Horizon 2020
European Union funding
for Research & Innovation

Portfolio of wildfire risk products developed for the European Territory within the FirEURisk project

Agenda of the Demonstration event

(Links indicate further information on each of the presented products)

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, Canopy fuel parameters	114	Elena Aragoneses
11.30 – 11.45	Propagation potential indicators	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	Recovery time / Coping capacity	122	Florent Mouillot (remotely)
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	Integrated fire risk index	131	Emilio Chuvieco
16.15 – 16.45	Fire mitigation	2	Domingos Viegas / Alexandra Neidermeier (remotely)
16.45 – 17.15	Fire adaptation & climate scenarios	3	Maik Billing / Alexandra Neidermeier (remotely)
17.15 – 18.00	Assessment of fire risk integration, mitigation and adaptation components		ET end-users

Danger Products

1 Human ignition probability

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 km^2.

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. Email: mclara.ochoa@uah.es

Is it publicly available? Only the paper (Ochoa et al., 2024)

https://doi.org/10.1016/j.scitotenv.2024.170443

1.2 Technical components

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

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 (Table1.) 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 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 1. 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 (Aragoneses et at., 2022)	2019	2023
3. Wildland- Urban Interface (WUI)	(Bar-Massada et al., 2013)	2022	2023
4. Wildland- Agricultural Interface (WAI)	From Fuel Map (Aragoneses et at., 2022)	2019	2023
5. Wildland- Forest Interface (WFI)	From Fuel Map (Aragoneses et at., 2022)	2019	2023
6. Forest-Urban Interface (FUI)	From Fuel Map (Aragoneses et at., 2022)	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

1.4 Data display

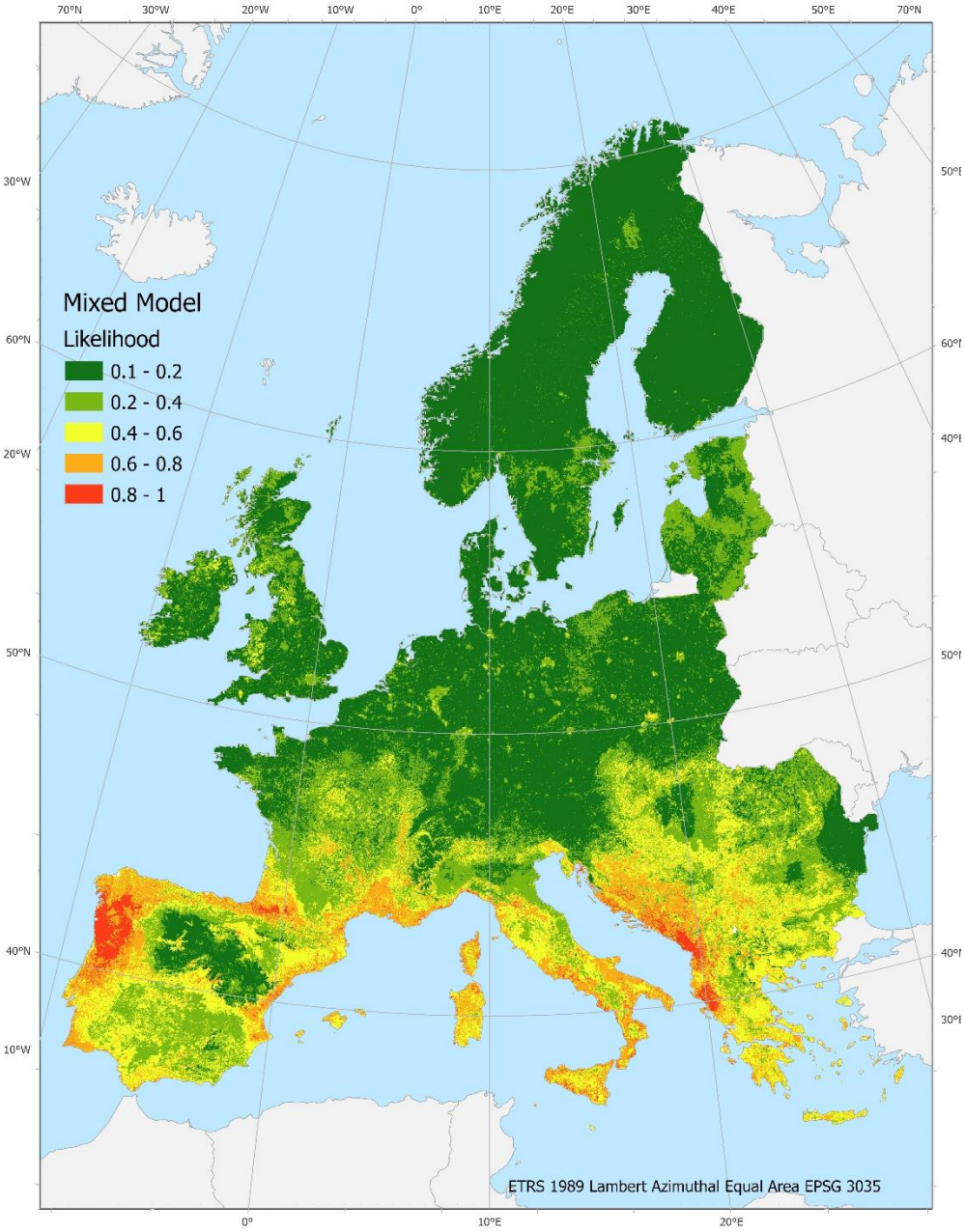


Figure 1. Human ignition probability map

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.

2 Natural ignition probability

2.1 Description

The Fire Forecasting Model (FFM, Sofiev et al, in prep.)-based Natural Ignition Probability product predicting 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@fmi.fi

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.

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

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), 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.

2.4 Data display

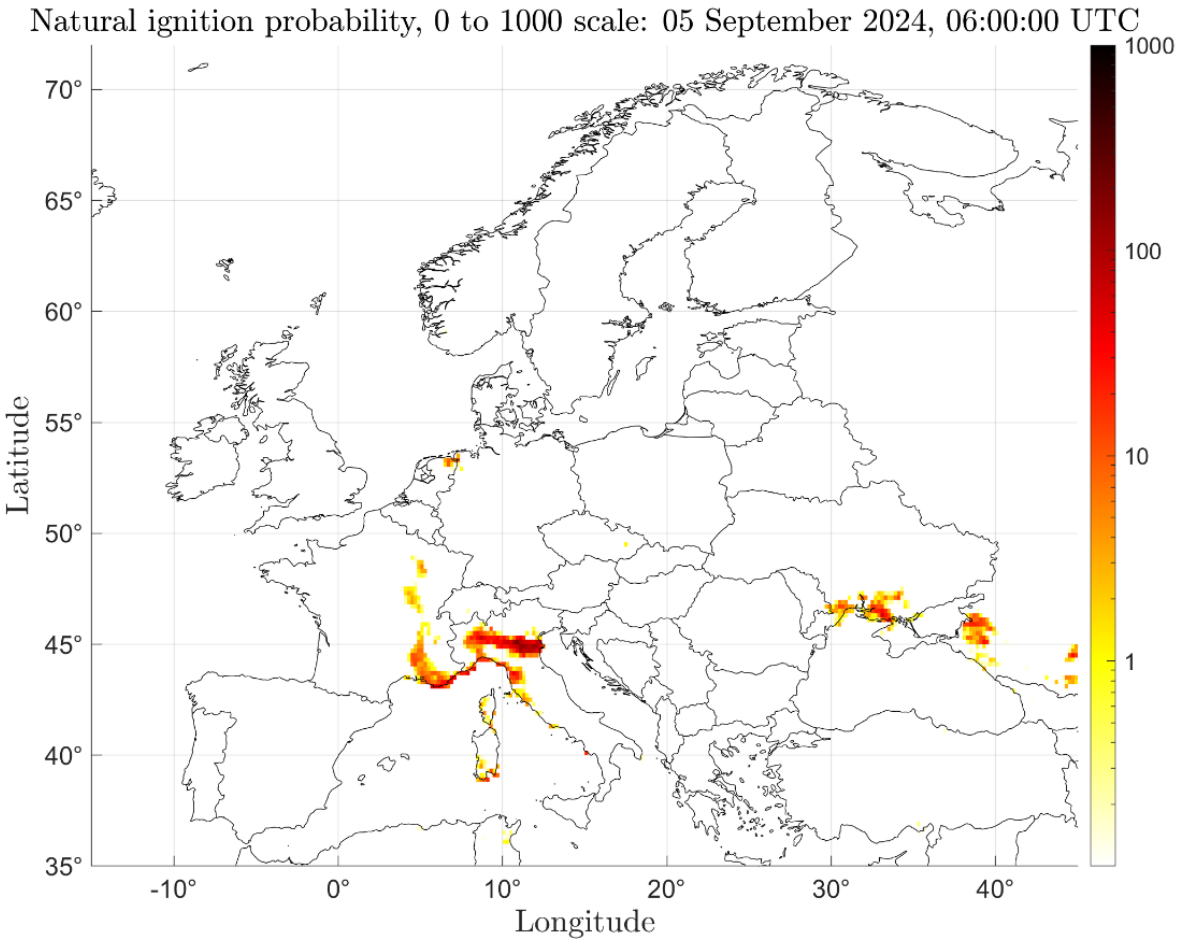


Figure 2. Example of product output on the European Territory on the 5th of September

3 Live Fuel Moisture Content

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@uniroma1.it

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

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)

3.3 Methodology

This product is based on the inversion of Look-Up Tables (LUT) created using a combination of the PROSPECT-D, 4SAIL 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. Latest publication available here: Pampanoni, Valerio, et al. "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, 2023. https://doi.org/10.1109/IGARSS52108.2023.10281970.

3.4 Data Display

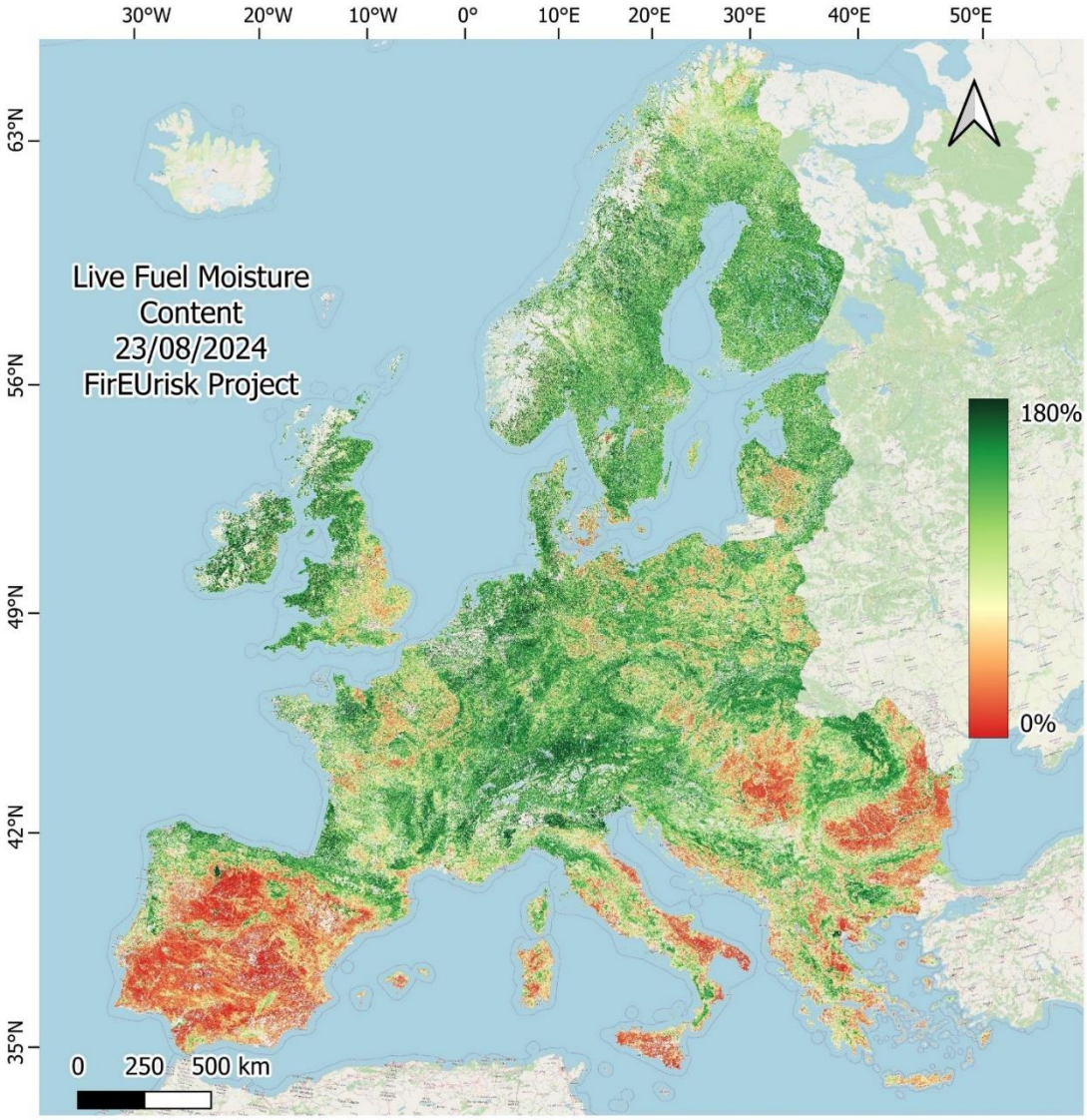


Figure 3: Example of product output on the European Territory on the 23rd of August 2024.

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.

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.

4 Fuel classification and map

4.1 Description

Brief description of the content:

The European fuel map is a raster layer representing the first-level fuel types of the FirEUrisk fuel classification system for the continental scale, in: Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E.: 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, 2023.

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).

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: A1114

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses (e.aragoneses@uah.es), University of Alcalá (UAH)

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

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

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

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).

4.4 Data display

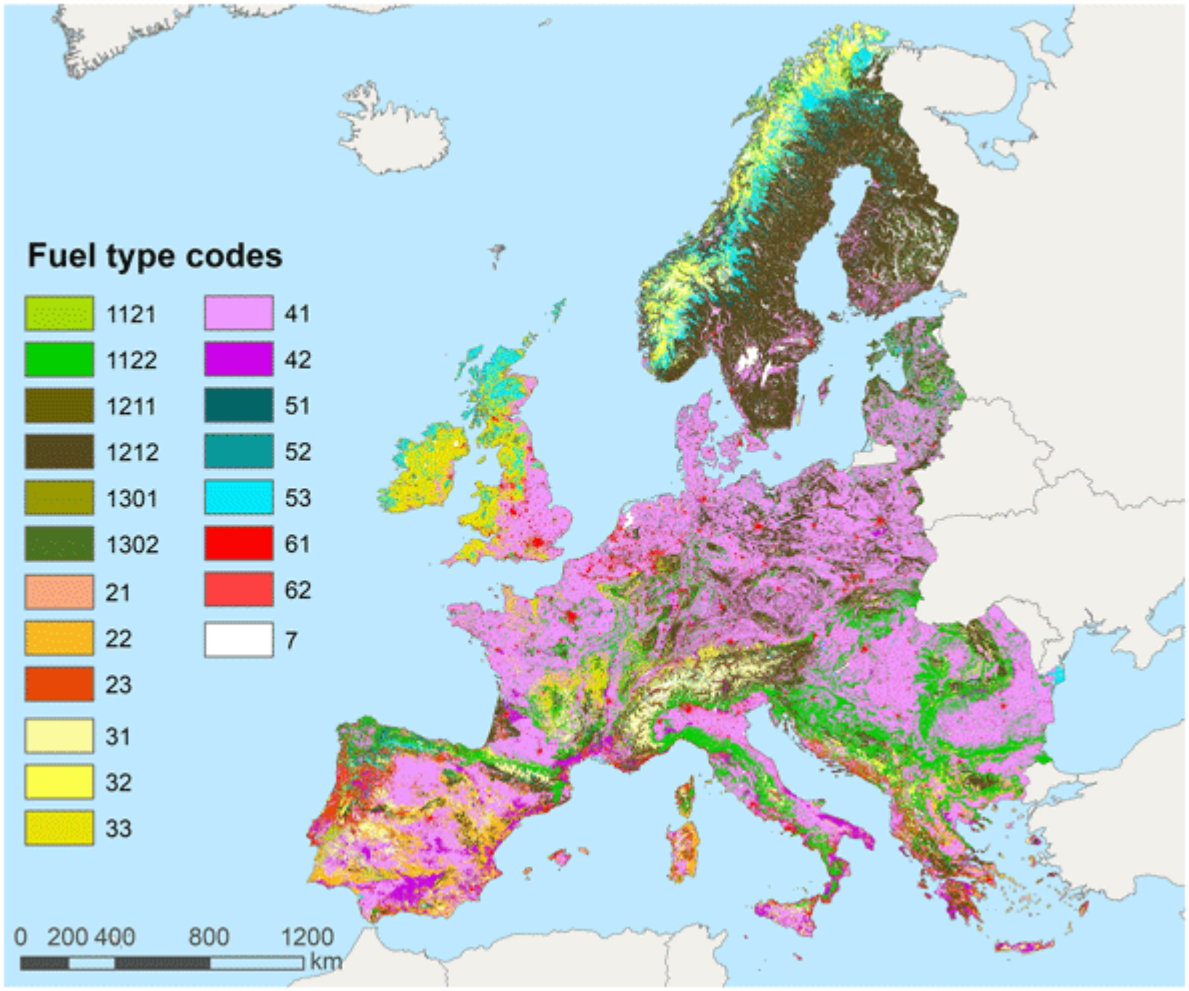


Figure 4: European Fuel Map.

4.5 References

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

5 Canopy fuel parameters

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 GEDI with other sensors. Further details about the generation of these maps can be read in Aragoneses, E., García, M., Ruiz-Benito, P., and Chuvieco, E.: Mapping forest canopy fuel parameters at European scale using spaceborne LiDAR and satellite data, Remote Sensing of Environment, 2024, 303. These maps complement the categorical information of the FirEUrisk European fuel type map for the forest fuel types in Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E.: 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, 2023.

In-detail description of the dataset and 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 Global Ecosystem Dynamics Investigation (GEDI) sensor, onboard the International Space Station (ISS). First, we simulated GEDI pseudo-waveforms from discrete 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 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.

FirEUrisk project: This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 101003890. The FirEUrisk project pretends to harmonize and upgrade current European strategies by including the socio-economic circumstances that affect the occurrence of extreme wildfires as well as the biophysical conditions, such as vegetation and climate. This mix of perspectives allows a better understanding of how vulnerable communities are to wildfires and which are the best practices to adapt.

Task in which it was carried out: A1114

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses (e.aragoneses@uah.es), University of Alcalá (UAH)

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

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

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

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 Global Ecosystem Dynamics Investigation (GEDI) sensor, onboard the International Space Station (ISS). First, we simulated GEDI pseudo-waveforms from discrete 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 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.

5.4 Data display

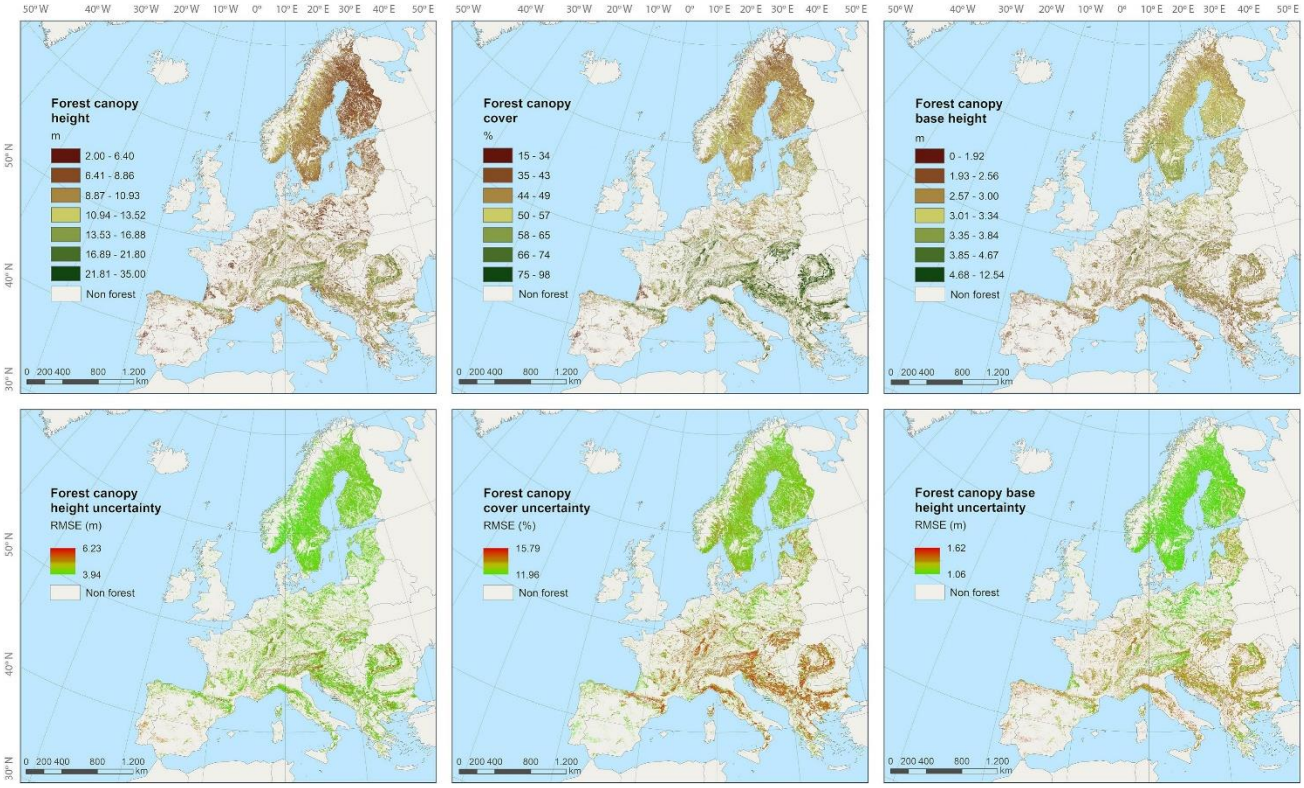


Figure 5: Maps of forest canopy height, canopy cover and canopy base height (above) with their corresponding uncertainty (below).

6 Canopy fuel load and canopy bulk density

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, E., García, M.; Tang, H. and Chuvieco, E.: 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, 2024 [under review]. These maps complement the categorical information of the FirEUrisk European fuel type map for the forest fuel types in Aragoneses, E., García, M., Salis, M., Ribeiro, L. M., and Chuvieco, E.: 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, 2023; and the European maps of forest canopy height, canopy cover and canopy base height in Aragoneses, E., García, M., Ruiz-Benito, P., and Chuvieco, E.: Mapping forest canopy fuel parameters at European scale using spaceborne LiDAR and satellite data, Remote Sensing of Environment, 2024, 303.

In-detail description of the dataset and methodology: We integrate satellite Light Detection and Ranging (LiDAR) observations of the Global Ecosystems Dynamics Investigation (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.

FirEUrisk project: This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 101003890. The FirEUrisk project pretends to harmonize and upgrade current European strategies by including the socio-economic circumstances that affect the occurrence of extreme wildfires as well as the biophysical conditions, such as vegetation and climate. This mix of perspectives allows a better understanding of how vulnerable communities are to wildfires and which are the best practices to adapt.

Task in which it was carried out: A1114

Fire risk component: Fuel

Contact details of the developer: Elena Aragoneses (e.aragoneses@uah.es), University of Alcalá (UAH)

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

6.2 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

6.3 Methodology

We integrate satellite Light Detection and Ranging (LiDAR) observations of the Global Ecosystems Dynamics Investigation (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.

6.4 Data display

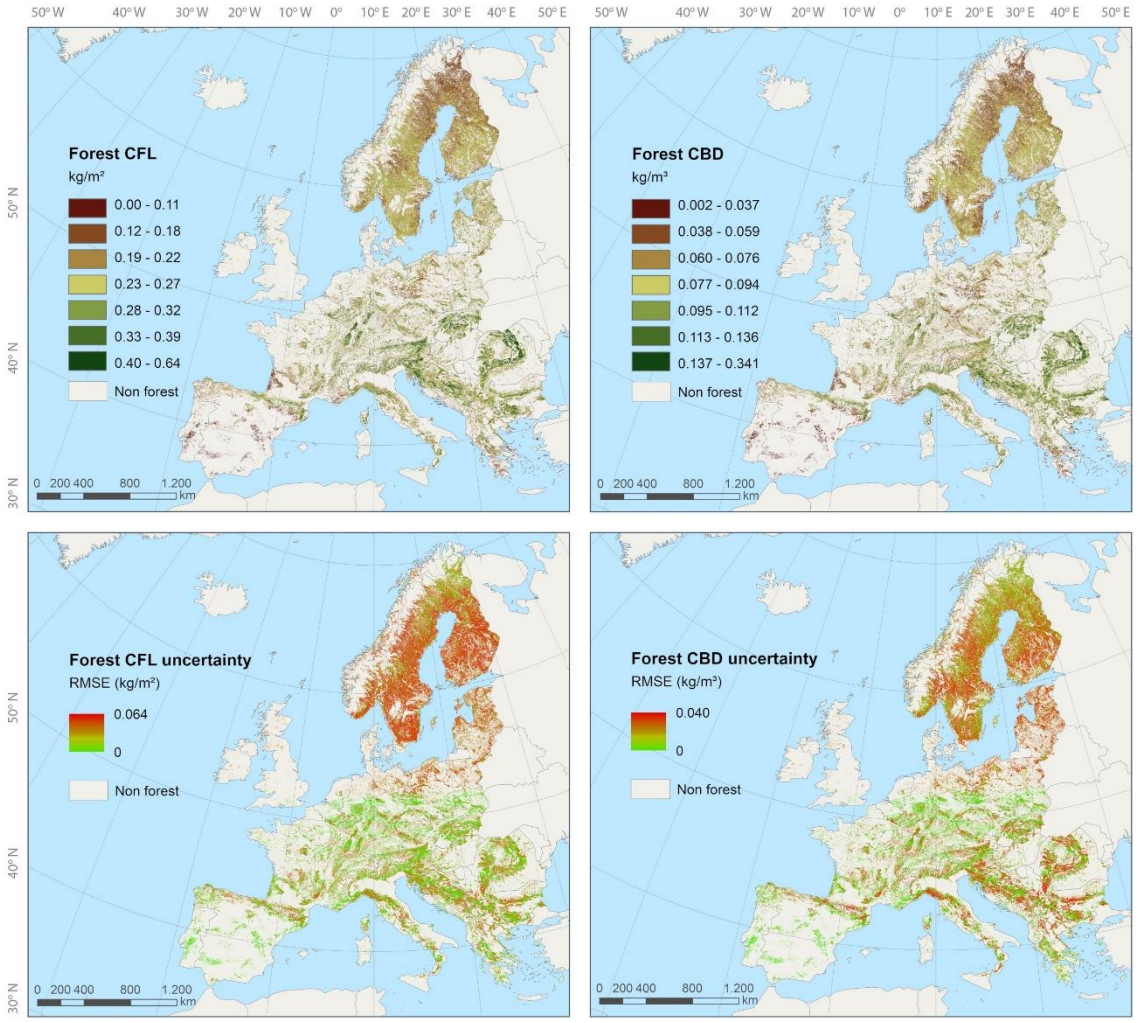


Figure 6: Maps of forest canopy fuel load (CFL) and canopy bulk density (CBD) (above) with their corresponding uncertainty (below).

7 Propagation potential indicators

7.1 Description

This product will include GeoTIFF raster maps of propagation potential indicators for European Territory, as well as report with detail description of methodology and obtained results. Propagation potential for EU territory will be calculated in 1 km2 resolution, based 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. Developer FESB SPLIT. The product developed within the Activity "A1.1.5 *Analysis of fire propagation, fuel consumption and smoke emission as risk factors*".

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.

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 then 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].

7.4 Proved accuracy at European Territory

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

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.

Vulnerability Products

8 Ecological values

8.1 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: fatima.arrogante@uah.es

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

If the affirmative case, include downloading address: It is available for download upon request by contacting us.

8.2 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

8.3 Methodology

The methodology used for ecological values assessment (EVA) is based on characterising the ecosystems' biological distinctiveness (BD) and conservation status (CS) (Figure 7) 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.

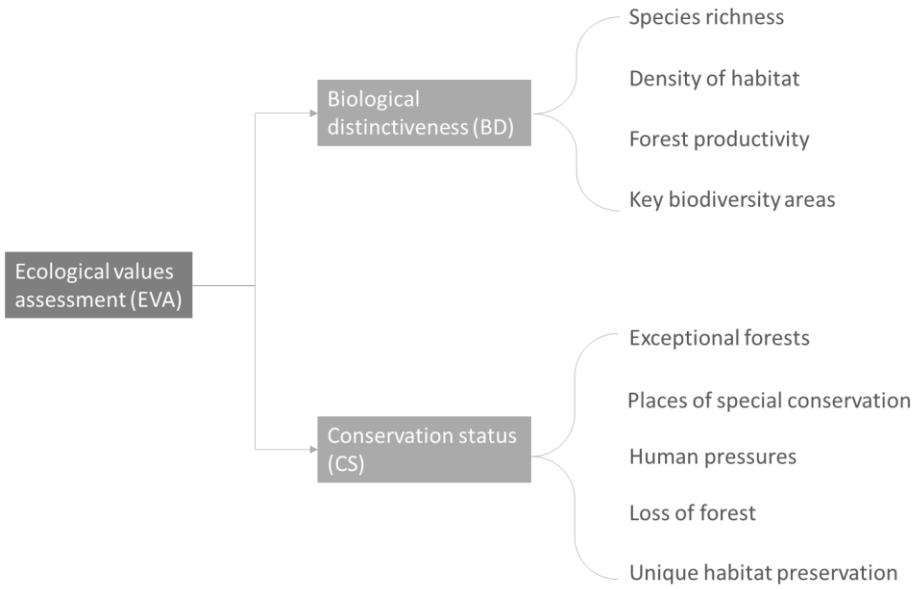


Figure 7. Components of the estimation of ecological values.

8.4 Data display

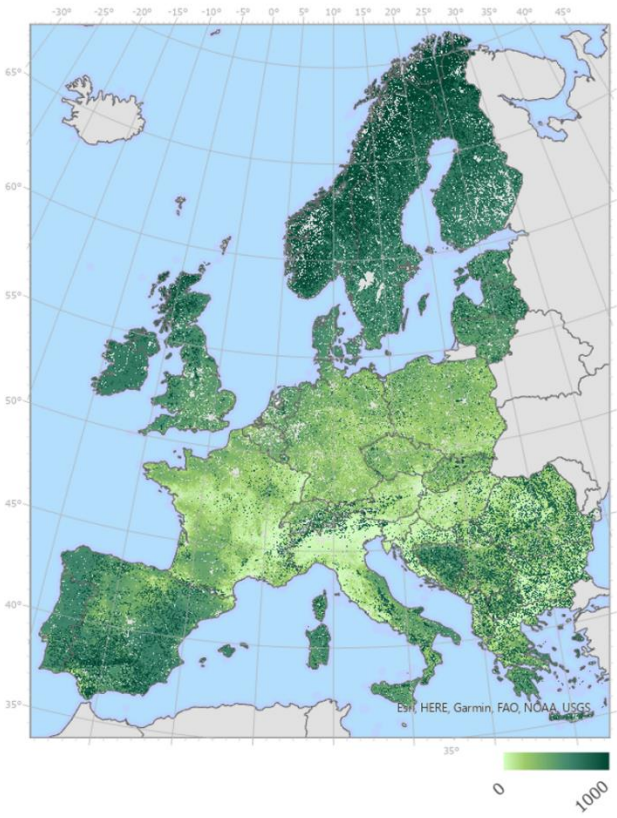


Figure 8. Map of ecological value assessment (EVA) in Europe, scaled from 0 (low value) to 1000 (maximum value). Zones with 0 values were related to areas not considered in this study, such as crops or urban areas.

8.5 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.

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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

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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

9 Recovery time

9.1 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, florent.mouillot@ird.fr

Is it publicly available? (Yes/No) Y

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

9.2 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:	5
Output Format:	Geotiff
Temporal coverage:	NA
Spatial resolution:	1km

9.3 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.

9.4 Data display



Figure 9: Map of Recovery Time (in years after fire) over Europe

9.5 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

10 Coping Capacity

10.1 Description

Ecosystem Coping Capacity (CC) 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, florent.mouillot@ird.fr

Is it publicly available? (Yes/No) Y

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

10.2 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:	0.1
Output Format:	Geotiff
Temporal coverage:	NA
Spatial resolution:	1km

10.3 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 (CC=0) during fire events, Species coping capacity was finally linearly reduced according to higher fire intensity.

10.4 Data display

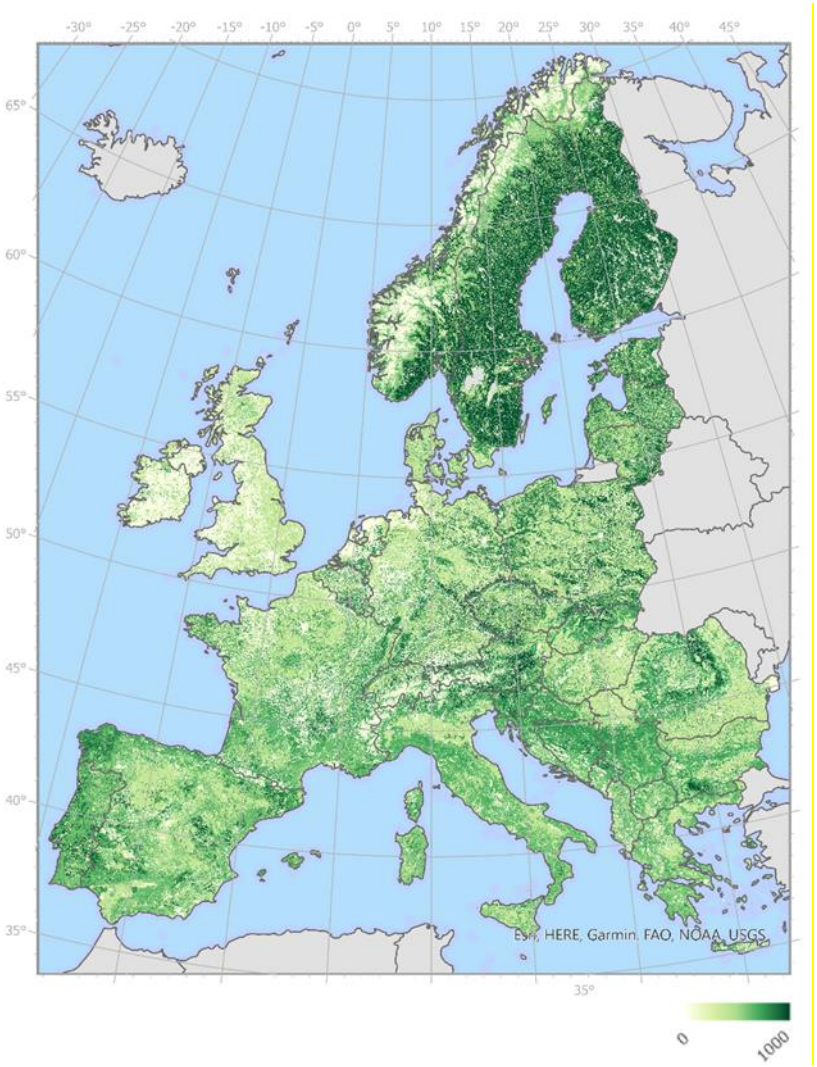


Figure 10: Map of the ecosystems' Coping Capacity to fire over Europe (0 non-resistance, 1000 high resistance).

10.5 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.

11 Ecosystem services

11.1 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- simone.martino@hutton.ac.uk; mclara.ochoa@uah.es

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

11.2 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:	
Output Format:	Geotiff
Temporal coverage:	2021
Spatial resolution:	1 km2

11.3 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; y 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; La Notte et al., 2021), while the value of properties is made by correcting national prices provided by *Numbeo* 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 (Mulliot et al., 2023; Chiuvieco 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.

11.4 Data display

The map proposed (Figure 11) 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 2) 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.

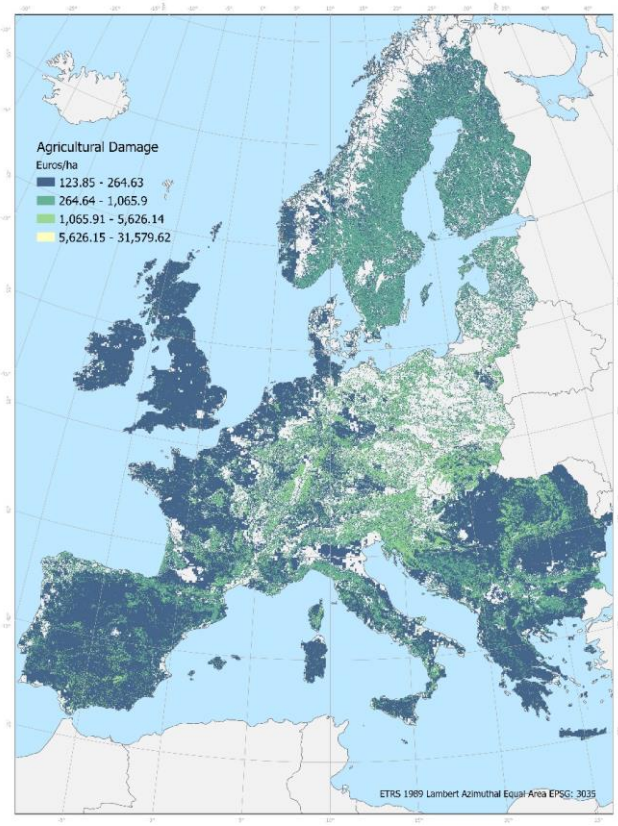


Figure 11: map of the total damage of the agro-forestry values.

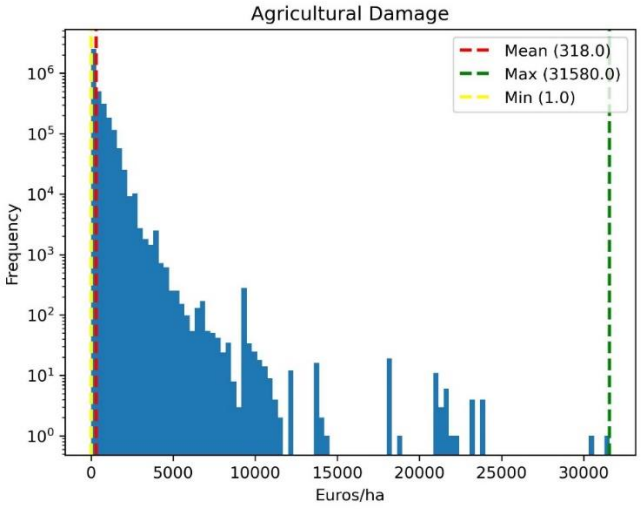


Figure 12: Histogram of the distribution of the damages reported in Figure 1

11.5 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.

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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.

Mulliot 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#:~:text=The%20Green%20Book%20is%20guidance,before%2C%20during%20and%20after%20implementation.

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.

Integration of components

12 Integrated fire risk index (IRI)

12.1 Description

Brief description of the content: Includes the different components of fire risk developed within the project, integrating Danger, Exposure and Vulnerabilty.

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. Email: emilio.chuvieco@uah.es

Is it publicly available? Only prototype

12.2 Technical components

Characteristics	Description
Type of products:	Geospatial
Units (if categorical data, include the description of each category):	Probabilty 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

12.3 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 2 includes a list of inputs, which can be further documented with their respective products' cards. Figure 13 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 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 0 the unburnable areas.

Table 2. 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
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, Regeneration time	years	Several species

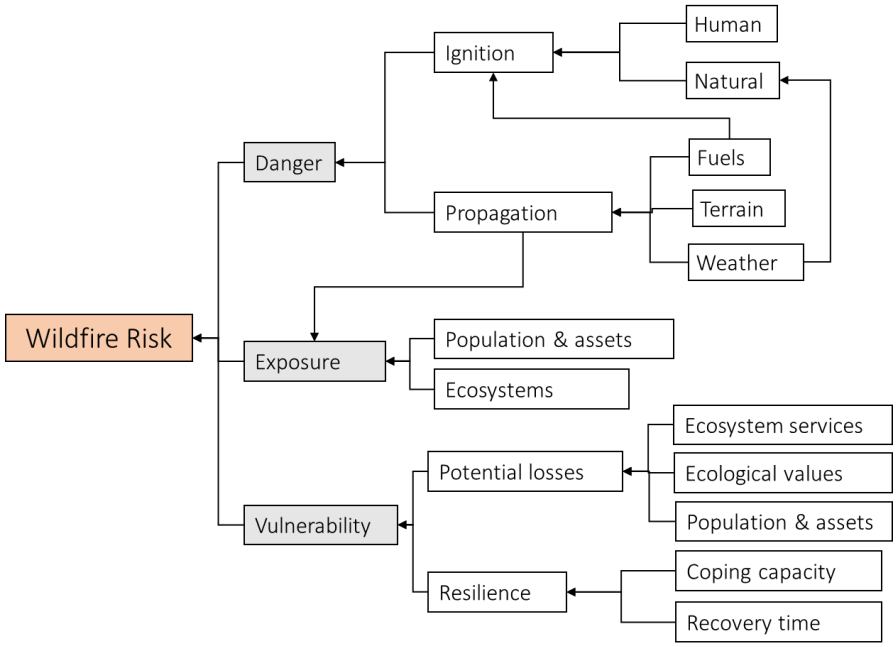


Figure 13. Conceptual integration of wildfire risk assessment components within the FirEUrisk project (after Chuvieco et al., 2023).

12.4 Data display

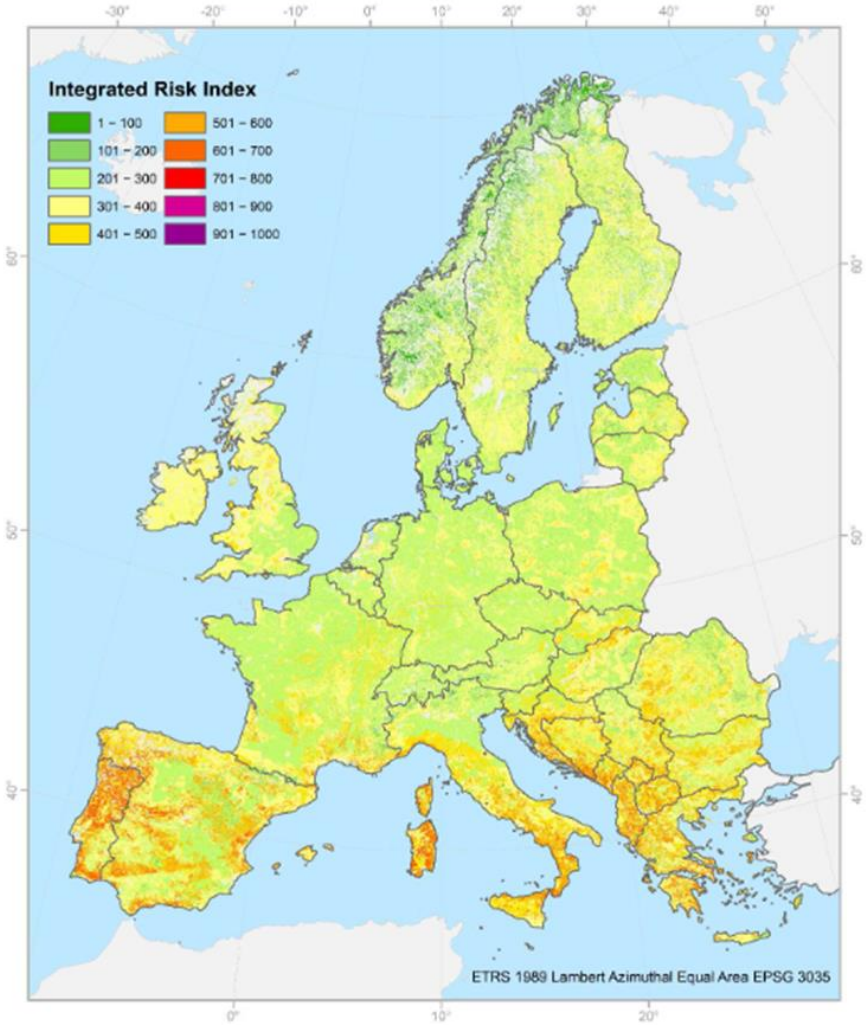


Figure 14: Example of IRI values for the extreme fire weather scenario.

12.5 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, doi210.3390/fire6050215.

See also product cards of the input datasets and deliverable D4.4 (in process).

Mitigation Products

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

13.1 Description

This product includes a set of maps which summarize suitable areas for the use of three relevant 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 (Neidermeier et al., 2024, 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 at a.neidermeier@vu.nl.

13.2 Technical components

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

13.3 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 (Joint Research Centre European Commission, 2022a; 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.

13.4 Data display

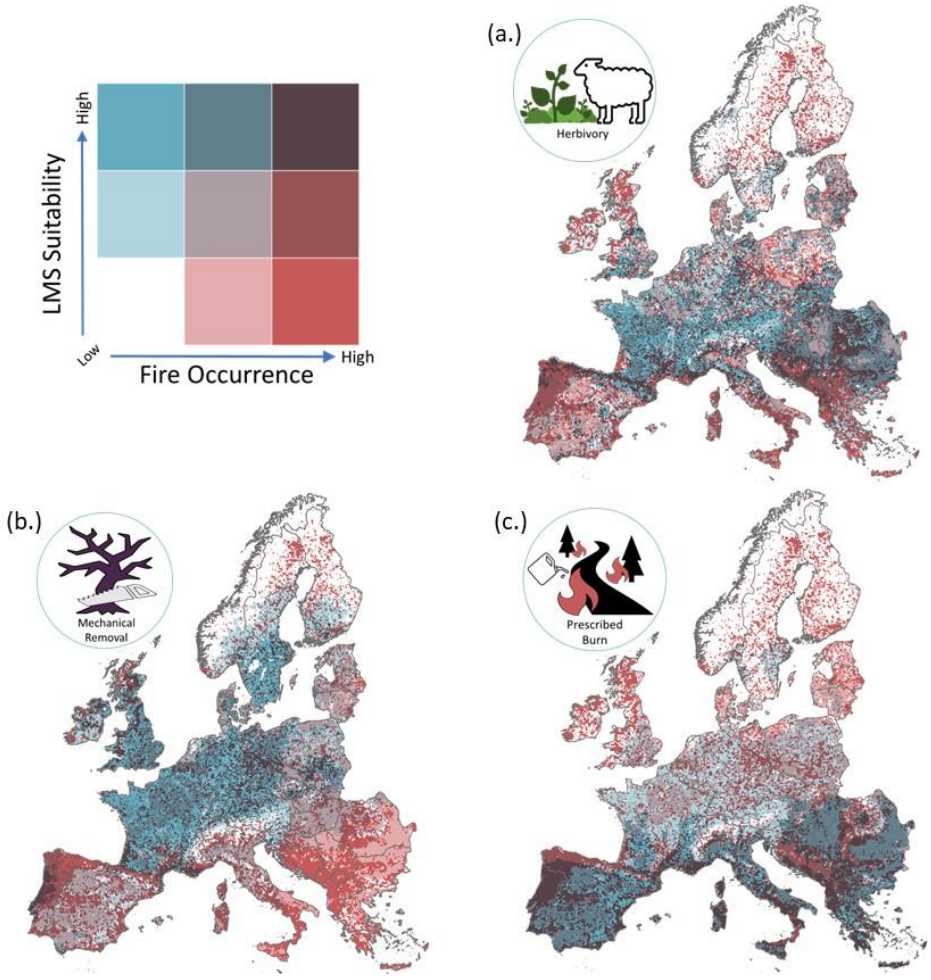


Figure 15: Bivariate choropleth maps of suitability of (a.) herbivory, (b.) mechanical fuel removal, and (c.) prescribed burn which overlap with areas of differing fire occurrence in Europe. Areas in white had low FRLMS suitability and low fire occurrence.

13.5 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*.

Future fire risk conditions products

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

14.1 Description

For Deliverable 3.2, VUA 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 incorporating 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.

14.2 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
Key contact for questions	Alex Neidermeier a.neidermeier@vu.nl

14.3 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” (Fig. 16). 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.

14.4 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 (Fig. 17), 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.

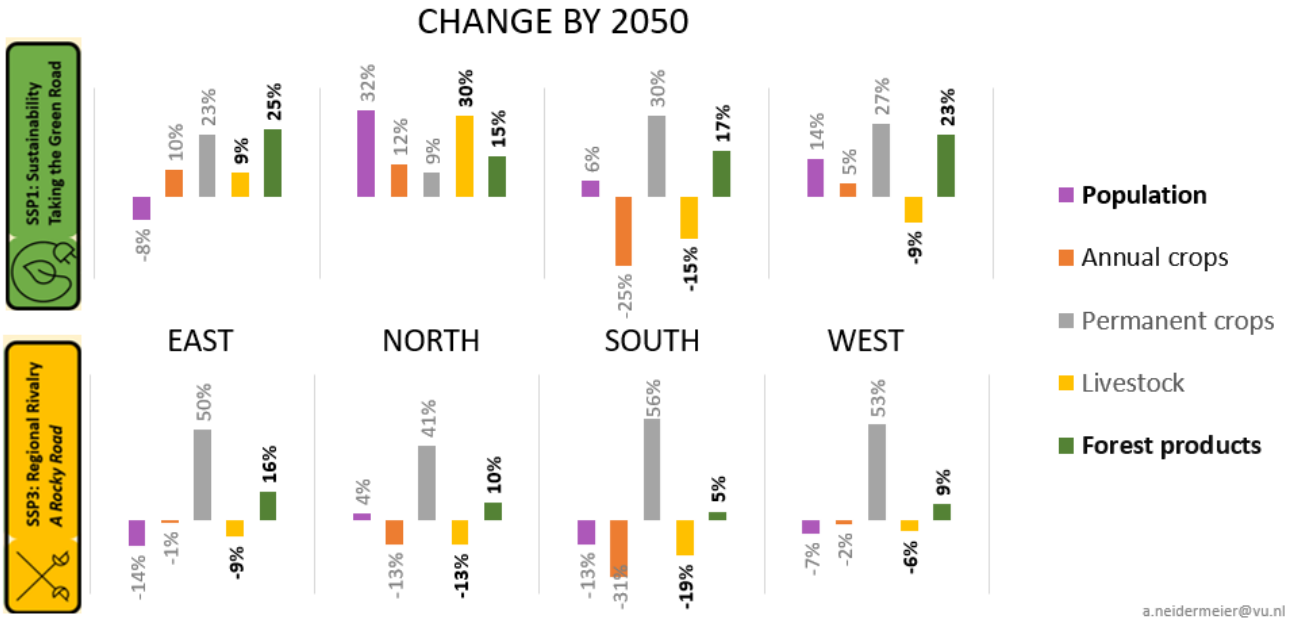


Figure 16: Percent change in demands by 2050 used to simulate future land use scenarios for population, annual crops, permanent crops, livestock, and forest products for each region of Europe (East, North, South, West) under SSP scenarios 1 (top) and 3 (bottom).

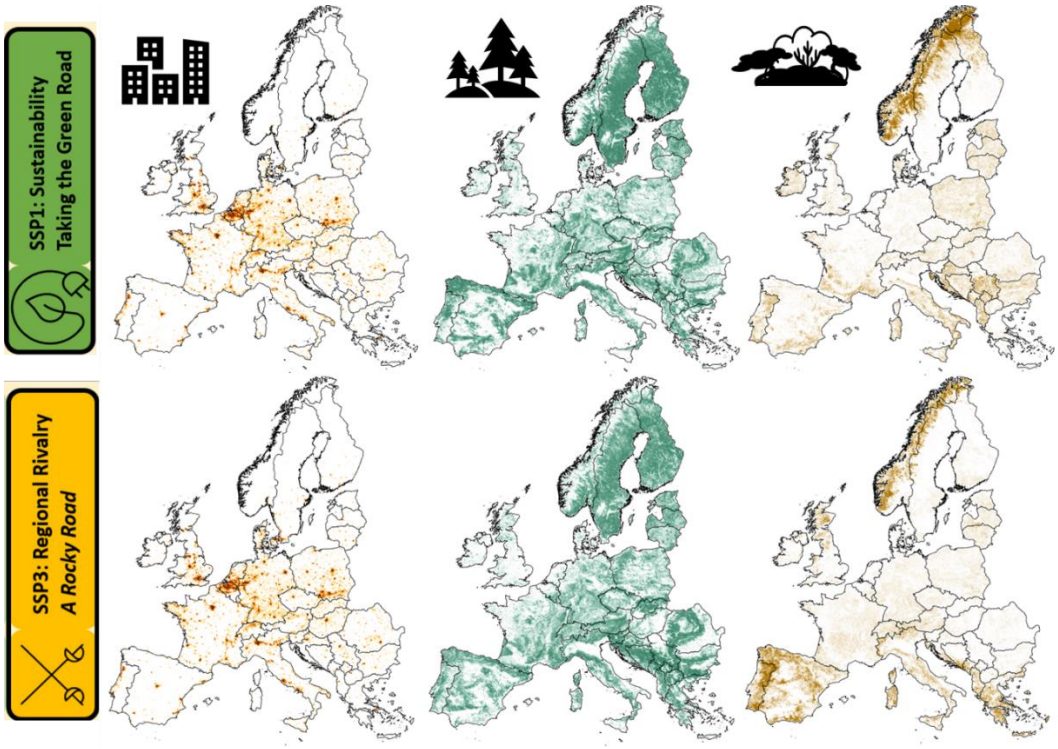


Figure 17: Simulated land cover in SSP 1 & 3 in 2050 for cities (left), forests (center), and shrublands (right).

14.5 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

15 Future fire regime data base

15.1 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

15.2 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:	n.a.
Estimated Accuracy:	n.a.
Output Format:	netcdf
Temporal coverage:	2020-2100
Spatial resolution:	9 km x 9 km

15.3 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, developed by SGN (with contributions from TUD, LSCE/UVSQ and IRD) 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 5 climate models from the SSP126 and SSP370 climate scenarios (as described in D3.1 as well as the land-use projections corresponding to those climate scenarios (as described in 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 (public).

15.4 Data display

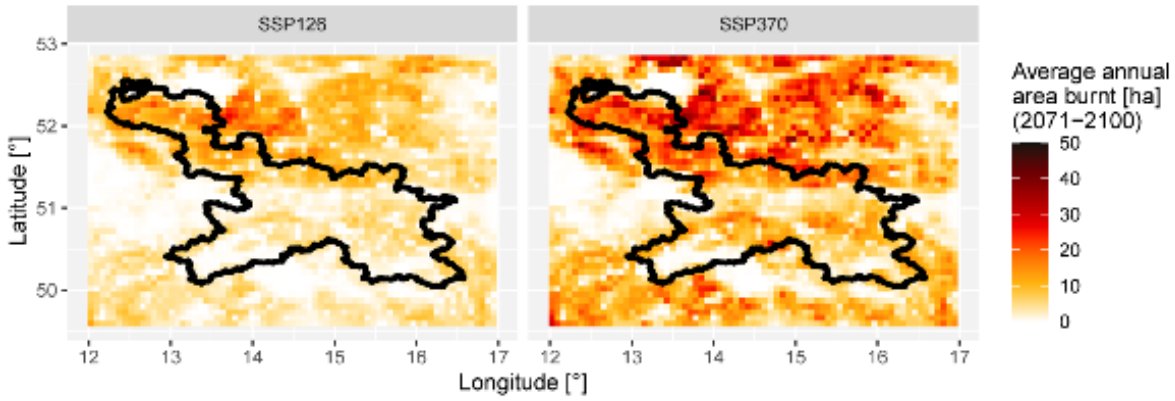


Figure 18. Simulated future burned area in the central European demonstration area using LPJmL-SPITFIRE. The simulated changes result from climate change (shown are averages over simulations using 5 different climate models for each scenario) and the corresponding changes in land cover. Vegetation composition and burned area result from changes in climate and changes in potential burned area due to land-cover change.

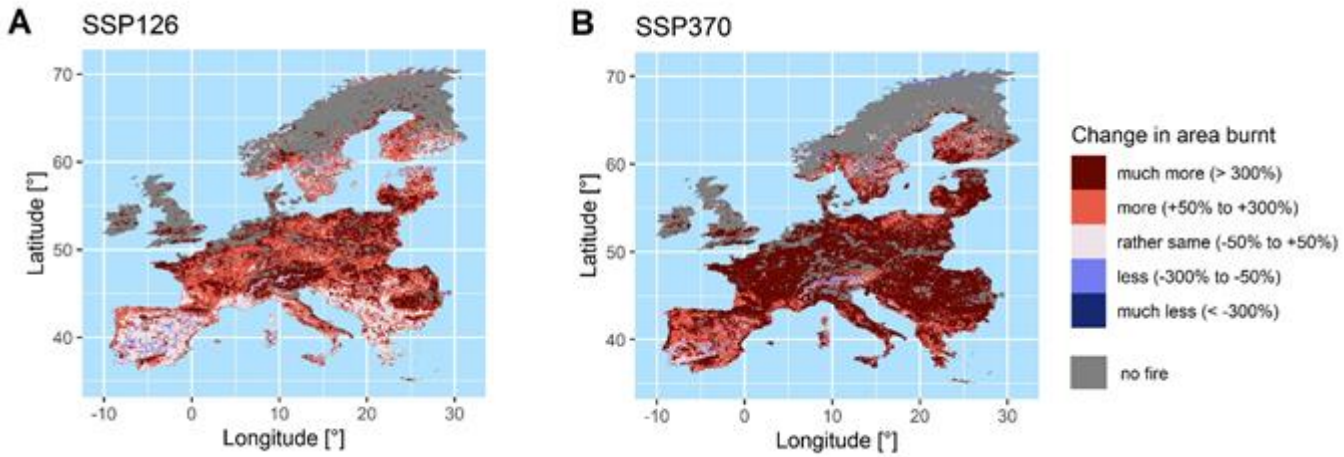


Figure 3.37 Relative changes in simulated burnt area between years 2000 – 2030 and 2070 – 2100 for SSP126 (panel A) and SSP370 (panel B) using LPJmL-SPITFIRE