al., 2023; and maps of hot-spots of ecosystem function (here used as an umbrella term which includes biodiversity and carbon storage) and wildfire occurrence (publication in review) in Europe can be found in deliverable 2.4.

The paper and data can be downloaded at: https://doi.org/10.1016/j.jenvman.2023.118941 and https://doi.org/10.34894/JQS5MD.

For further details, please contact Alex Neidermeier.

3.4.1.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units (if categorical data, include the description of each category):	Suitability of each FRLMS per square kilometre
Update Frequency:	NA
Estimated Accuracy:	NA
Output Format:	.tiff
Temporal coverage:	EU wide
Spatial resolution:	1km

3.4.1.3 Methodology

A semi-systematic literature review identified constraints and opportunities of adopting different FRLMS to reduce wildfire risk in Europe. Although more than ten strategies were identified, we narrowed our study to those most frequently referenced in the literature to provide the broadest evidence base; selecting those which targeted fuels and biomass reduction by way of land management specifically (instead of land-use changes, e.g., replacement of species, construction of vegetation mosaics or fire breaks). Spatially explicit suitability factors for the adoption of the three FRLMS were defined based on the results. In summary, the suitability map for herbivory encompasses areas which (1) have greater presence or diversity of domesticated or wild ungulate grazers or browsers; (2) have greater accessibility to livestock and can allow for transportation of livestock products; (3) have a greater share of suitable pasture. The suitability for mechanical fuel removal, including pruning, silvicultural activities, and extraction for industry, was represented by areas with (1) greater forest biomass availability; (2) greater proximity to documented biomass conversion powerplants; (3) greater accessibility for transportation of raw materials and products; and (4) were located on suitable degrees of slope for machine and labor access. Finally, suitability for prescribed burning reflects areas with (1) a greater number of days with safe and effective prescribed burn conditions, considering the ecological impact as well ('prescribed burn days,' or PBD); (2) greater accessibility to allow for transport of equipment and labor; and (3) sufficient distance from major settlements (which may be adversed to resulting smoke). We used a static Wildfire Danger by Thermal Anomaly (WDTA) dataset, developed by EFFIS (https://effis.jrc.ec.europa.eu/apps/fire.risk.viewer/), to prioritize the results by areas most affected by wildfire in Europe. The full methodology and results of the literature review can be found in FirEUrisk Deliverable 2.3 ("Guidelines for Land Management Strategies: Applicability, socioeconomics and environmental concerns") and in the 2023 publication by Neidermeier et al.

3.4.1.4 Data display

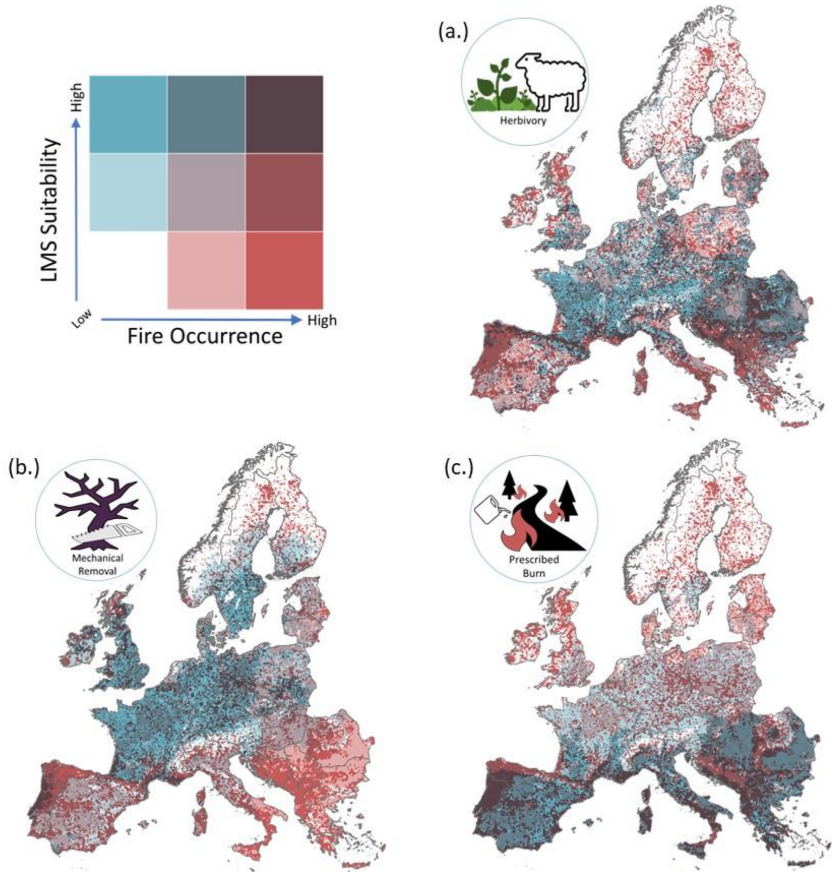


Figure 22: Bivariate choropleth maps of suitability of (a.) herbivory, (b.) mechanical fuel removal, and (c.) prescribed burn which overlap with areas of differing fire occurrence in Europe. Areas in white had low FRLMS suitability and low fire occurrence

3.4.1.5 References

Neidermeier, A.N., Zagaria, C., Pampanoni, V., West, T.A.P., & Verburg, P.H. (2023). Mapping opportunities for wildfire hazard reduction in Europe through targeted land management strategies. Journal of Environmental Management 346, 118941.

3.5 Future fire risk conditions products

3.5.1 Continental land-use change scenarios and stylized fuel management scenarios

3.5.1.1 Description

For Deliverable 3.2, we created a blended land use dataset spanning the years from 1960 to 2050 at a 9 km2 resolution and a consolidated legend with seven land use classes. This dataset is a key input for the Dynamic Global Vegetation Models (DGVMs) which have been coupled with fire spread models (e.g., SPITFIRE) to explore how burned area, carbon emissions, and vegetation (amongst other variables) may respond to several global socioeconomic and climate scenarios. The blended land use dataset was developed using historic land use from 1960-2015 using HILDA+ (Winkler et al., 2021) and simulated land use to 2050 using the CLUMondo model. The blended product incorporated variables critical to fuel distribution across European landscapes, such as afforestation, forest fragmentation, and land abandonment, which will in turn improve the ability of the DGVMs to simulate future fire regimes.

3.5.1.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units:	Land cover classes
Update Frequency:	Static
Accuracy:	N/A
Output Format:	.tiff
Fire risk component (accordingly to the Integrated Scheme of the FirEUrisk project):	Risk Adaptation
Temporal coverage:	1960-2050 (decadal)
Spatial resolution:	9 x 9 km
Availability on FirEUrisk platform:	All data can be found on DataverseNL[2]
Key contact for questions	Alex Neidermeier

3.5.1.3 Methodology

Historic baseline data developed in HILDA+ combines several open data streams (remote sensing, reconstructions and statistics) to estimate historic land use change at 1 km^2. The CLUMondo future scenarios were generated by dynamically allocating anticipated resource demands to European areas deemed suitable. The demands given to CLUMondo are based on outputs from global, macroeconomic GLOBIOM model output for Shared Socioeconomic Pathways (SSP) 1, "Sustainability", and SSP3, "Regional rivalry" (Figure 23). Europe is split and run as four separate regions in CLUMondo-North, South, East, and West with different demands within each region. While the time series is based on a 1 km resolution, we made a conversion in aggregating the data to a 9 km resolution and an aggregated land cover class legend to match that used natively in the DGVMs.

3.5.1.4 Overview of Results

Under SSP1, population, permanent crops, and forest product demands increase overall. In SSP3, demand for permanent crops increases, but all others decrease. Comparing SSP results for 2050 (Figure 24), large differences are seen between regions. The decrease in forest cover in Eastern Europe seen in SSP3 is striking, as are the increases in shrublands in Southern Europe in SSP3.

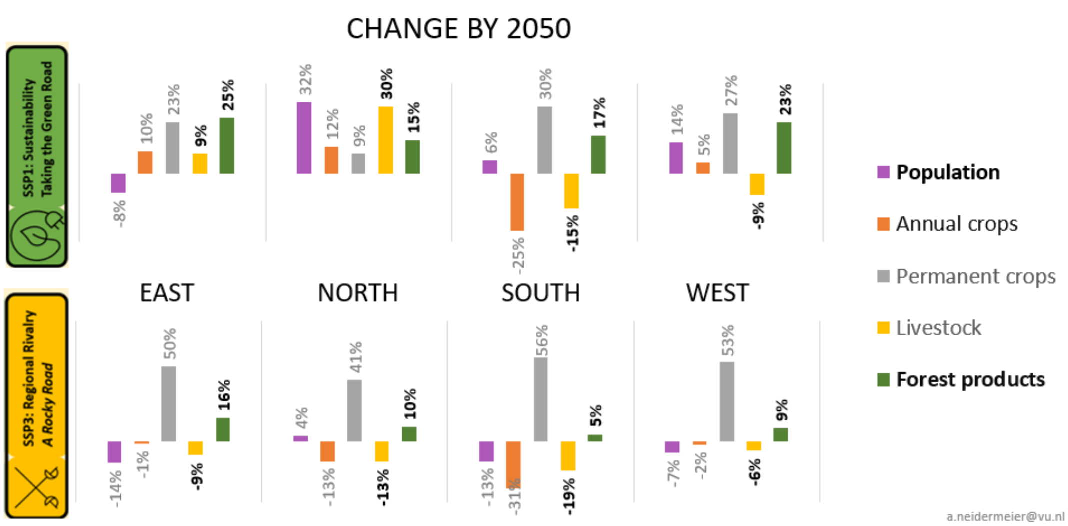


Figure 23: Percent change in demands by 2050 used to simulate future land use scenarios for population, annual crops, permanent crops, livestock, and forest products for each region of Europe (East, North, South, West) under SSP scenarios 1 (top) and 3 (bottom).

[2] https://doi.org/10.34894/ALZTYS

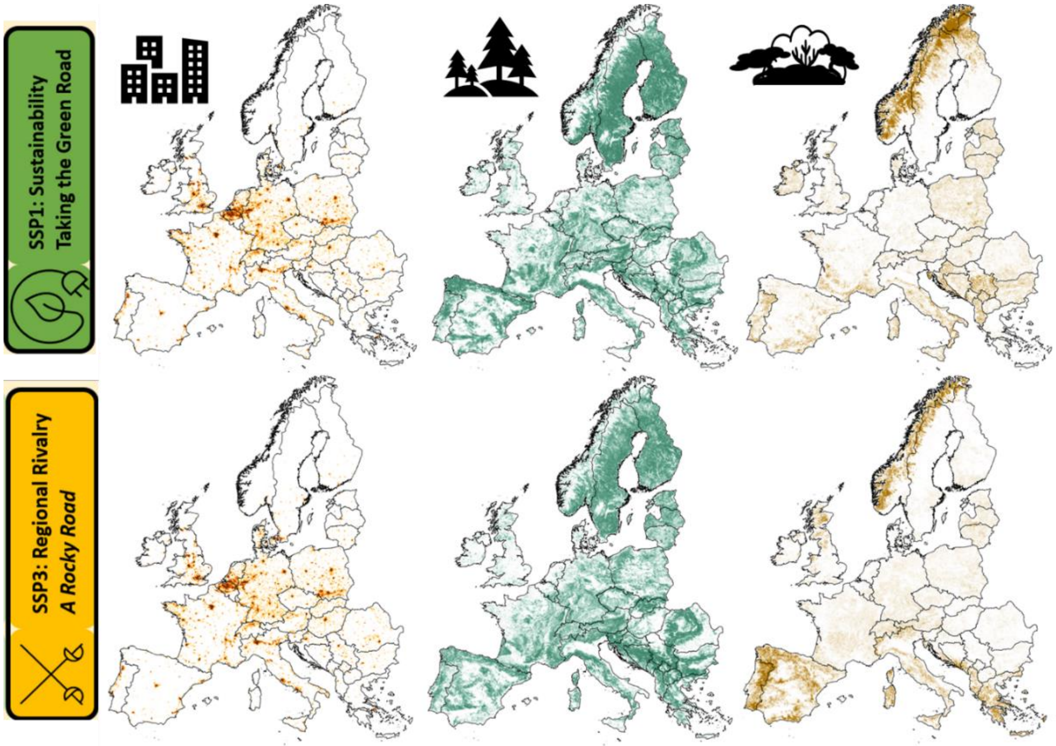


Figure 24: Simulated land cover in SSP 1 & 3 in 2050 for cities (left), forests (centre), and shrublands (right).

3.5.1.5 References

Asselen, S. van, Verburg, P.H. (2013). Land cover change or land-use intensification: simulating land system change with a global-scale land change model. Global Change Biology 19, 3648–3667. https://doi.org/10.1111/gcb.12331

Winkler, K., Fuchs, R., Rounsevell, M., Herold, M. (2021). Global land use changes are four times greater than previously estimated. Nat Commun 12, 2501. https://doi.org/10.1038/s41467-021-22702-2

3.5.2 Future fire regime database

3.5.2.1 Description

Brief description of the content: This product contains changes in future fire regimes (fire ignitions, burned area, fire intensity, biomass burned) compiled from simulated spatio-temporal fire variables of fire-enabled DGVMs.

Task in which it was carried out: Task 3.2

Fire risk component: Danger

Contact details of the developer: Kirsten Thonicke und Maik Billing, Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany

Is it publicly available? Yes

Download address: https://www.pik-potsdam.de/data/doi/10.5880/PIK.2023.005/, includes data description document (data_description.docx).

When using the data set, cite as follows: Billing, Maik; Forrest, Matthew; von Bloh, Werner; Bowring, Simon; Hetzer, Jessica; Oberhagemann, Luke; Thonicke, Kirsten (2023): Projections of future fire and vegetation variables on European scale. GFZ Data Services. https://doi.org/10.5880/pik.2023.005

3.5.2.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units (if categorical data, include the description of each category):	Burned area in [ha] [kgC/m²] for biomass burnt; dead and life fuel (i.e. litter and vegetation biomass)
Update Frequency:	NA
Estimated Accuracy:	NA
Output Format:	netcdf
Temporal coverage:	2020-2100
Spatial resolution:	9 km x 9 km

3.5.2.3 Methodology

The product contains information on simulated future fire regimes using the LPJmLv5.6-SPITFIRE and LPJmLv5.6-SPITFIRE-BASE vegetation-fire models. SPITFIRE is a process-based fire model, developed at PIK, the performance of which was improved and documented in Deliverable D3.3. The Burnt Area Simulator for Europe (BASE) is an empirical burned area model that is based on remotely sensed information using generalised linear model (GLM) techniques, provided by several data sources, originated—among others— from FirEUrisk. This product contains a set of future changes in vegetation and fire variables under future climate and land-use change at the European Territory (ET) at 9 km covering the period 2003-2100. The fire-enabled Dynamic Global Vegetation Model (DGVM) was forced with outputs from five climate models from the SSP126 and SSP370 climate scenarios (as described in Deliverable D3.1 as well as the land-use projections corresponding to those climate scenarios (as described in Deliverable D3.2). The variables provided in this dataset are at monthly (fire) and annual (vegetation) temporal resolution. Simulated changes in the spatiotemporal patterns of fire and vegetation are the result of changes in climate and land use and the resulting fire-vegetation feedbacks.

Detailed description of algorithm of calculation and data sources available here: Deliverable D3.4[3] (public).

3.5.2.4 Data display

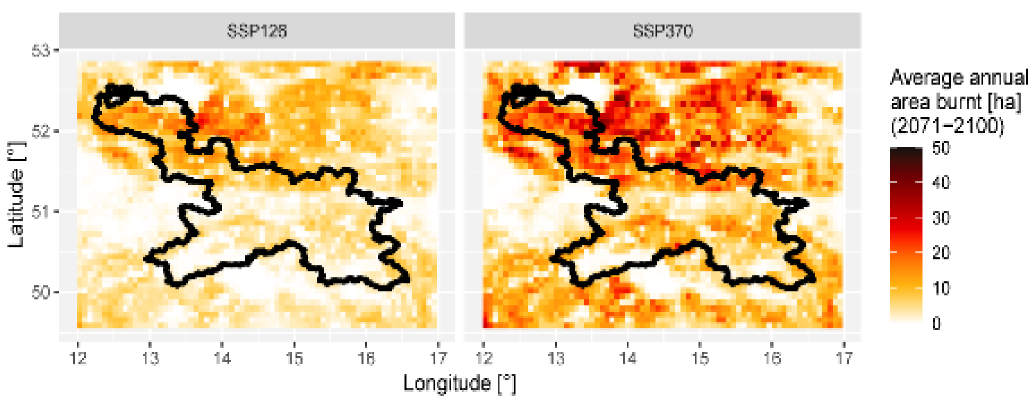


Figure 25: Simulated future burned area in the central European demonstration area using LPJmL-SPITFIRE. The simulated changes result from climate change (shown are averages over simulations using 5 different climate models for each scenario) and the corresponding changes in land cover. Vegetation composition and burned area result from changes in climate and changes in potential burned area due to land-cover change.

[3] https://fireurisk.eu/wp-content/uploads/2024/05/FirEUrisk_D3.4-v1.0.pdf

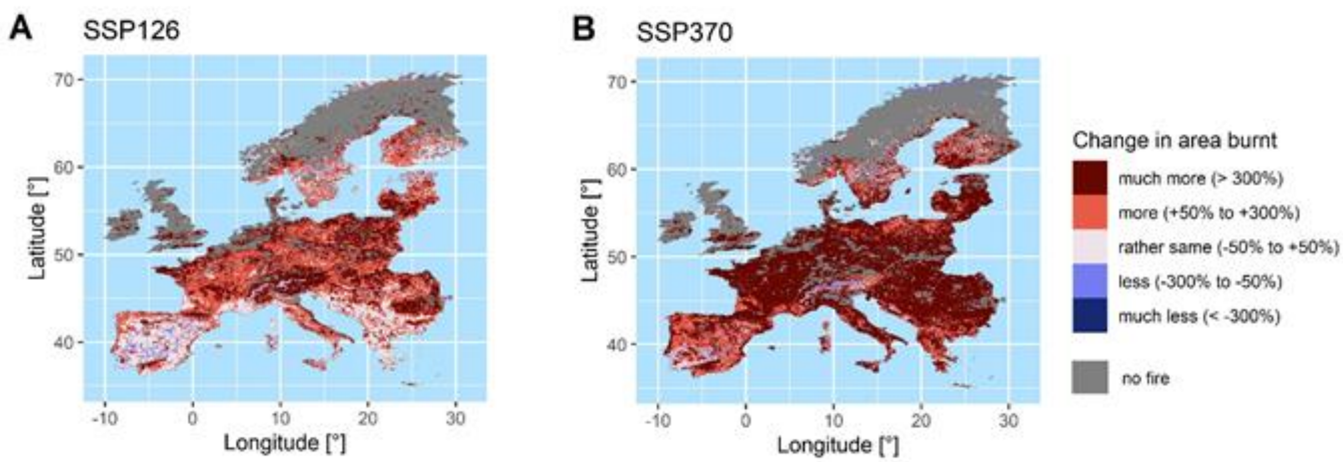


Figure 26: Relative changes in simulated burnt area between years 2000 – 2030 and 2070 – 2100 for SSP126 (panel A) and SSP370 (panel B) using LPJmL-SPITFIRE

4 Validation

4.1 Protocol

One of the main objectives of the event was to present the FirEUrisk's products developed for the ET and gather feedback for further improvement whenever possible. To facilitate this, interactive surveys were introduced during the event using the Zoom Webinar Survey tool (https://www.zoom.com/en/products/webinars/) to capture individual perspectives on each product. For the attendees in person, a paper copy of the surveys were provided, and the participants could answer in writing. A copy of the questions asked during the survey appear in the Annex.
The questions of the survey were asked in three different moments of the DE, as indicated in the agenda (section 2.3) as "Assessment of…". Most of them were in the format "To what extent do you agree with the approach followed to estimate…" the different products. The attendees could grade their agreement with values between 1 (not at all) to 5 (completely agree). In the case that they selected a value of 3 (partially agree) or less, they were invited to provide more specific feedback suggesting improvement to the methodology used by FirEUrisk.

4.2 Results

In this section, we present the responses to the questionnaires collected during the event. Since the question were divided in three sessions, and not all the online attendees were connected during the whole meeting, and also not all of the attendees answered all the questions, the number of total answers vary from question to question.

4.2.1 Current professional relationship with fires

78 participants answered this question, but since they could select more than one option if necessary, a total of 136 answers were recorded. They are indicated in Figure 27. The majority of the participants who answered this question work in Academia and/or research, followed by firefighters and personnel working on fire management. It is important to notice that the information provided in this section is only a sub-sample of the characteristics of the attendees who answered the survey, and hence cannot be applied to all the participants to the DE.

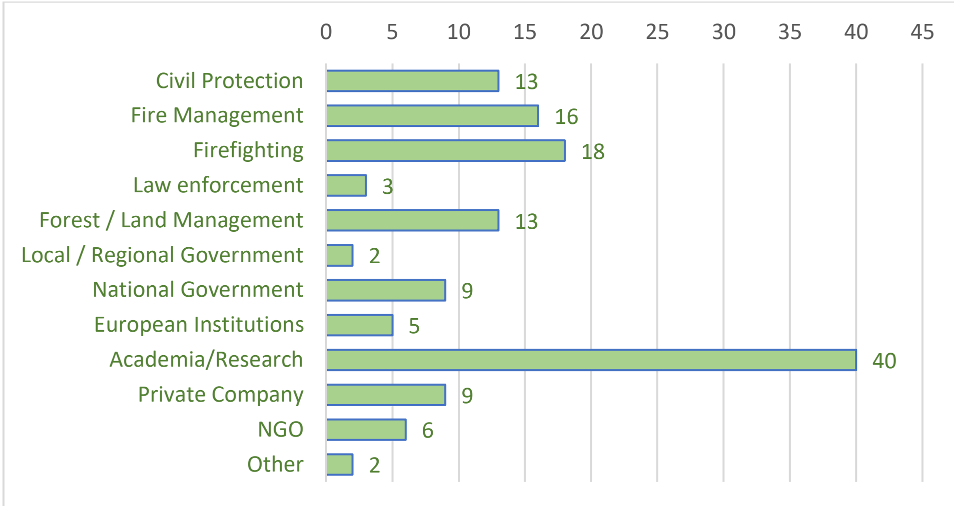


Figure 27: Answers to the survey referring to the professional relationship with fires of the participants in the DE.

4.2.2 Topics of work of the participants

As in the previous section, 78 participants answered this question, but since they could also select more than one option if necessary, a total of 174 answers were recorded. They are indicated in Figure 28. Most of the participants who answered work in fire behaviour, followed by fire assessment and strategic planning, but all topic options were well represented. From those who answered "Other", the participants who provided more information indicated: emergency mapping, promotion of EU standards for building design, fire management and communications.

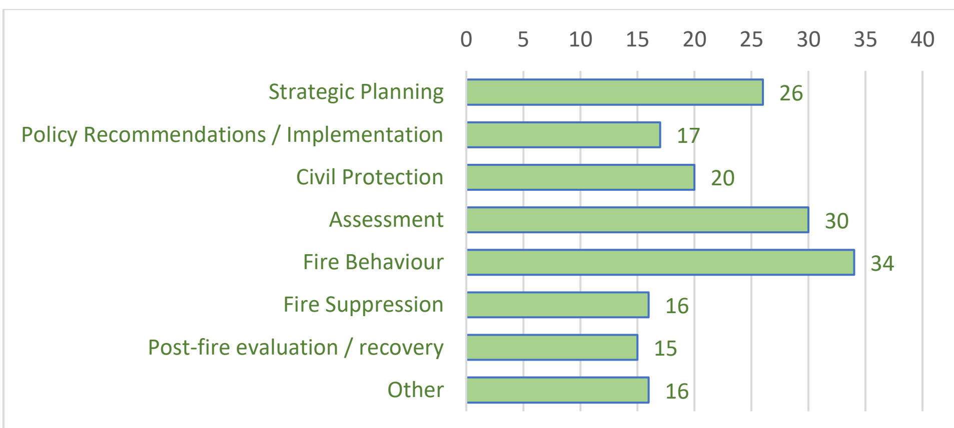


Figure 28: Answers to the survey referring to the topic of work of the participants.

4.2.3 Agreement on the approach followed to estimate probability of human ignition

75 answers were received to this question. The summary of the answers is presented in Figure 29. The 73.33% of the answers corresponded to classes 4 and 5.

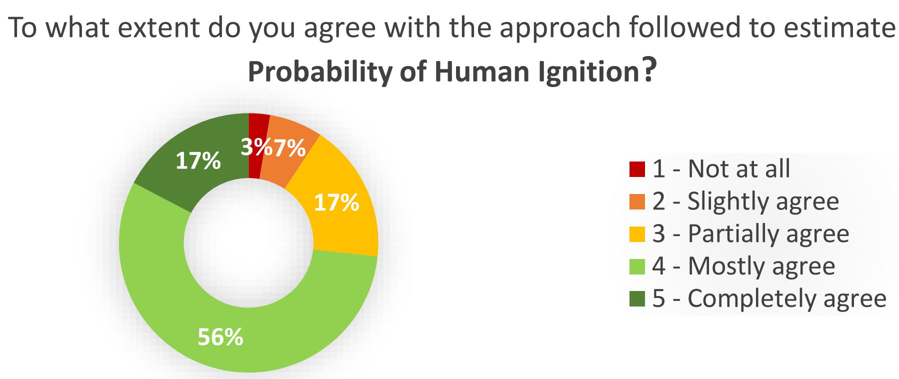


Figure 29: Agreement on the approach followed to estimate probability of human ignition

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Possibility of errors due to extracting ignition points both from natural and human ignitions (although he/she indicated that he/she could not suggest any other solution).
- Potential improvement if also considering dynamic processes, such as summer/vacation time and people access to forested areas and other seasonal factors.
- Limitation of applicability to future conditions.
- Recognition of the difficulty to gather data at European level in a consistent way to properly characterize human ignitions.

4.2.4 Agreement on the approach followed to estimate probability of natural ignition

76 answers were received to this question. The summary of the answers is presented in Figure 30. The 80.26% of the answers corresponded to classes 4 and 5.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Suggestion to validate the product with observational data (ground methods), and to try other models than random forest.
- Suggestion to establish a framework to collect ignition sources.
- Limitation of applicability to future conditions.
- Suggestion to also consider self-ignition of the fuels, as well as other natural ignitions different from lightning.

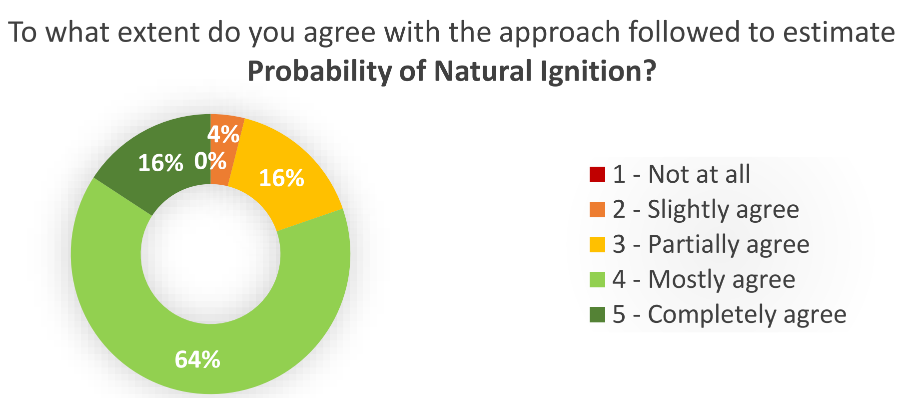


Figure 30: Agreement on the approach followed to estimate probability of natural ignition

4.2.5 Agreement on the approach followed to estimate live fuel moisture content

74 answers were received to this question. The summary of the answers is presented in Figure 31. The 90.54% of the answers corresponded to classes 4 and 5.

Due to the significant agreement with the method used, no particular suggestions were proposed by the attendees.

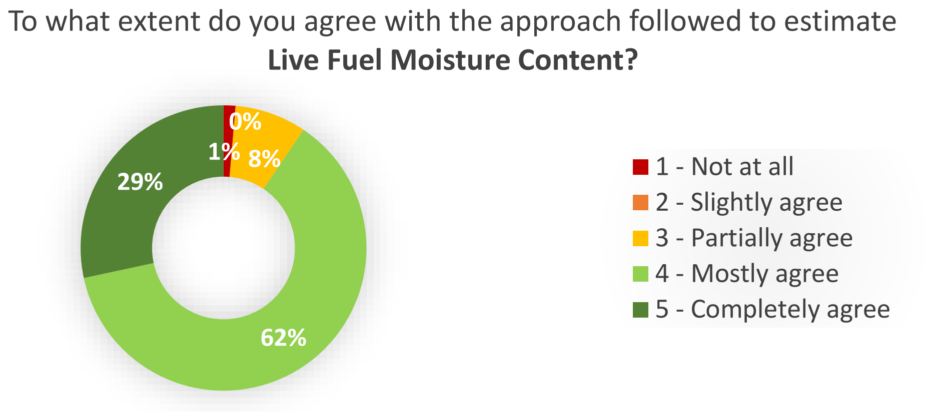


Figure 31: Agreement on the approach followed to estimate live fuel moisture content.

4.2.6 Agreement on the approach followed to classify and map fuel types and models

76 answers were received to this question. The summary of the answers is presented in Figure 32. The 84.21% of the answers corresponded to classes 4 and 5.

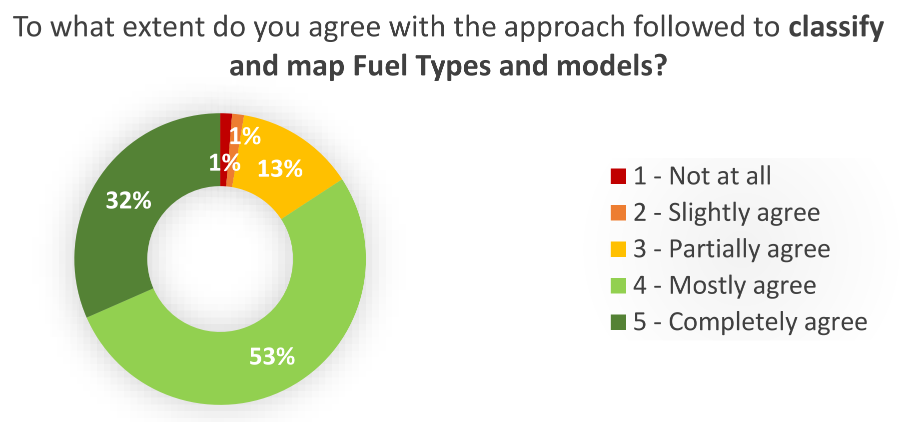


Figure 32: Agreement on the approach followed to classify and map fuel types and models.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Limitation of the spatial resolution (1 km) for fire propagation estimations and for operational applications.
- Suggestion to further the consideration of mixed forests and mixed stands.
- Suggestion to provide associated combustion parameters.
- Suggestion to consider the porosity of the fuels for outbreaks and spread modelling.
- One of the participants indicated that he considered the standardized classification of the fuels as one of the best outcomes of the FirEUrisk project.

4.2.7 Agreement on the approach followed to estimate fire propagation potential

76 answers were received to this question. The summary of the answers is presented in Figure 33. The 88.16% of the answers corresponded to classes 4 and 5.

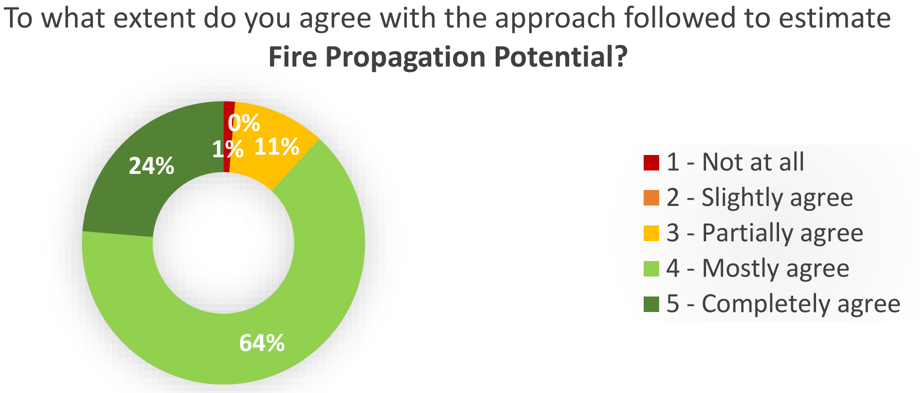


Figure 33: Agreement on the approach followed to estimate fire propagation potential.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Importance of information that is spatially and temporally coherent.
- Stress on the importance of the potential being dynamic depending on meteorological conditions.
- Suggestion to clarify if the propagation is only of surface fires or if it includes crown fires.
- Suggestion to consider fire suppression activities.
- Suggestion to consider in the future physical models instead of Rothermel's empirical one.
- General comments on the limitations of the Rothermel model's wind speed limit.

4.2.8 Agreement on the approach followed to estimate ecological values

47 answers were received to this question. The summary of the answers is presented in Figure 34. The 85.11% of the answers corresponded to classes 4 and 5.

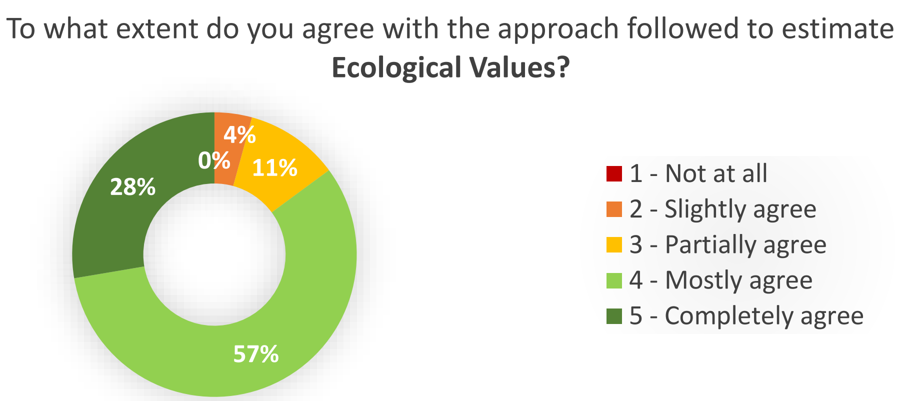


Figure 34: Agreement on the approach followed to estimate ecological values.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Suggestion to consider ecotones, and to include impacts in soils and water.

- Suggestion to not include the value 0 in the map, considering that even crops have some ecological value even if it is lower than old growth forests.
- Suggestion to consider ecological values before and after a fire, for those cases where fire can have a long-term benefit.

4.2.9 Agreement on the approach followed to estimate coping capacity / recovery time

46 answers were received to this question. The summary of the answers is presented in Figure 35. The 82.61% of the answers corresponded to classes 4 and 5.

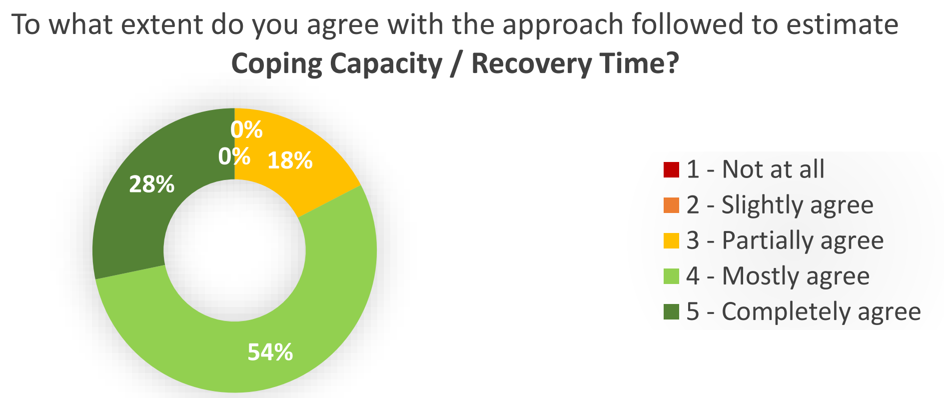


Figure 35: Agreement on the approach followed to estimate coping capacity / recovery time.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Agreement on the complex issue that is the coping capacity, and limitation of the results due to the local dependencies of species, land and water management, etc.
- Suggestion to reduce the recovery time for the plots that have values of several hundred years.
- Suggestion to consider multiple burns that might have occurred in the same areas during the years.
- Suggestion to include impacts of unforeseen circumstances such as invasive species, repeated fires and degradation of remaining vegetation and soil.
- Suggestion to consider the synergies and remaining environment/landscape.
- Suggestion to include, in future developments, the human dimension and infrastructures and communities.

4.2.10 Agreement on the approach followed to estimate ecosystem services

46 answers were received to this question. The summary of the answers is presented in Figure 36. The 86.96% of the answers corresponded to classes 4 and 5.

To what extent do you agree with the approach followed to estimate **Ecosystem Services?**

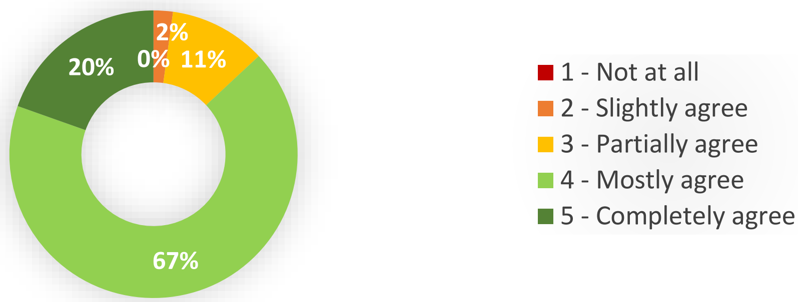


Figure 36: Agreement on the approach followed to estimate ecosystem services.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Suggestion to consider the soil erosion and loss after a fire, provision of clear water and flood control, or debris-flows after fires, as they are relevant for humans and infrastructures.
- Agreement on the complexity to fully tackle this component.

4.2.11 Agreement on the approach followed to estimate fire mitigation measures

37 answers were received to this question. The summary of the answers is presented in Figure 37. The 86.49% of the answers corresponded to classes 4 and 5.

To what extent do you agree with the approach followed to estimate **Fire Mitigation Measures?**

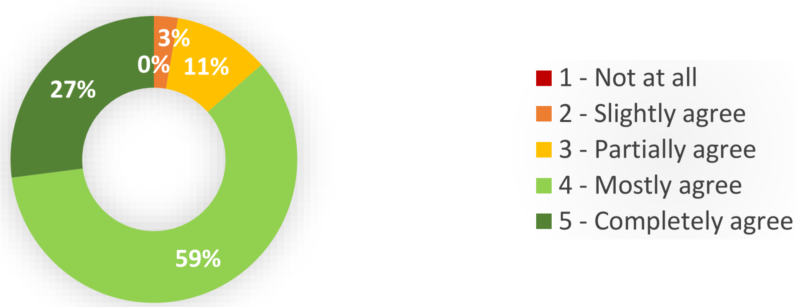


Figure 37: Agreement on the approach followed to estimate fire mitigation measures.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Suggestion to consider terrain steepness, wind, and location in respect to the Wildland Urban Interface.
- Comments appreciating the comprehensive and clear analysis.

4.2.12 Agreement on the approach followed to estimate future scenarios and adaptation

39 answers were received to this question. The summary of the answers is presented in Figure 38. The 82.05% of the answers corresponded to classes 4 and 5.

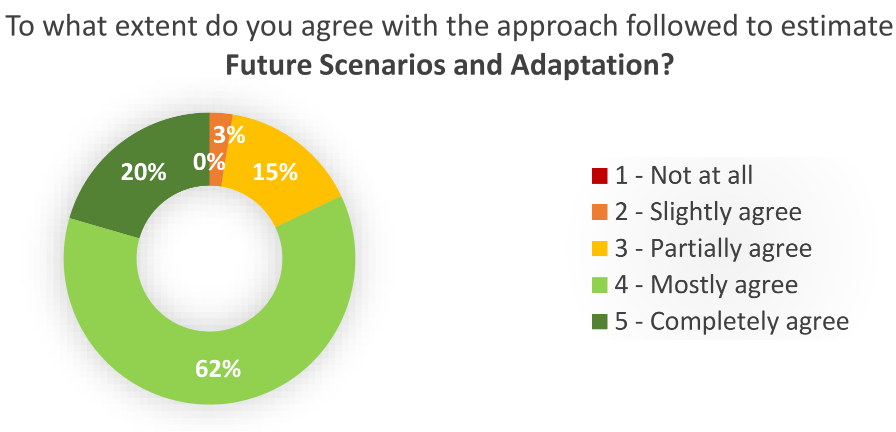


Figure 38: Agreement on the approach followed to estimate future scenarios and adaptation.

Those participants that provided more information, either because they had selected options 3 or lower, or because they wanted to provide additional feedback, indicated the following:

- Suggestion to incorporate other variables, such as population.
- Suggestion to use land monitoring through Earth observation data as an adaptation measure.
- Suggestion to consider sea level rise (with the explicit mention of the Po Plain)

4.2.13 Relative weight to the ignition / propagation components for fire danger estimation

41 answers were received to this question, either selecting one of the suggested weights, or proposing a new one. Those participants who proposed an alternative weighting factor leaned toward assigning a lower weight to ignition and a higher to propagation, some of them indicating explicitly that the propagation component is more significant than the ignition one for danger assessment. It was suggested that the weights could vary depending on in there is an automatic or manual surveillance system. It was also suggested to perform a parametric study of the weights.
The summary of the answers is presented in Figure 39.

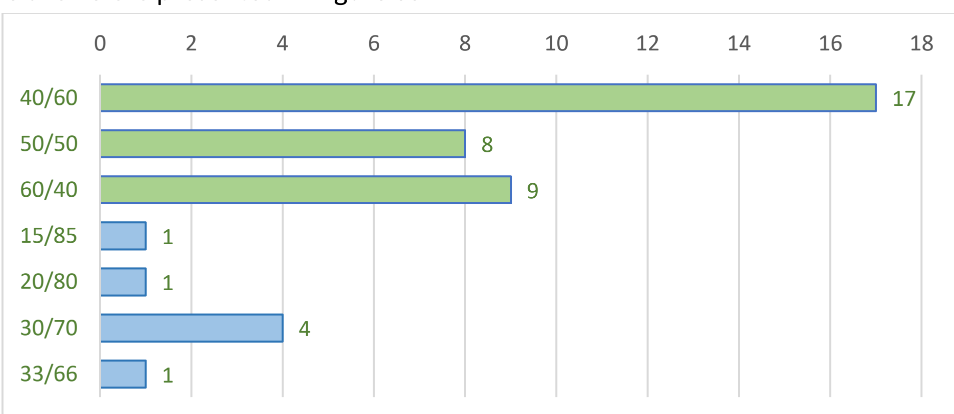


Figure 39: Weights suggested for the ignition and propagation components by the attendees. The ones in green were suggested by default in the survey to be selected. The ones in blue were directly suggested by the attendees after selecting the option "Other".

4.2.15 Mathematical method for the integration of the components

41 answers were received to this question. The results were:

- 27 answers (66%) suggested keeping the FirEUrisk approach as a first approximation for the integration.
- 8 answers (20%) suggested to change to a multiplicative integration keeping the weights being currently used.
- 6 answers (15%) suggested to change to a multiplicative integration assigning other weighting values to ignition and propagation.

Those who selected the third option, in one case suggested to use 30/70, and in another 60/40. Other answers also suggested to perform calculations using different weighting factors and evaluate the changes in the results, or to be able to change the weights pixel per pixel considering that in some areas the danger of ignition might be quite low, but if it happened the risk of propagation could be very high, or vice versa.

4.2.16 Agreement with the scheme and the use of the different components

45 answers were received to this question. Of those, 41 (91%) corresponded to Yes.
Of those answers that did not agree, the suggestions were:

- 2 answers suggested to use only danger and vulnerability
- 2 answers suggested to use another option, but without providing a specific alternative scheme.

5 Conclusions and Lessons Learnt from the Demonstration Event

Throughout this report, we have provided a comprehensive account of the Demonstration Event, which served as an opportunity to present the FirEUrisk products developed at European level, and their integration into the IRI. Complementary, the event aimed to gather feedback of the attendees on their agreement on the methods used and results obtained by the FirEUrisk consortium to estimate fire risk throughout Europe, and in particular from those stakeholders working in European Institutions and/or at European scale, who were the main target of the event.
The most relevant indicators of the event were:

- 13 presentations showcasing 15 FirEUrisk products
- Active participation of 14 partners (including the presentation online of A. Neidermeier)
- Presentations covered mostly products of WP1 (fire risk components and integration), but also those of WP2 (fire mitigation) and WP3 (future fire risk conditions).
- 35 in person attendees plus 144 online participants
- In person participants from 9 countries, mostly European.
- Online participants from 35 countries (21 European countries part of the ET Pilot Site, plus 14 countries not part of the Pilot Site).
- 10 attendees belonging to European Commission organizations, mostly the Joint Research Centre.

Overall, the general feedback received from the attendees was very good, emphasizing the amount of work carried out during the project, and the results achieved. They expressed their interest in the results and appreciated the effort of the different members of the consortium.

5.1 Conclusions on validation results

During the DE, several objective questions were asked regarding the agreement with the methods used to generate the products. Most questions were in the form of punctuating the agreement in a 1 to 5 scale. For these type of questions, in average including all the questions of this type, 83.78% of all answers were either "4 – Mostly agree" or

"5 – Completely agree". Since most of the participants of the DE are specialists in the fire phenomenon, either as researchers or fire practitioners (as shown in section 4.2.1), this shows that the methods used to generate the different products are well accepted by the fire community.

The comments received for the specific questions mostly focused on suggestions to improve the different products in further research, considering additional parameters. They also included comments on a limited applicability of some products for some applications. Some comments also stressed the complexity of the phenomena being studied, and hence the difficulty to address the different components under study.

Regarding the methods for the integration of the fire danger, most answers agreed with the method proposed by FirEUrisk. The alternative weighting factors proposed for the integration of the ignition and propagation components (which gave equal or more weight to the ignition compared to the propagation) received a significant number of selections. Still, all the answers where the participants proposed their own weights gave more importance to the propagation component than the one used by FirEUrisk, somehow undermining the idea that a higher weight for the ignition component could be a better option. The 66% of the answers agreed on the mathematical method of integration used by FirEUrisk, but the 34% that selected one of the other options reflects that there is not a general consensus on the best mathematical formula for integration.

With respect to the framework for fire risk estimation, the vast majority of the answers (91%) agreed with the importance of all the components used in FirEUrisk (danger, exposure and vulnerability). Only two answers discarded the use of the exposure component.

Overall, the answers reflected the extensive agreement of the participants who answered the survey with the approaches and methods used by FirEUrisk. A summary of all the answers received is included in Table 5.

Table 5: Summary of validation results

Question: agreement with the approach to …	Number of answers	% of agreement with FirEUrisk method*
Estimate Probability of Human Ignition	75	73.33
Estimate Probability of Natural Ignition	76	80.26
Estimate Live Fuel Moisture Content	74	90.54
Classify and map Fuel Types and models	76	84.21
Estimate Fire Propagation potential	76	88.16
Estimate Ecological values	47	85.11
Estimate Coping Capacity / Recovery Time	46	82.61
Estimate Ecosystem Services	46	86.96
Estimate Fire Mitigation Measures	37	86.49
Estimate Future Scenarios and Adaptation Measures	39	82.05
Apply weights to ignition and propagation	41	41.46
Mathematically calculate Danger	41	65.85
Use Danger, Exposure and Vulnerability in the Fire Risk scheme	45	91.11

* In questions with a range of answers between 1 (completely disagree) and 5 (completely agree), it is consider that the answers agree with the methods of FirEUrisk if they have values of 4 or 5.

5.2 Lessons learnt about the organization of the meeting

Type and characteristics of the meeting

The organization of the meeting as a hybrid event allowed many more attendees to participate than those who would have been able to travel to Milan for an in-person only meeting. The selection of Milan as the place of the event wanted to facilitate the participation in person of personnel of the JRC working on fires as part of the European Forest Fire

Information System (EFFIS, located in Ispra, close to Milan). This was partially achieved, as only some of the EFFIS team could attend. However, other members of the EC could also attend in person, and another five connected online, so there was a good representation of members of European institutions.

The facilities of CNR were very adequate and comfortable to host the event, and they provided all the necessary equipment and technical personnel to assure a smooth hybrid meeting.

For those participants that attended in person, the coffee breaks and lunch provided an opportunity to continue discussing the different products demonstrated with the presenters, and gathering more detailed information on them. All presenters adhered to their schedule, so the meeting run on time, and even ahead of time in some moments, which allowed finishing earlier than scheduled, and was appreciated by the participants. In addition, this provided the opportunity to have rounds of questions after each presentation, increasing the interaction between the presenters and the attendees (both in person and online) and to answer the doubts that might have remained from the presentations.

Organization of the survey

The use of the Zoom Webinar survey option provided a smooth way to transition between the different presentations and the surveys. For the in person attendees, printed copies of the survey were provided, to avoid forcing these participants to have to connect to the Zoom meeting using their mobile phones or laptops. This facilitated the completion of the surveys by the in person attendees, but implied an additional effort of the organizers of the DE to manually transcribe the answers to a digital medium and incorporate them to the online results.

Some participants who completed the surveys indicated that the content of the DE was quite long and complex, and that they would need more time to review the slides and product cards at their own pace to provide a more comprehensive feedback. Following this notion, two participants sent their surveys by email a few days after the DE took place.

The distribution of the survey in three separate questionnaires was a good tactic, since it allowed the attendees to provide their feedback just after the corresponding presentations of each block. This facilitated that the participants remembered better the information received just minutes before, which would have been more difficult if just one survey had been provided at the end of the event. What is more, since the online participation in the event was fluid, meaning that not all attendees were connected throughout the whole event, it allowed the participants who were only able to attend part of the meeting to provide their feedback for the portion of the meeting they had attended.

6 References

To facilitate the reading, the following references are also presented in Section 3, in the reference sections of their respective product.

Adámek, M., Hadincová, V. and Wild, J., 2016. Long-term effect of wildfires on temperate Pinus sylvestris forests: Vegetation dynamics and ecosystem resilience. Forest Ecology and Management, 380, pp.285-295. La Notte, A. et al., 2021. Ecosystem Services Accounting – Part III - Pilot accounts for habitat and species maintenance, on-site soil retention and water purification Available at https://publications.jrc.ec.europa.eu/repository/handle/JRC126566.

Andersen, T., Carstensen, J., & Hernandez-Garcia, E., Duarte, C. M. (2009). Ecological thresholds and regime shifts: approaches to identification. Trends in Ecology & Evolution, 24(1), 49–57.

Aragoneses, E., García, M., Ruiz-Benito, P., and Chuvieco, E. (2024) Mapping forest canopy fuel parameters at European scale using spaceborne LiDAR and satellite data, Remote Sensing of Environment, 303, 114005.

Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E. (2023) Classification and mapping of European fuels using a hierarchical, multipurpose fuel classification system, Earth System Science Data, 15, 1287–1315, https://doi.org/10.5194/essd-15-1287-2023.

Aragoneses, E., García, M.; Tang, H. and Chuvieco, E. (2024) A multi-sensor approach allows confident mapping of forest canopy fuel load and canopy bulk density to assess wildfire risk at the European scale, Remote Sensing of Environment. (in review)

Archibald, S., Archibald, S., Hempson, G. P., & Lehmann, C. (2019). Research review A unified framework for plant life-history strategies shaped by fire and herbivory. https://doi.org/10.1111/nph.15986

Arrogante-Funes, F., Aguado, I., & Chuvieco, E. (2022). Global assessment and mapping of ecological vulnerability to wildfires. Natural Hazards Earth Systems Sciences, 22, 2981-3003.

Arrogante-Funes, F., Mouillot, F., Moreira, B., Aguado, I. & Chuvieco, E. (2024). Mapping and assessment of ecological vulnerability to wildifres in Europe. Fire Ecology (in press).

Asselen, S. van, Verburg, P.H. (2013). Land cover change or land-use intensification: simulating land system change with a global-scale land change model. Global Change Biology 19, 3648–3667. https://doi.org/10.1111/gcb.12331

Brun, P., Zimmermann, N. E., Graham, C. H., Lavergne, S., Pellissier, L., Münkemüller, T., & Thuiller, W. (2019). The productivity-biodiversity relationship varies across diversity dimensions. Nature Communications, 10(1), 5691. https://doi.org/10.1038/s41467-019-13678-1

Castillo, M.E., Molina, J.R., y Silva, F.R., García-Chevesich, P. and Garfias, R., 2017. A system to evaluate fire impacts from simulated fire behavior in Mediterranean areas of Central Chile. Science of the total environment, 579, pp.1410-1418.

Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Ramona Velea, Florent Mouillot, Juan R. Molina, Ana I. Miranda, Diogo Lopes, Michele Salis, Marin Bugaric, Mikhail Sofiev, Evgeny Kadantsev, Ioannis Gitas, Dimitris Stavrakoudis, George Eftychidis, Bar-Massada, A., Alex Neidermeier, Valerio Pampanoni, Pettinari, M.L., Arrogante, F., Ochoa, C., Moreira, B., & Viegas, D. (2023). Towards an integrated approach to wildfire risk assessment: when, where, what and how may the landscapes burn. Fire, 6, 215, https://doi.org/10.3390/fire6050215.

Dinerstein, E., Olson, D., Graham, D., Webster, A., Pimm, S., Bookbinder, M., & Ledec, G. (1995). A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean. World Bank.

Gomez, E. and Alvarez, K., 2009. Forest fires: detection, suppression and prevention. Nova Science Publishers.

Kummu, M., Taka, M. and Guillaume, J.H., 2018. Gridded global datasets for gross domestic product and Human Development Index over 1990–2015. Scientific data, 5(1), pp.1-15.

Martino, S. et al. 2023. Economic Impacts of Fire – A Focus on Analysis of Economic Vulnerability of Natural and Human Capitals and proposal of an Integrated Capitals Approach to wildfire vulnerability. Chapter 7. Deliverable D1.4- Report on Methodological frameworks for vulnerability assessment. Available at https://fireurisk.eu/wp-content/uploads/2024/05/D1.4_FirEUrisk_ReportMethodologicalFrameworksVulnerability_V1.pdf.

Milazzo, F., P. Fernández, A. Peña, and T. Vanwalleghem. "The resilience of soil erosion rates under historical land use change in agroecosystems of Southern Spain." Science of The Total Environment 822, 153672.

Molina, J.R., Herrera, M.A., Zamora, R., Rodríguez y Silva, F., González-Cabán, A., 2011. Economic losses to Iberian swine production from forest fires. Forest Policy Econ. 13, 614–621.

Molina, J.R., Herrera, M.A. and y Silva, F.R., 2019. Wildfire-induced reduction in the carbon storage of Mediterranean ecosystems: An application to brush and forest fires impacts assessment. Environmental Impact Assessment Review, 76, pp.88-97.

Mouillot et at., 2023. Environmental Vulnerability and Resilience Assessment – A Focus on Ecological Vulnerability. Chapter 6. Deliverable D1.4- Report on Methodological frameworks for vulnerability assessment. Available at https://fireurisk.eu/wp-content/uploads/2024/05/D1.4_FirEUrisk_ReportMethodological FrameworksVulnerability_V1.pdf.

Neidermeier, A.N., Zagaria, C., Pampanoni, V., West, T.A.P., & Verburg, P.H. (2023). Mapping opportunities for wildfire hazard reduction in Europe through targeted land management strategies. Journal of Environmental Management 346, 118941.

Ochoa, C., Bar-Massada, A., & Chuvieco, E. (2024). A European-scale analysis reveals the complex roles of anthropogenic and climatic factors in driving the initiation of large wildfires. Science of the total environment, 170443. https://doi.org/10.1016/j.scitotenv.2024.170443

Pampanoni, V., Laneve, G., & Santilli, G. (2022). Evaluating Sentinel-3 Viability for Vegetation Canopy Monitoring and Fuel Moisture Content Estimation. In, IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium (pp. 5634-5637). Kuala Lumpur, Malasya: IEEE.

Pampanoni, Valerio, et al. (2023) "Early Validation of A Live Fuel Moisture Content Product Based on Sentinel-2 and Sentinel-3 Images." IGARSS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium. IEEE. https://doi.org/10.1109/IGARSS52108.2023.10281970.

Rodríguez-Silva, F, Molina, J.R., González-Cabán, A. and Machuca, M.Á.H., 2012. Economic vulnerability of timber resources to forest fires. Journal of Environmental management, 100, pp.16-21.

Román, M.V., Azqueta, D. and Rodrígues, M., 2013. Methodological approach to assess the socio-economic vulnerability to wildfires in Spain. Forest Ecology and Management, 294, pp.158-165.

Schwrorer C., Henne PD, Tinner W. (2014). A model-data comparison of Holocene timberline changes in the Swiss Alps reveals past and future drivers of mountain forest dynamics. Gobal change biology, 20 (5) : 1512-1526. https://doi.org/10.1111/gcb.12456

Sritharan, M. S., Scheele, B. C., Blanchard, W., Foster, C. N., Werner, P. A., & Lindenmayer, D. B. (2022). Plant rarity in fire-prone dry sclerophyll communities. Scientific Reports, 12(1), 1–10. https://doi.org/10.1038/s41598-022-15927-8

Stevens J.T., Klinh M.M., Schwilk D.W., Varner J.M., Kane J.M. 2020. Biogeography of fire regimes in western U.S. conifer forests: A trait-based approach. Global Ecology and Biogeography 29(5):944-955.

UK Gov. 2024. The green book 2022. Available at https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020#

Vallecillo, S., et al. 2018. Ecosystem services accounting. Part I Outdoor recreation and crop pollination. JRC technical reports. Available at https://publications.jrc.ec.europa.eu/repository/handle/JRC110321.

Vargas, P., Heleno, R., & Costa, J. M. (2023). EuDiS - A comprehensive database of the seed dispersal syndromes of the European flora. Biodiversity Data Journal, 11. https://doi.org/10.3897/BDJ.11.E104079

Winkler, K., Fuchs, R., Rounsevell, M., Herold, M. (2021). Global land use changes are four times greater than previously estimated. Nat Commun 12, 2501. https://doi.org/10.1038/s41467-021-22702-2

Yebra, M., Dennison, P., Chuvieco, E., Riaño, D., Zylstra, P., Hunt, E.R., Danson, F.M., Qi, Y., & Jurdao, S. (2013). A global review of remote sensing of live fuel moisture content for fire danger assessment: moving towards operational products Remote Sensing of Environment 136, 455-468.

Annex: Demonstration event survey

Demonstration Event: European Territory fire risk

1. Name (optional)

2. What is your current professional relationship with wildfires? (select all that apply)

	Civil Protection		Forest / Land Management		Academia/Research
	Fire Management		Local / Regional Government		Private Company
	Firefighting		National Government		NGO
	Law enforcement		European Institutions		Other:

3. In what topics do you currently work? (select all that apply)

	Strategic Planning		Assessment
	Policy Recommendations / Implementation		Fire Behaviour
	Civil protection		Fire Suppression
	Other:		Post-fire evaluation / recovery

Assessment of Fire Danger components

4. To what extent do you agree with the approach followed to estimate Probability of Human Ignition?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

5. To what extent do you agree with the approach followed to estimate Probability of Natural Ignition?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

6. To what extent do you agree with the approach followed to estimate Live Fuel Moisture Content?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

7. To what extent do you agree with the approach followed to classify and map Fuel Types and models?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

8. To what extent do you agree with the approach followed to estimate Fire Propagation potential?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

Assessment of Fire Vulnerability components

9. To what extent do you agree with the approach followed to estimate Ecological values?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

10. To what extent do you agree with the approach followed to estimate Coping Capacity / Recovery Time?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

11. To what extent do you agree with the approach followed to estimate Ecosystem Services?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

Assessment of Fire Risk integration, mitigation and adaptation components

12. To what extent do you agree with the approach followed to estimate Fire Mitigation Measures?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

13. To what extent do you agree with the approach followed to estimate Future Scenarios and Adaptation Measures?

	1. Not at all		2. Slightly agree		3. Partially agree		4. Mostly agree		5. Completely agree

In case your answer is 3 or lower, what would you propose to improve the approach?

14. The project has presented a framework for danger assessment based on ignition and propagation. In order to integrate them into a single index, which relative weight should be given to the ignition/propagation components?

	40/60		50/50		60/40		Indicate your own values:

15. The integration is currently done with an additive component (D=PI*0.4+PP*0.6); are you in favour of:

	Keeping this as a first approximation
	Change to a multiplicative integration keeping the weights
	Change to a multiplicative integration assigning the following weighting values to ignition and propagation:

16. The project has presented a framework for risk assessment based on Danger, Exposure and Vulnerability. Do you agree with this scheme?

	Yes
	No, I would keep only danger and vulnerability
	No, I would keep only danger and exposure
	No, I would keep only exposure and vulnerability
	No, I would use the following option: