DEMONSTRATION EVENT

Demonstration Event: European Territory fire risk

Critical assessment of the methods developed within the project



fireurisk

Agenda and organisation

Emilio Chuvieco and Lucrecia Pettinari, Universidad de Alcalá (Spain)



This project has received funding from the European Union 's Horizon 2020 research and innovation programme under grant agreement No 101003890

Demonstration Event: European Territory fire risk

Agenda

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

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Welcome!

The meeting will start at 9:30 CEST.

In the meantime, for further information on the products that are being presented during the workshop, we invite you to access:

https://tinyurl.com/FirEUrisk

fireurisk

General instructions

- For presenters:
  - Be very strict about your allocated time (we have a tied schedule).
  - Questions can be answer with the zoom Q&A's functionality.
- For in-person attendants:
  - Questions may be done if time allows. Otherwise, please, contact the speakers in the breaks.
- For all:
  - You are welcome to send questions with the zoom Q&A's functionality.
  - Product cards are available at the link provided by Lucrecia.
  - Presentations will be sent to attendants in the next few days.

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Project presentation

Domingos Viegas, ADAI
(Portugal)



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Project Demo at the European Territory

- Welcome to the Demo Event of FirEURisk Project results and products to be applied in the whole European Territory.
- The FirEURisk Project developed an extensive research on various problems associated to wildfire risk management and produced solutions that can be applied to better assess and reduce the risk, and also to better adapt our system to face future challenges.
- We planned six events to demonstrate the applicability and use of our products in different Regions of Europe that have particular problems of wildfire risk.
- This demo that we have today is the last one and it is aimed at the European Territory.

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- These demonstration events are already a landmark of FirEURisk Project. We started them in Catalonia in May 2023, followed by Central Europe in June, Portugal in November, Greece in April 2024 and Sweden in July.
- They represented a great effort for the Consortium but were a rewarding challenge, as they helped us converge in obtaining research solutions for a great variety of fire management problems.
- We called them “products” as they were intended to be applied at various scales and regions.

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Gantt Chart

WP	NAME	LEADER	YEAR 1												YEAR 2												YEAR 3												YEAR 4											
			M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45	M46	M47	M48
WP1	**Fire risk assessment to improve prevention**	**UdL**																																																	
T1.1	Fire Danger Assessment	METEOGRID SL																		D1.3						D1.1 D1.2																									
T1.2	Exposure & Vulnerability	HU																								D1.4 D1.5 D1.6																									
T1.3	Integrated Risk Assessment and Validation	AUTH																								D1.7 D1.8																									
WP2	**Risk reduction to improve protection**	**SAFE CLUSTER**																																																
T2.1	Reduce probability and potential of ignitions	CNR																																				D2.1 D2.2													
T2.2	Land Management Strategies (LMS) to reduce fire risk	STICHTING VU																														D2.3										D2.4									
T2.3	Improve response to reduce risk of high-impact fires	SAFE CLUSTER																																				D2.5 D2.6													
T2.4	Reduce communities' vulnerability	ADAI																																				D2.7					D2.8							
T2.5	Integration and validation of fire reduction strategies	UAH																																												D2.9			
WP3	**Adaptation to future fire regimes**	**PIK**																																															
T3.1	Generate future scenario data for the three spatial scales	SGN																		D3.1 D3.2		D3.3																													
T3.2	Estimation of future fire risks	IRD																												D3.4						D3.5 D3.6													
T3.3	Integration of fire adaptation strategies	ISIG																																										D3.7		D3.8					
WP4	**Multi-level integration**	**TUD**																																															
T4.1	Integration within the project	TUD					D4.1 D4.2							D4.3																																				
T4.2	Risk-wise integrated strategy of fire management	ADAI																																		D4.4 D4.6											D4.5			
T4.3	Integration with external platforms and legacy systems	SAFE CLUSTER																								D4.7																D4.8								
WP5	**Pilot Sites and Demonstration Areas**																																																
T5.1	Selection of products for PS scalability demos	GMV		D5.4																		D5.1				D5.2 D5.3																									
T5.2	Management of study cases	GMV																		D5.5										D5.6				D5.7			D5.8			D5.9			D5.10				D5.11			D5.12	
WP6	**Policy integration & outreach- Networking & dissemination**	**IICT-BAS**																																															
T6.1	Networking	SAFE CLUSTER			D6.1																					D6.2																								D6.3
T6.2	Outreach and training activities	UAVR																								D6.4																								D6.5
T6.3	Communication and Dissemination	SCS						D6.6 D6.9 D6.11																		D6.7 D6.12																								D6.8 D6.10 D6.13
T6.4	Policy integration	KEMEA																												D6.14																				D6.15
WP7	**Project Management and Coordination**	**ADAI**																																															
T7.1	Project Management Committee	ADAI																																																
T7.2	Scientific and Technical Management	UAH																																																
T7.3	Research Ethics, Legal and Societal Management	KEMEA												D7.1																														D7.2								
T7.4	Administrative Management	KEMEA																																																
WP8	Ethics Requirements	**ADAI**																																															

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Our Partners



- 38 partners.
- 18 countries
- 21 research institutions
- 12 Operational agencies
- 5 Enterprises
- Interdisciplinary:
  - Mechanical engineers.
  - Forest engineers.
  - Social scientists
  - Ecologists / environ. scientists.
  - Geographers.
  - Climatologists
  - …

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Steering Committee

- General Coordinator

Domingos Xavier Viegas

ADAI/UC-Portugal



- Technical Coordinator

George Eftychidis

AUTH - Greece



- Scientific Coordinator

Emilio Chuvieco Salinero

UAH-Spain



- Data Manager

Ioannis Gitas

AUTH - Greece



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FirEUrisk project objectives

1. Expand the capabilities of existing wildfire **risk assessment** systems.
2. Use risk-assessment to drive wildfire management and **reduce current fire risk conditions**.
3. **Adapt fire management strategies** to expected future climate and socio-economic changes.
4. **Integrate** all fire management phases and activities.

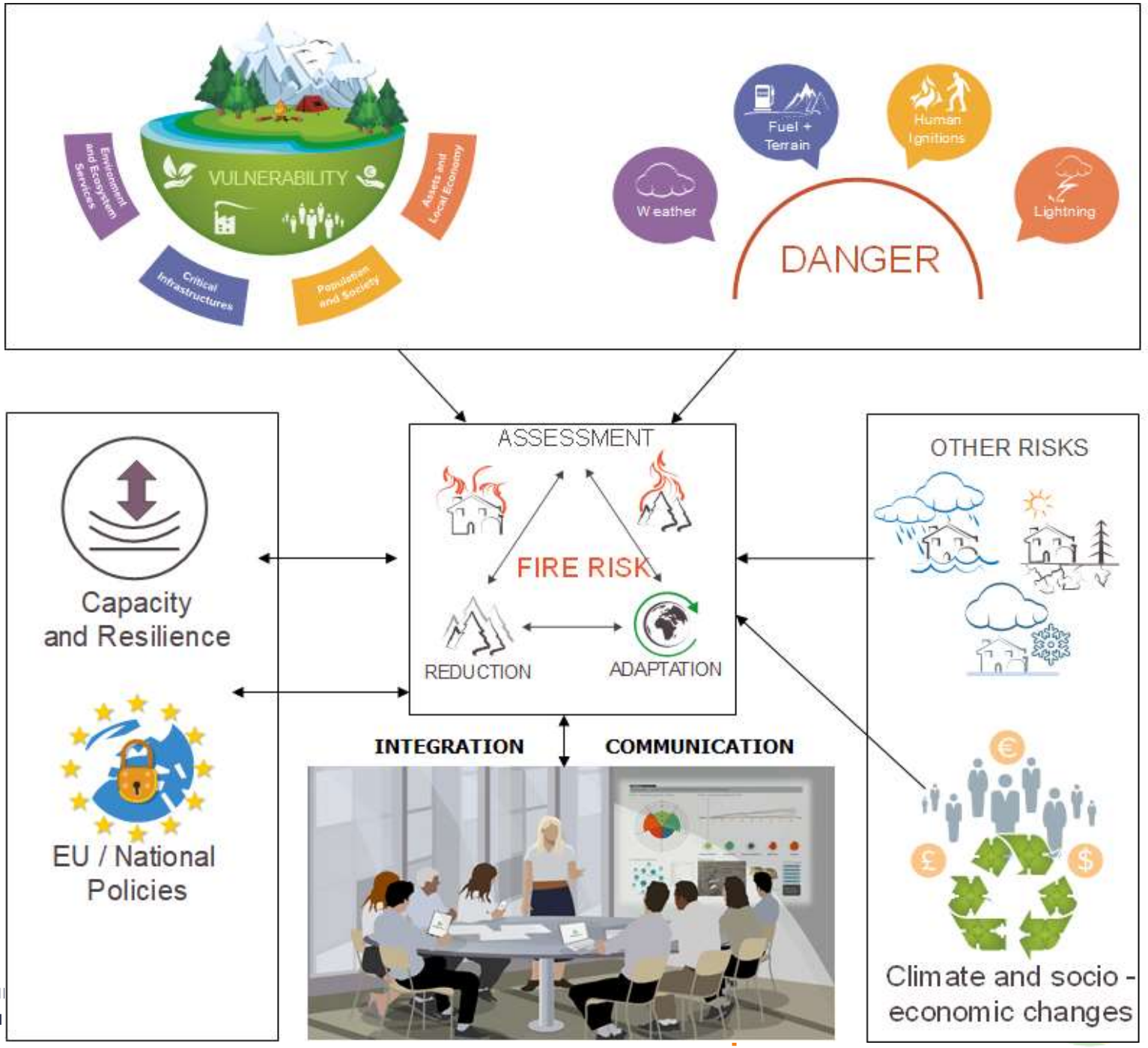


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Shift towards managing the risk

FirEUrisk framework





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Wildfire risk **ASSESSMENT**

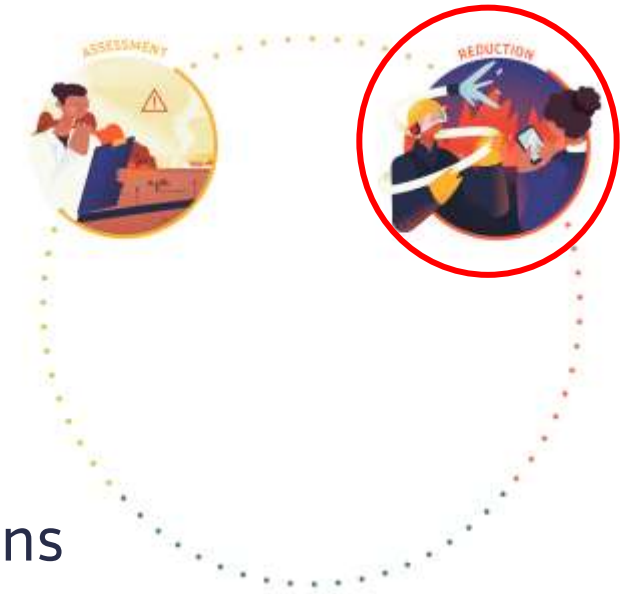
- Go beyond fire danger as base of fire management
- Assess risk conditions and potential (vulnerability and impact)
- Include social & ecological aspects of risks (holistic approach)
- Focus to managing fire risk conditions in WUI areas
- Involve local population in fire management aspects (citizen-science).



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Wildfire risk **REDUCTION**

- Test different fire reduction strategies
- Reduce ignitions caused by human activity
- Increase socio-ecological resilience (capacity building)
- Capitalize on the experience from previous extreme events
- Improve training and preparedness of all stakeholders (citizens and volunteers, forest and fire managers, decision and policy makers)



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Wildfire risk **ADAPTATION**

- Generate and elaborate fire regime scenarios linked to changes due to the future climate conditions
- Integrate risk-change drivers into future scenarios
- Support adaptation plans in new fire-prone regions (higher altitude and northern areas)
- Improve resilience of WUI areas to extreme fire behavior



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Integration and **Communication**

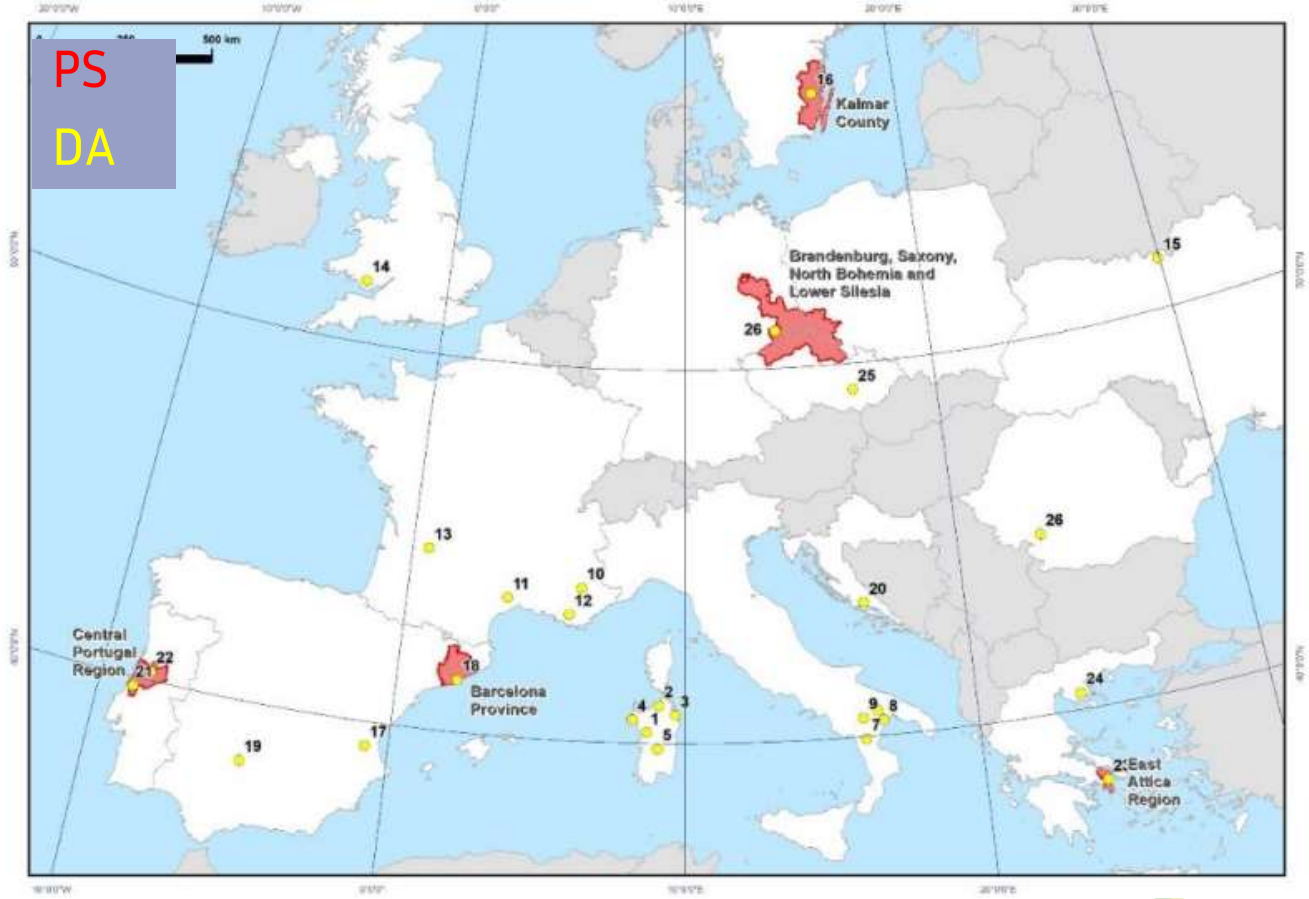
- Integration of results into existing risk systems (e.g., EFFIS)
- Integrate existing platforms and satellites services (e.g., Copernicus)
- Two-way communication with citizens living in fire-prone areas (e.g., WUI)
- Consider potential cascading effects related to wildfires
- Networking with the international wildfire research community (Boards & FEU Observatory)
- Capitalization of results using Knowledge Management platforms such as DRMKC/JRC including a Repository of the fuel management tools & apps



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Demonstration plan

- 26 Demonstration Areas (DA) (NUT-3)
  - Field data collection campaigns for modelling and testing purposes
- 5 Pilot Sites (PS)
  - Portugal, Spain, Greece, Germany, Sweden (field tests)
- EU scale
  - Projection of fire regime and wildfire risk for 2050 and 2100



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fireEUrisk

The report on the fires of 2023 is in preparation.

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Integrated Wildfire Risk Management (IWRM)

Inputs:

EFFIS
DRMKC
Member States
Scientic
Institutions and
projects

Actors:

Science and technology
Industry and Services
Forest Managers
Land Owners
Mayors
Citizens
Policy Makers and
Managers
Operational Agents



Scales:

International
EU
National
Regional/Province
Local

Past, present and future

Output:

ROADMAP
for an IWRM
strategy for
Europe

Scientific Strategy → Management Framework → Governance and policies:

Wildfire risk:
- Assessment
- Reduction
- Adaptation

Scales:
- Principles
- Goals
- Guidelines
- Processes

Governance and policies:
- Coordination
- Agencies
- Legislation
- Jurisdiction

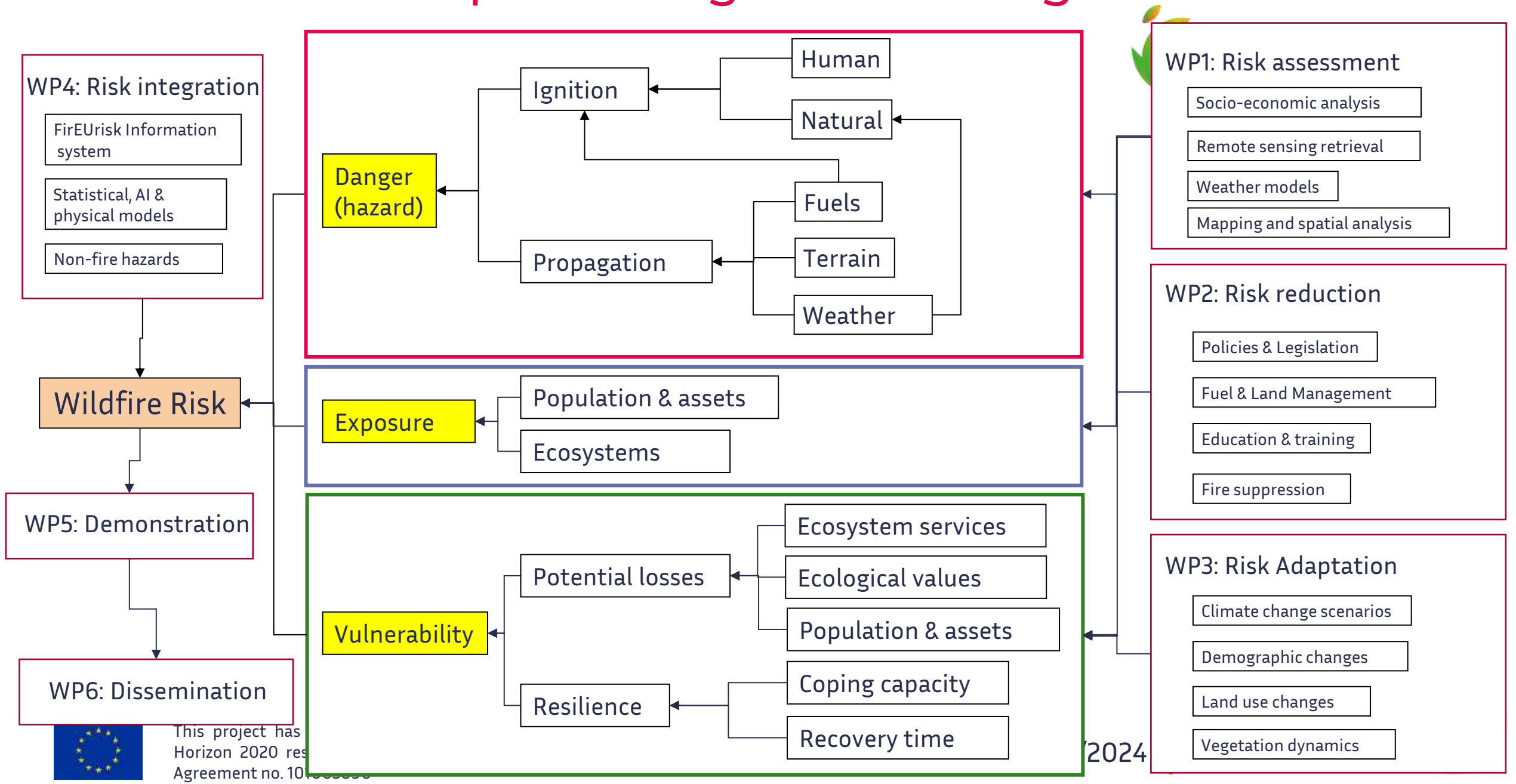
FirEURisk framework

Emilio Chuvieco, Universidad de Alcalá (Spain)



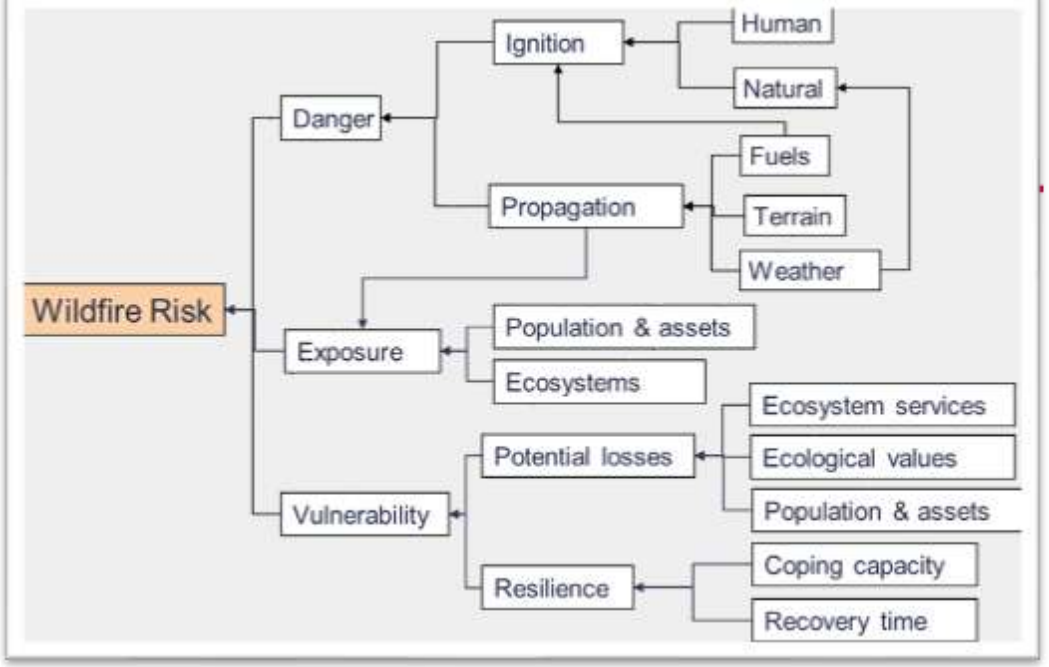
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FirEUrisk conceptual integration among WPs



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Horizon 2020 res
Agreement no. 10
/2024

FirEUrisk framework and Integration Scheme





Article Views	9834
Citations	30

Open Access | Editor's Choice | Concept Paper

Towards an Integrated Approach to Wildfire Risk Assessment: When, Where, What and How May the Landscapes Burn

by Emilio Chuvieco [1,*], Marta Yebra [2,3], Simone Martino [4], Kirsten Thonicke [5], Marta Gómez-Giménez [6], Jesus San-Miguel [7], Duarte Oom [7], Ramona Velea [8], Florent Mouillot [9], Juan R. Molina [10], Ana I. Miranda [11], Diogo Lopes [11], Michele Salis [12], Marin Bugaric [13], Mikhail Sofiev [14], Evgeny Kadantsev [14], Ioannis Z. Gitas [15], Dimitris Stavrakoudis [15], George Eftychidis [15], Avi Bar-Massada [16], + Show full author list

[1] Environmental Remote Sensing Research Group, Department of Geology, Universidad de Alcalá, Geography and the Environment, Calle Colegios 2, 28801 Alcalá de Henares, Spain

WP113
Probability of Human ignitions

Clara Ochoa[1], Avi Bar-Massada[2], Emilio Chuvieco[1]



[1] *Universidad de Alcalá, Department of Geology, Geography and the Environment*

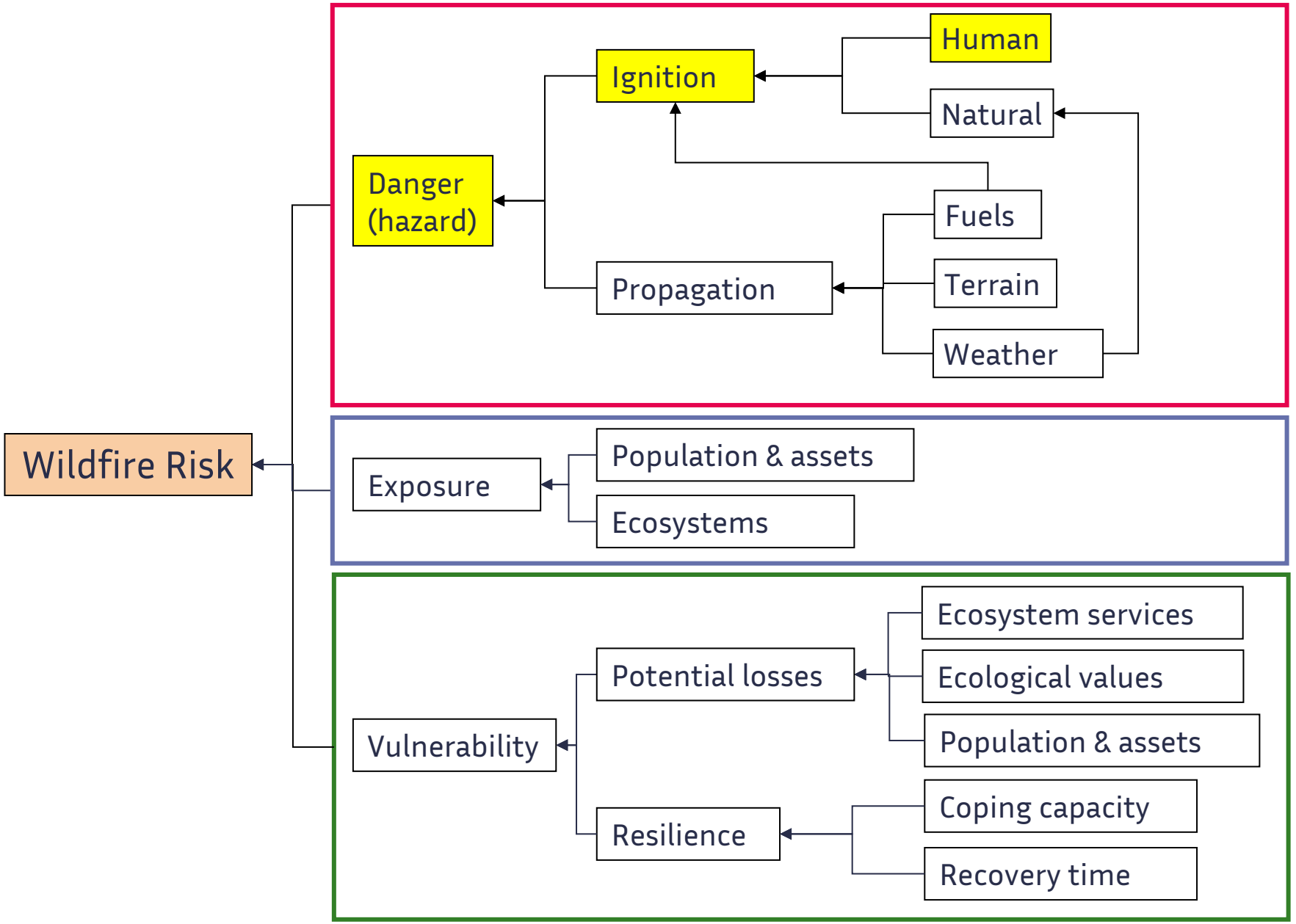
[2] *Department of Biology and Environment, University of Haifa at Oranim*

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Contents

- 1. Dependent variable
- 2. Independent variables
- 3. Model
- 4. Results
- 5. Conclusions

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1. Dependent Variable: Initiation Points

- The initiation points for the period 2001-2019 derived from the FireCCI51 pixel-based burned area product using the FRY flood-fill algorithm as described by Laurent et al. (2018).
- Initiations with BA > 100 ha
- Exclusion of points in cropland and built-up areas, but those < 500 m from forests, grass and shrubland
- Exclusion of points in Herbaceous wetlands in the Danube delta.

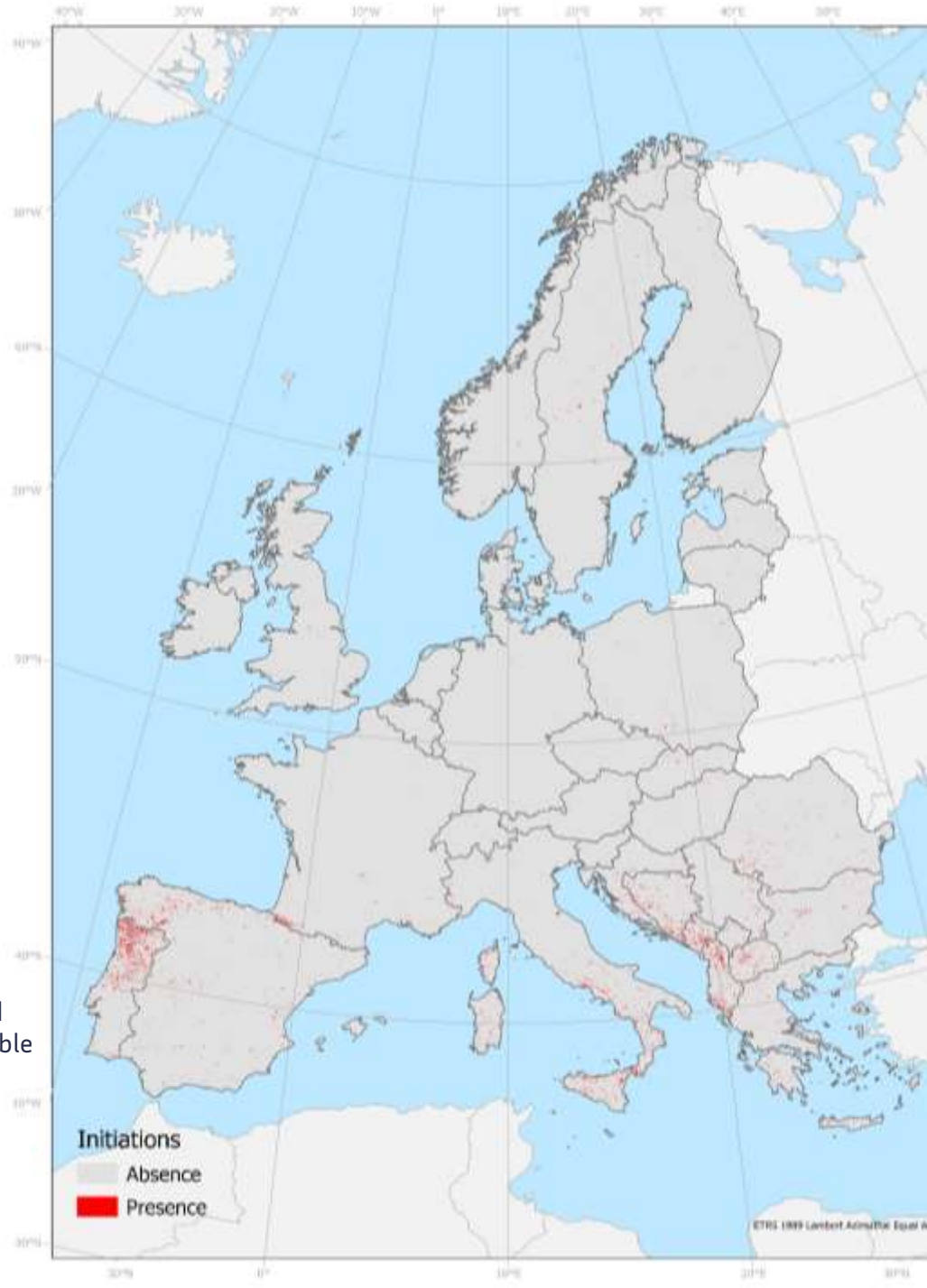


Fig. 2. Suggested area for FirEUrisk and representation of the dependent variable (in red) from 2001 to 2019.

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2. Socio-economic Independent Variables

- 13 Socio-economic Variables describing the ET
- 1 km resolution
- Limited by availability
- Cattle, Goats and Sheep were transformed in to one single variable called grazing.

Grazing

Variable	Source	Year	Publication
1. Distance to secondary 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	-

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2.2 Climatic Independent Variables

- 4 climatic independent variables describing the ET
- 1 km resolution
- Bioclimates: Cool, Cold and Warm
- Ecological regions for stratified sampling

Variable	Source	Year	Publication
14. Evapotranspiration	Antonio Trabucco, Robert Zomer (2019)	2018	2019
15. Aridity Index	Antonio Trabucco, Robert Zomer (2019)	2018	2019
16. Bioclimates (Cool, Cold, Warm)	European Commission and the University of Edinburgh	2000	2018
17. Ecological Regions	FAO	2000-2010	2013

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3. Models

- Tests were carried out using different methods to balance the data, and the fires selected
- Models were run with only human, only climate and mixed variables
- Mixed model being the best prediction and the one used for the Project

Models	Climatic	Human	Mixed
Number of initiation points:	33,388	33,388	33,388
Hyperparameters (CV):			
• Max_depth: max features	10	10	10
• Min_simple_leaf	Auto	Auto	Auto
• Min_simple_Split	4	4	1
• n_estimators	10	2	5
• Random_state	200	100	100
• Absence sampling method	Stratified sampling 1:1.5	SMOTE sampling	Stratified sampling 1:1.5
AUC	0.78	0.61	0.80

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4. Results: Global importance and likelihood

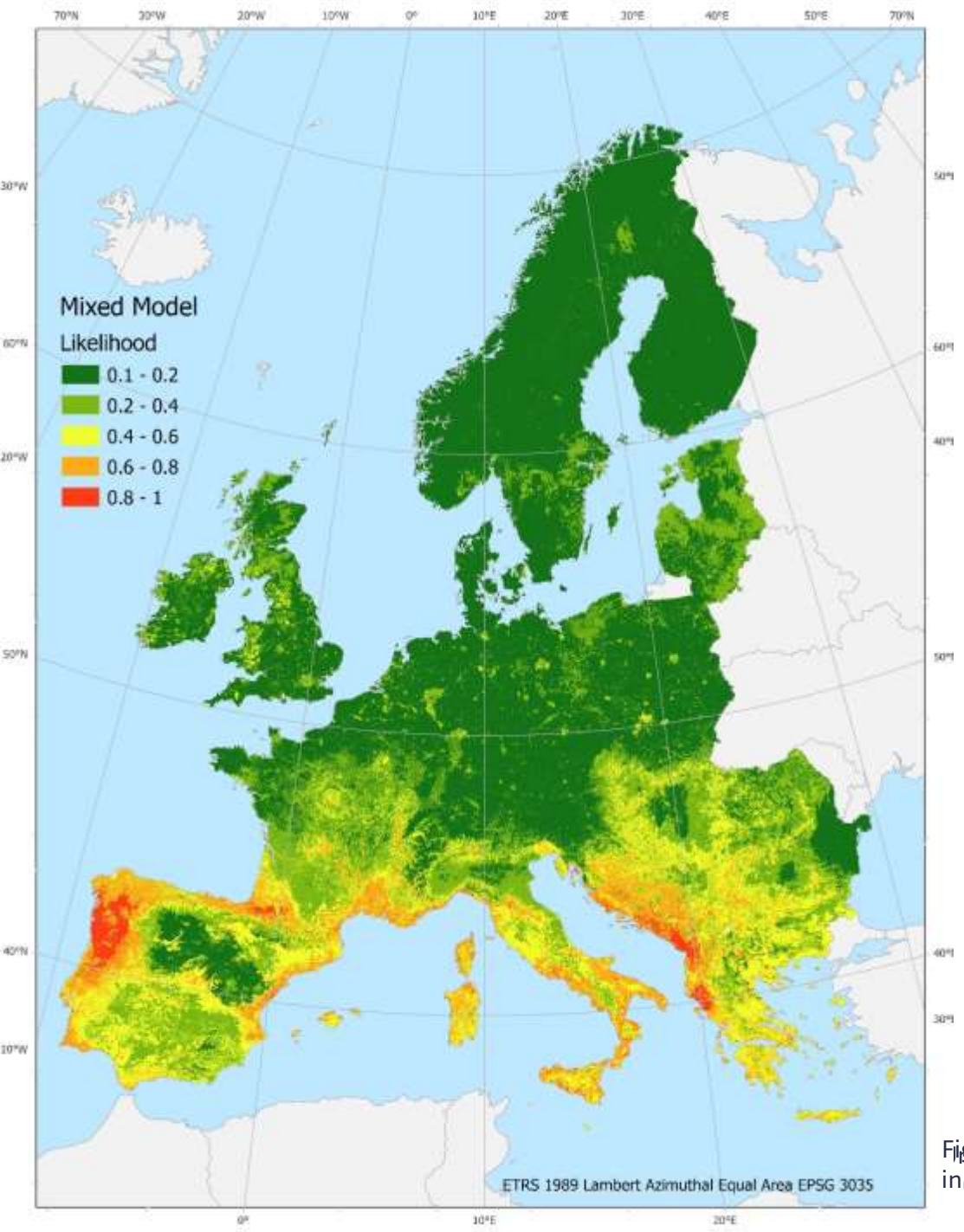


Fig. 3 Likelihood of human ignition for mixed model

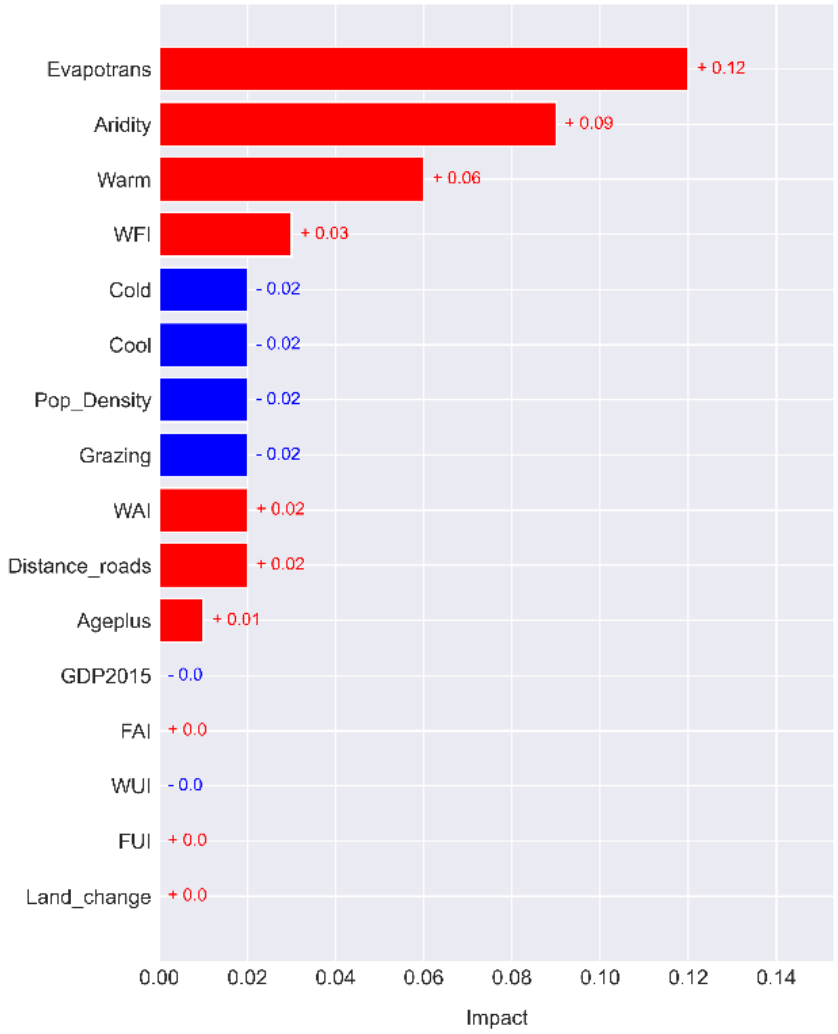


Fig. 4. Global variable importance in the mixed model for large fires.

5. Conclusions

1. Enhancing Fire Risk Understanding.
2. Informed Policy Development.
3. Strategic Fire Management.
4. Data-Driven Decision Making.
5. Foundation for Future Research.

Clara Ochoa – Universidad de Alcalá
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Natural ignition probability

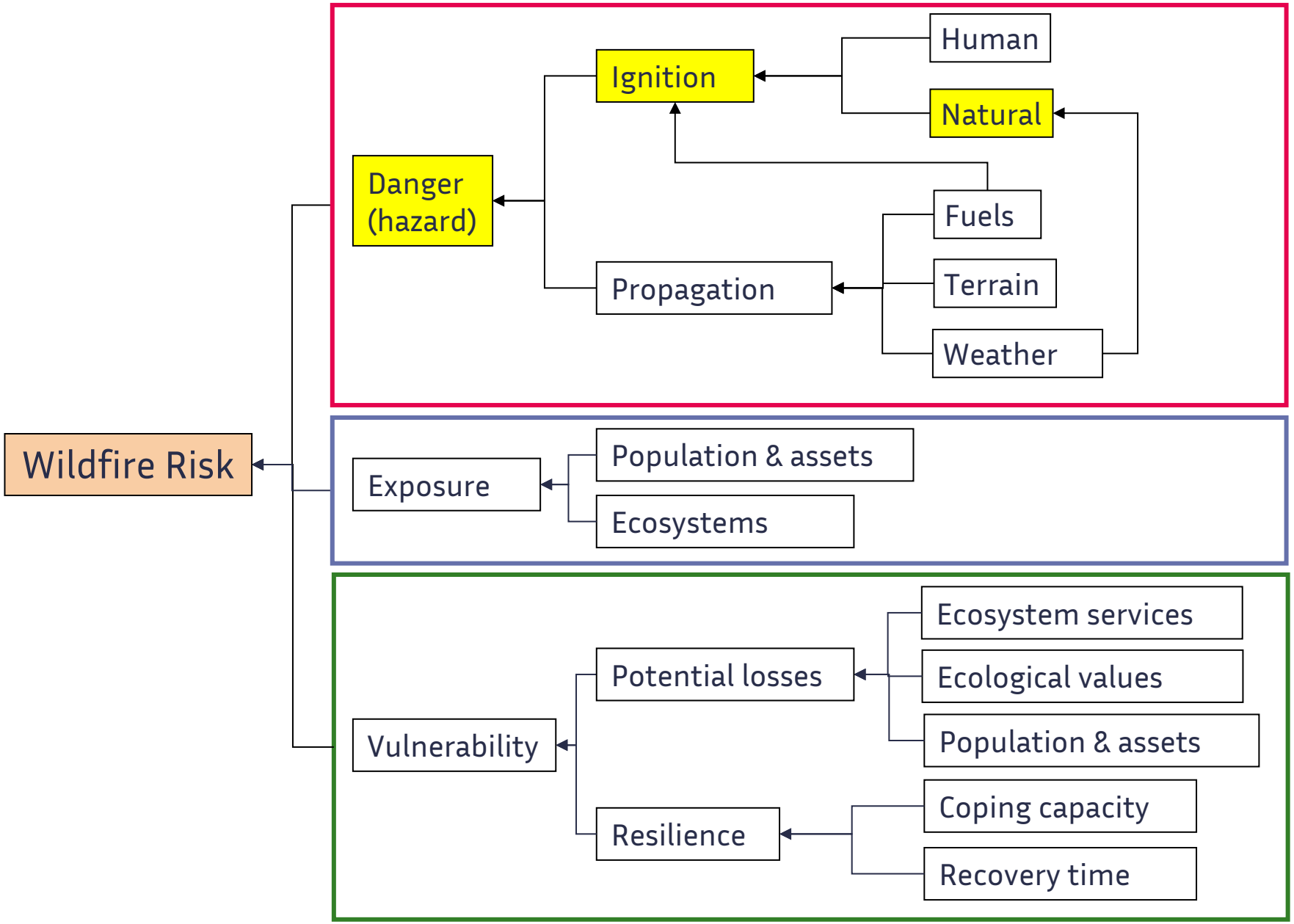
Evgeny Kadantsev

Finnish Meteorological Institute

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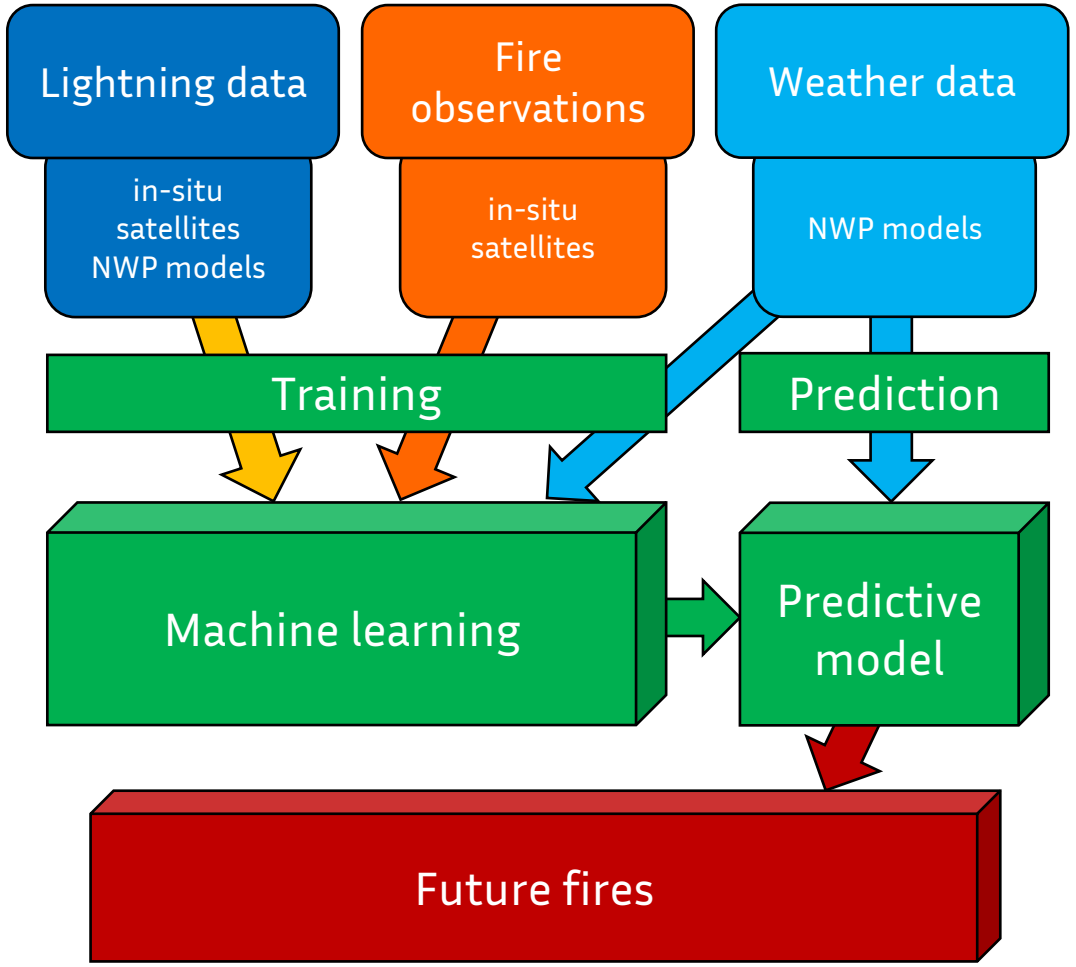
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Natural fire ignition

- Majority of fires caused by human activity (up to 90%)
  - depending on the accessibility of the area to people
  - varying between regions
- Natural fire ignition is predominantly caused by lightning
- Our task was to
  - develop a predictive model for fire ignition due to lightning
  - establish an operational system to deliver daily forecasts



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NWP lightning scheme

Lightning Parameterization for the ECMWF Integrated Forecasting System (Lopez, 2016; doi: 10.1175/MWR-D-16-0026.1):

Total lightning flash density depends on

~ $\sqrt{CAPE}$ (convective available potential energy)

~ Q_R (the charging rate resulting from collisions between hydrometeors within the charge separation region)

ECMWF provides the total lightning flash density as a product of IFS model since summer 2018

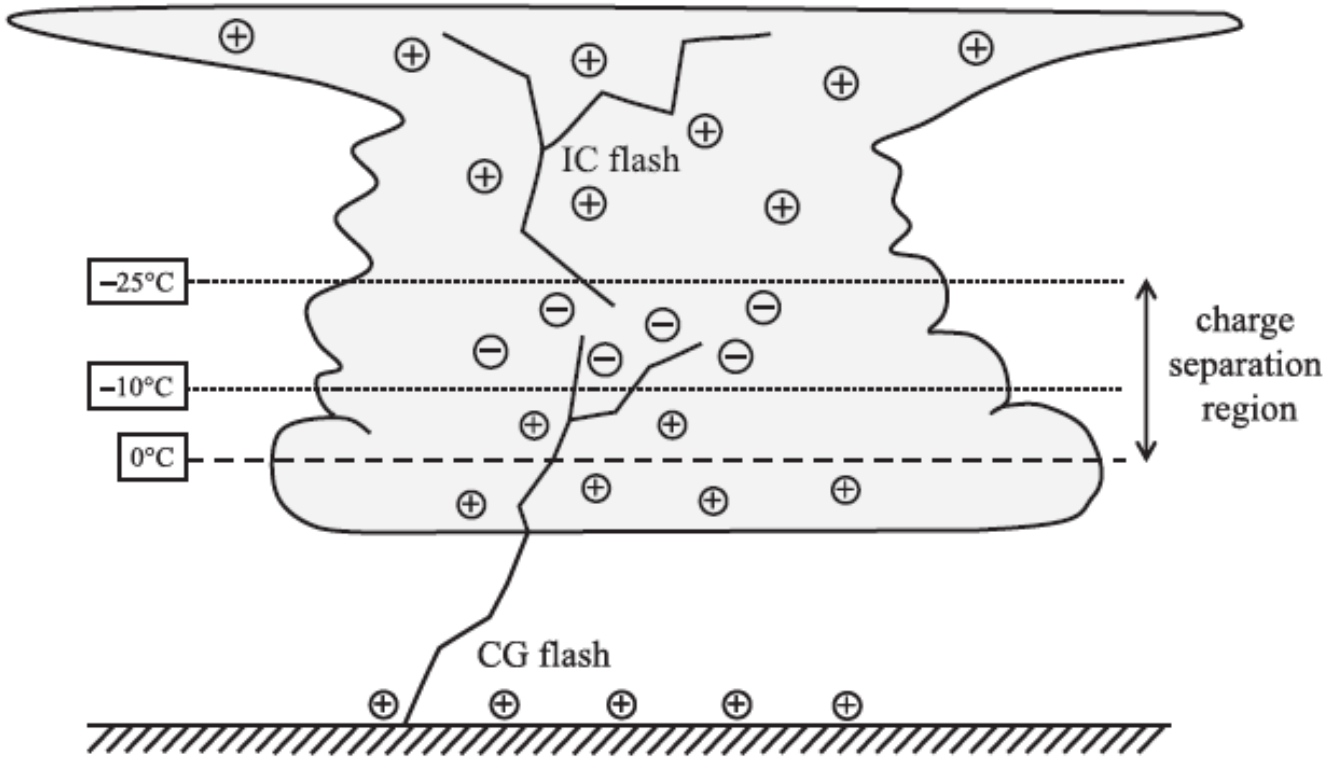


FIG. 1. Idealized electric charge distribution in a mature thunderstorm. Here "CG" and "IC" stand for cloud-to-ground and intra/inter-cloud lightning, respectively.

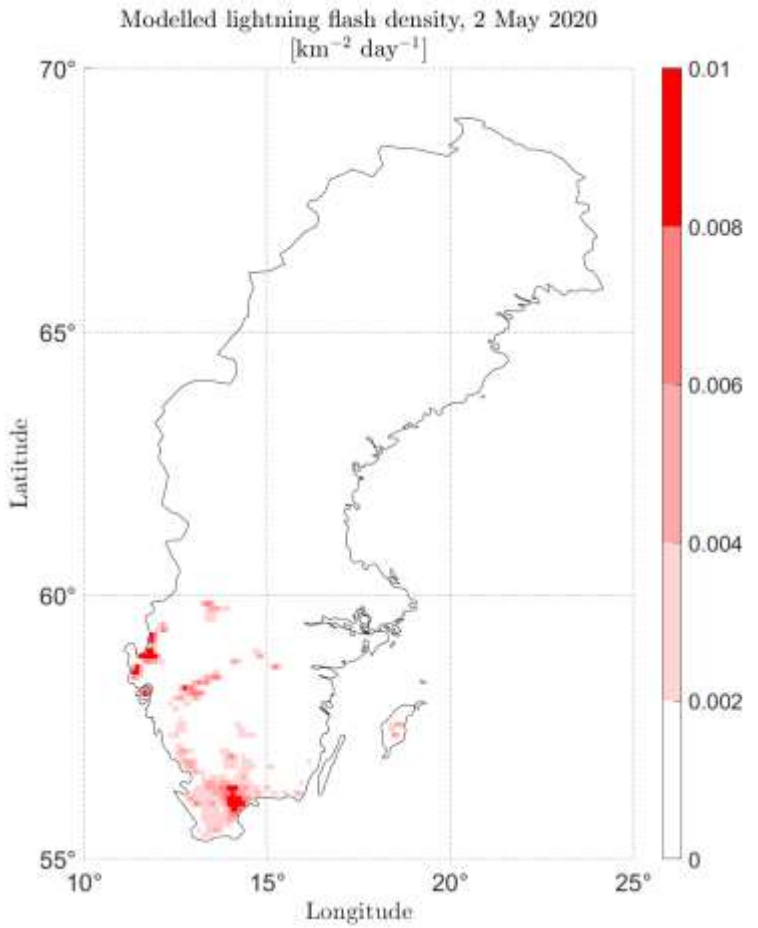
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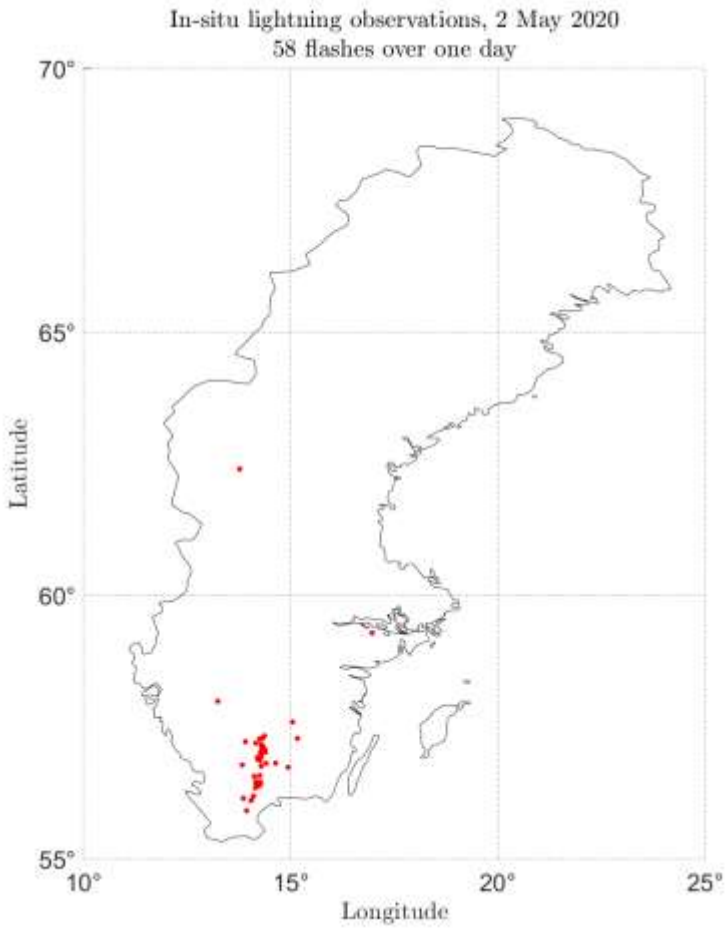
Model vs in-situ observations

Unlike satellite fire observations (e.g., MODIS, VIIRS, SEVIRI), modelled lightning flash density shows a reasonable correspondence with in-situ observations

Example date

2 May 2020





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Cloud-to-ground lightning flash density

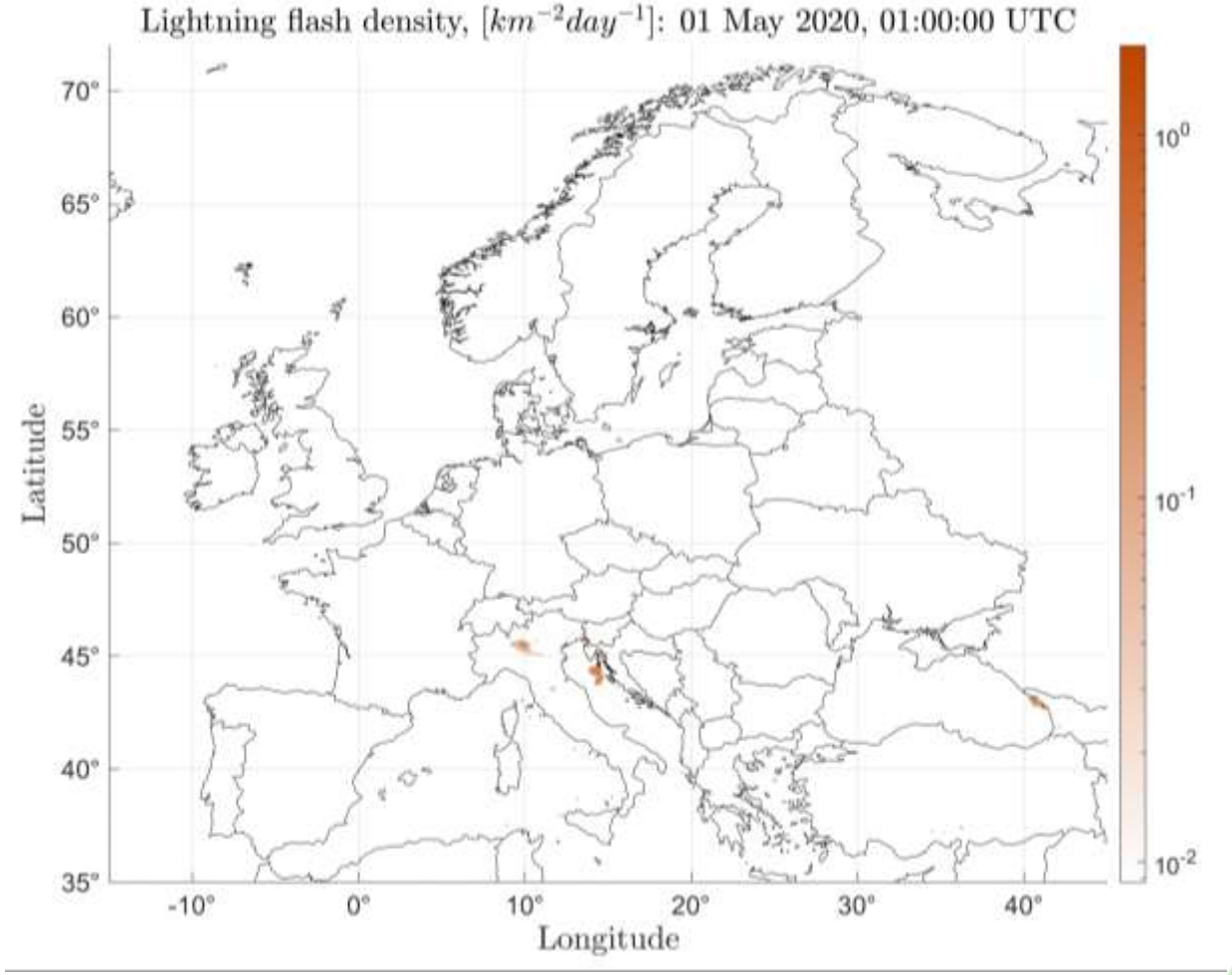
The Cloud-to-ground fraction is computed following Coughlan et al., 2020 (doi: 10.1002/met.1973)

It requires specific meteorological data

- Temperature vertical profile
- Water content vertical profile
- CAPE
- Relative Humidity

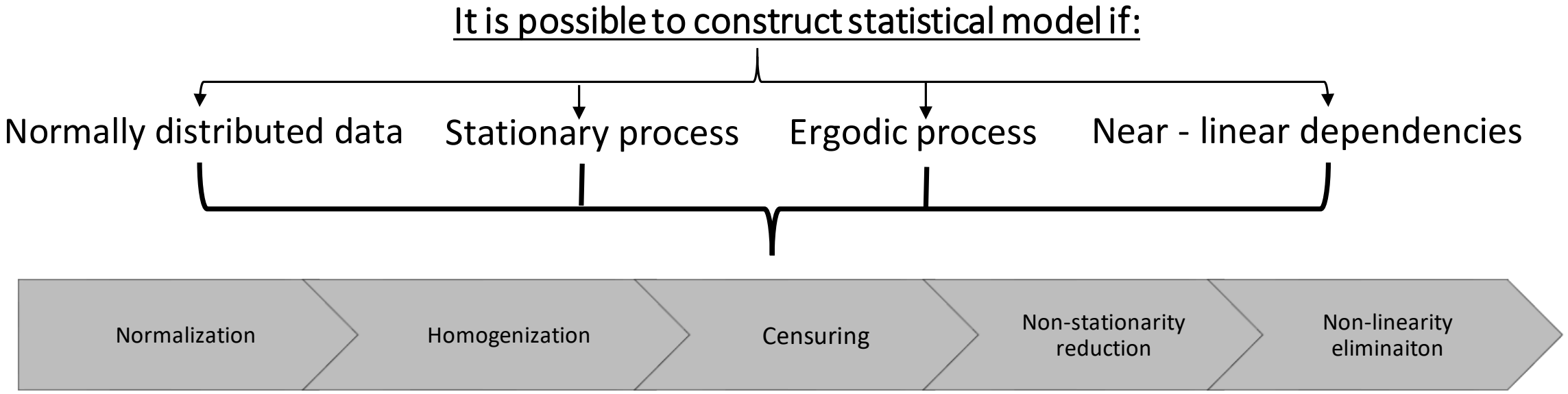
The result is a continuous, smooth field rather than point sources, making it suitable for matching with NWP and satellite predictors

Example dates: 1-3 May 2020



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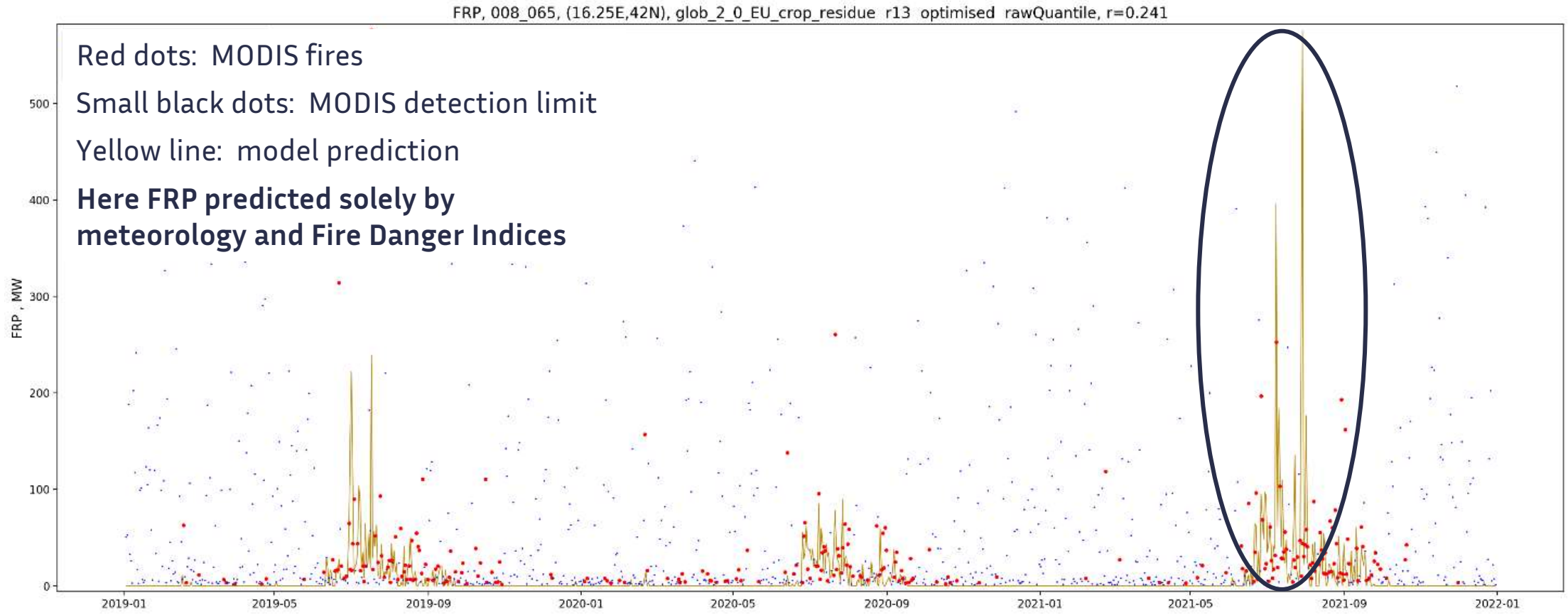
Multi-step machine-learning procedure



- Fire Forecasting Model (FFM) model was trained to predict Fire Radiative Power (FRP)
- Cloud-to-ground lightning flash density was shown to be statistically significant
- Extending the training period would likely improve the model's accuracy

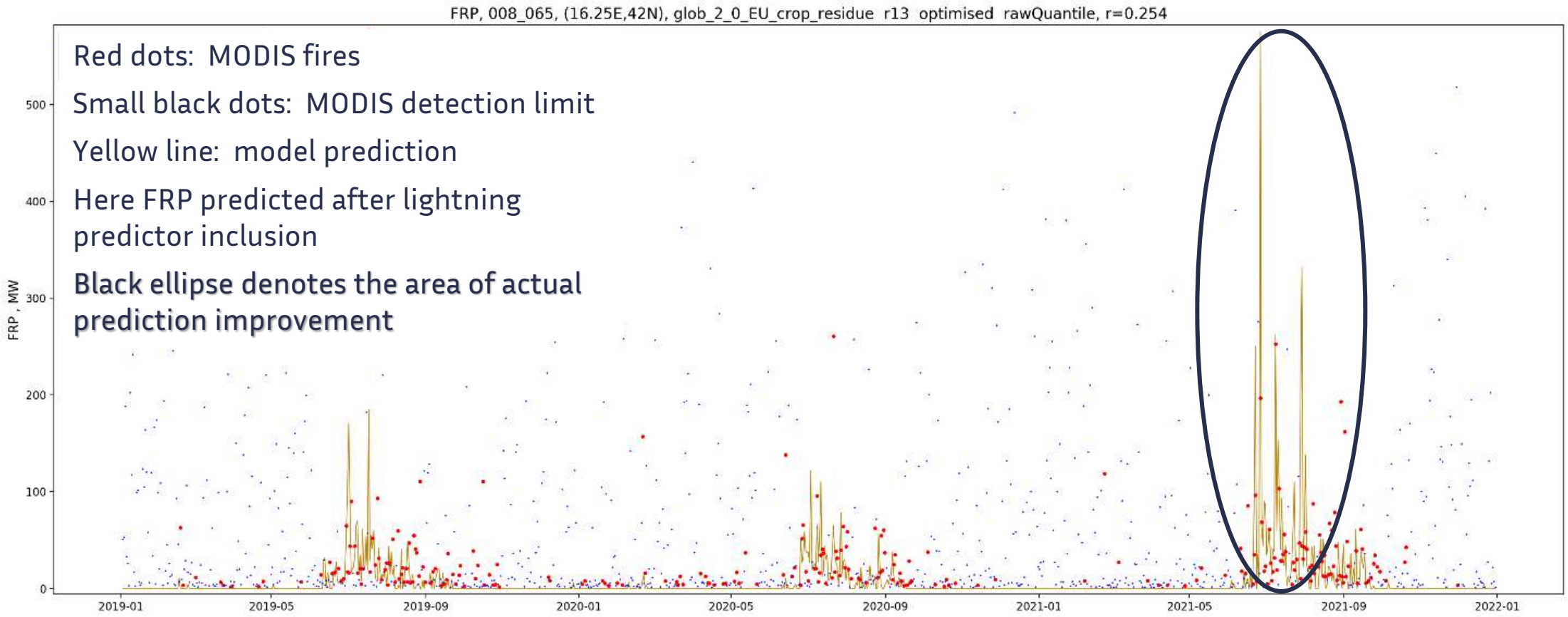
This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

FFM model predicting FRP



This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

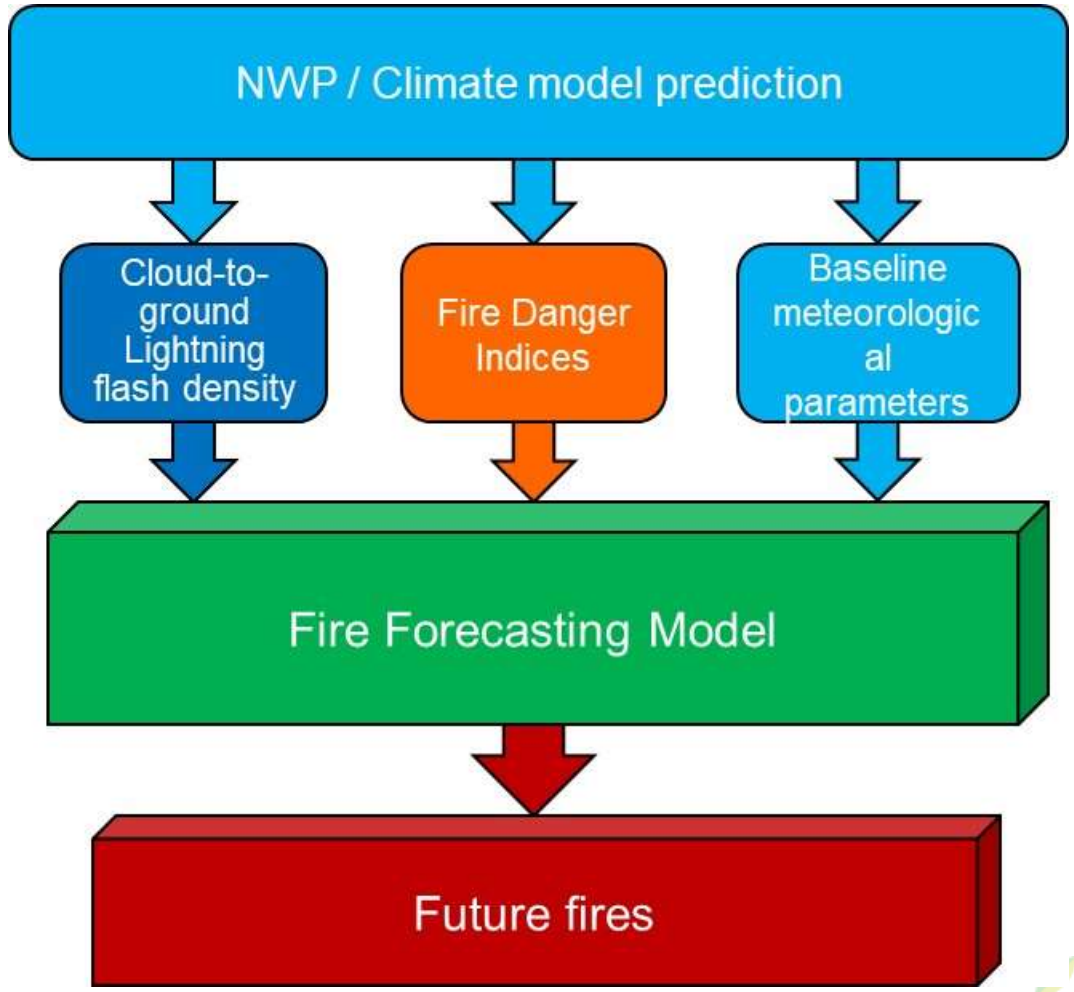
FFM model predicting FRP



This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Predicting lightning-ignited wildfires

The training procedure combines independent predictors in a superposition, with each predictor contributing to the total FRP



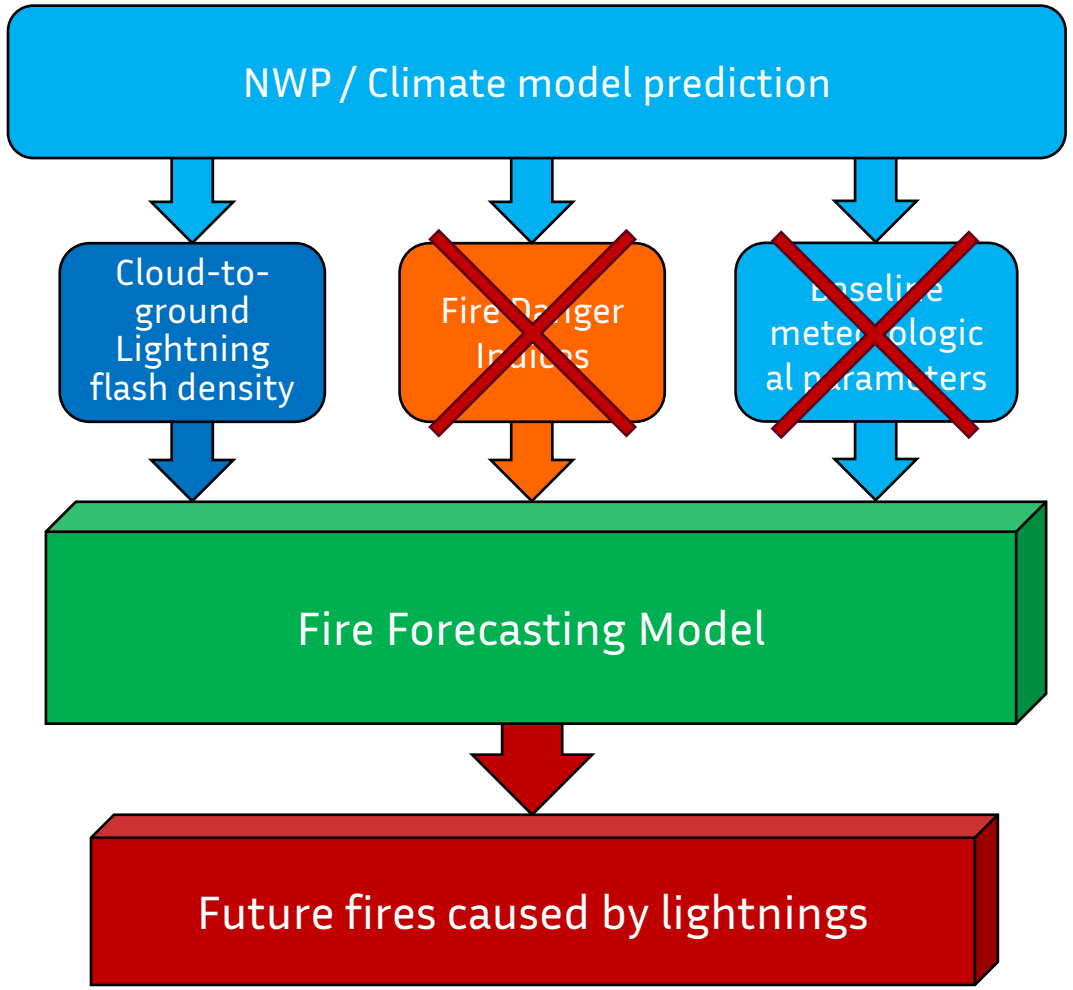
This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Predicting lightning-ignited wildfires

The training procedure combines independent predictors in a superposition, with each predictor contributing to the total FRP

Disregarding all predictors except lightning leads to a model that predicts FRP solely from fires caused by lightnings

However, the principal additivity of different models, including those predicting human-induced fires, requires careful validation



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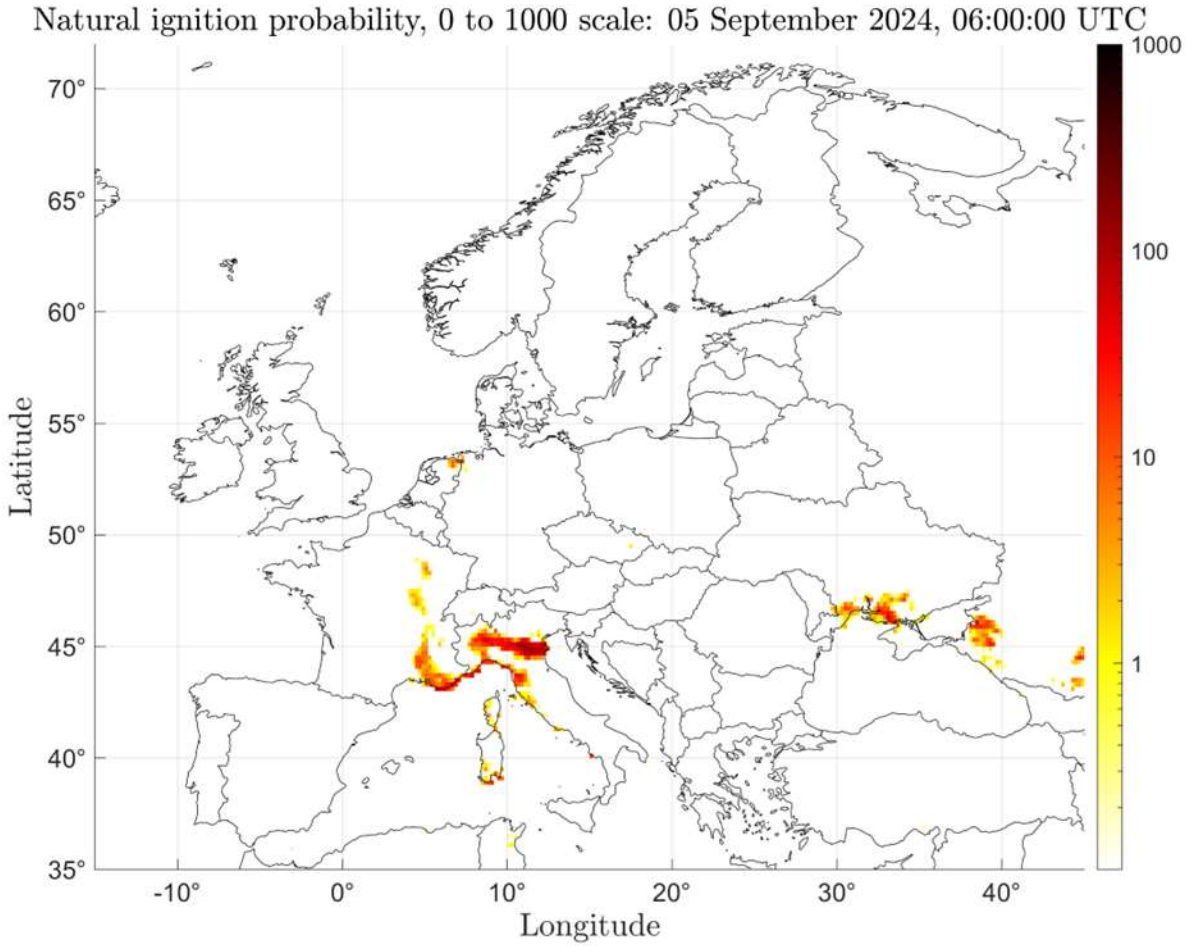
Lightning-ignition probability forecast

FMI receives the ECMWF IFS 5-day forecast at approximately 6:00 UTC

Meteorological parameters are available at 3-hour timesteps globally, with a 0.2°x0.2° resolution

FFM delivers its daily 5-day forecast of FRP and lightning-ignition probability by 7:00 UTC, at the same resolution

The lightning-ignition probability is then submitted to the FirEURisk Data Hub for further integration



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Live Fuel Moisture Content

Valerio Pampanoni

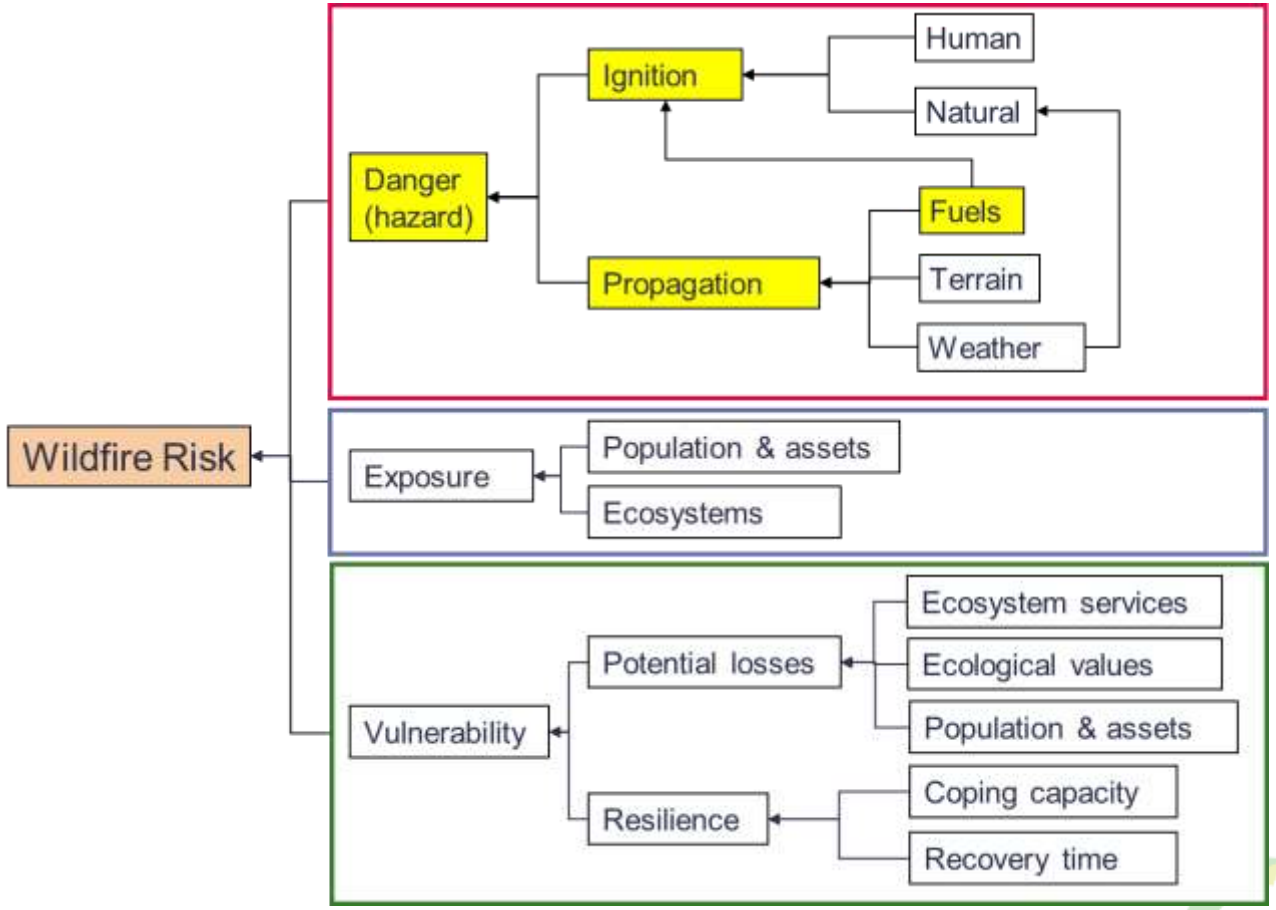


SAPIENZA UNIVERSITÀ DI ROMA
EOSIAL Lab.
Scuola di Ingegneria Aerospaziale

This project has received funding from the European Union 's Horizon 2020 research and innovation programme under grant agreement No 101003890

What is Live Fuel Moisture Content?

- **Live Fuel Moisture Content** is defined as the weight ratio between leaf water content and dry matter:
- $LFMC_{\%} = 100 \times \frac{Water\ Weight}{Leaf\ Weight}$



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What is Live Fuel Moisture Content?

Live Fuel Moisture Content has an important role in determining the nature of the **interaction of fire with live fuels**:

- Fire **Ignition** (will the fire start?)
- Fire **Severity** (how strong will the fire be?)
- Fire **Spread** (how fast and how far will the fire spread?)

Strong interest in **measuring** or **estimating** LFMC

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How do we Measure LFMC?

- Live Fuel Moisture Content can be directly measured *in situ* using **gravimetric techniques**:

$$LFMC_{\%} = 100 \times \frac{Fresh\ Weight\ - Dry\ Weight}{Dry\ Weight}$$





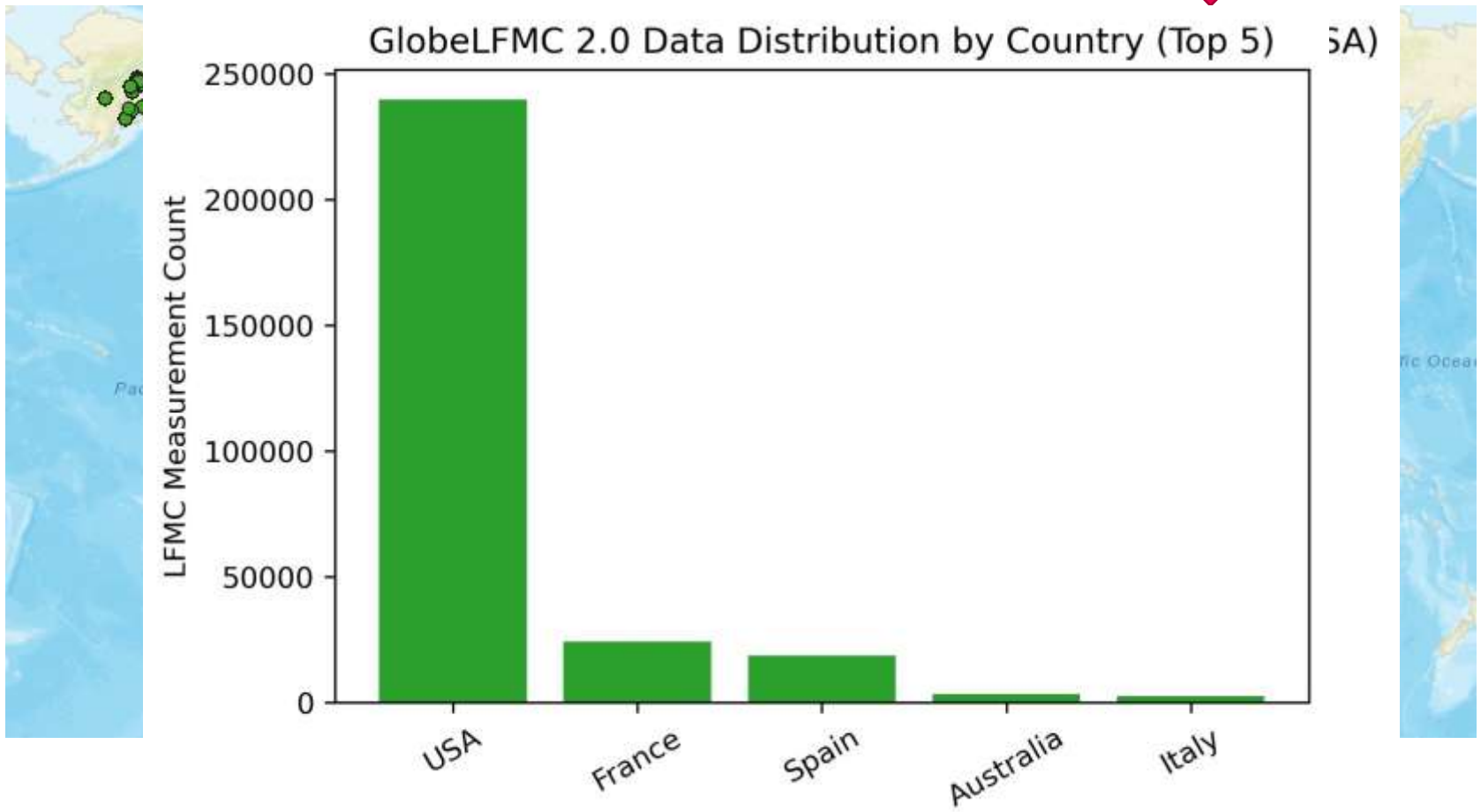




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How do we estimate it?

- Machine Learning not the solution to all problems



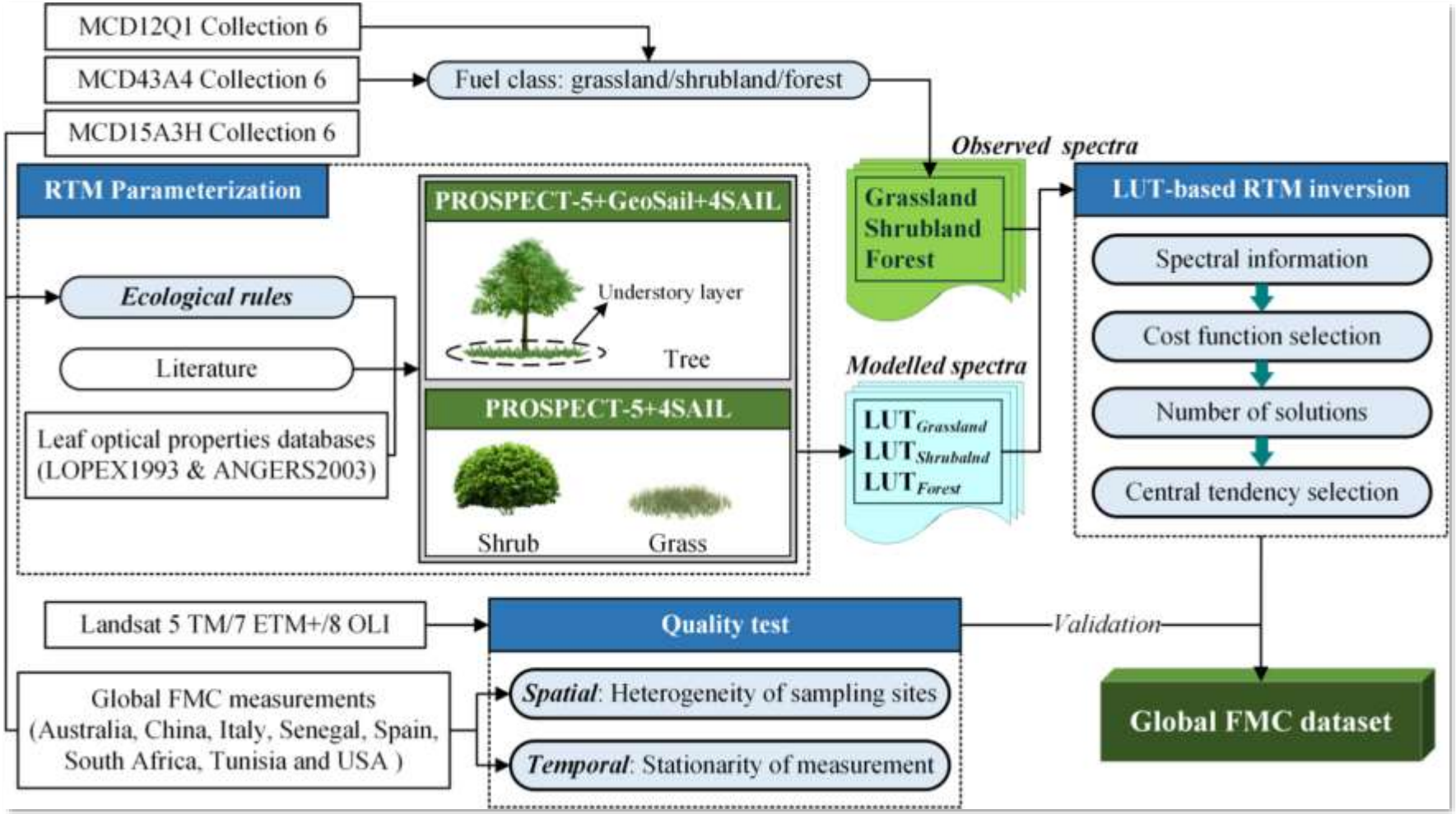
Spatial Distribution of Globe-LFMC 2.0 datasets [2]

Vast majority concentrated in:

- **Western USA**
- **Med. Europe**
- **Australia**

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Theoretical Basis



Quan, Yebra, Riano, He, Lai, Hu

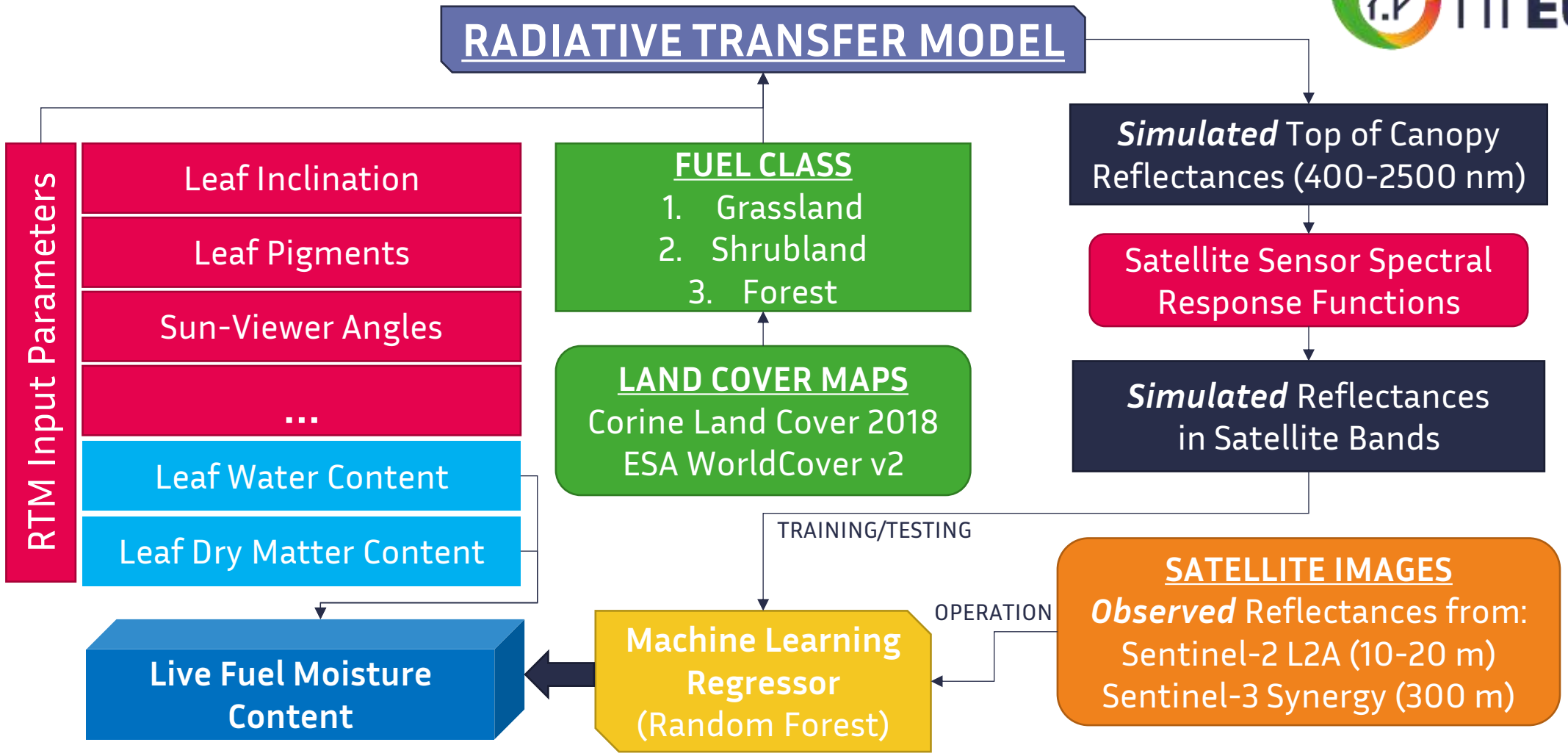
International Journal of Applied Earth Observations and Geoinformation

"Global Fuel Moisture Content Mapping from MODIS"

2021 [3]

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LFMC Inversion Scheme: RTM foundation + ML Inversion

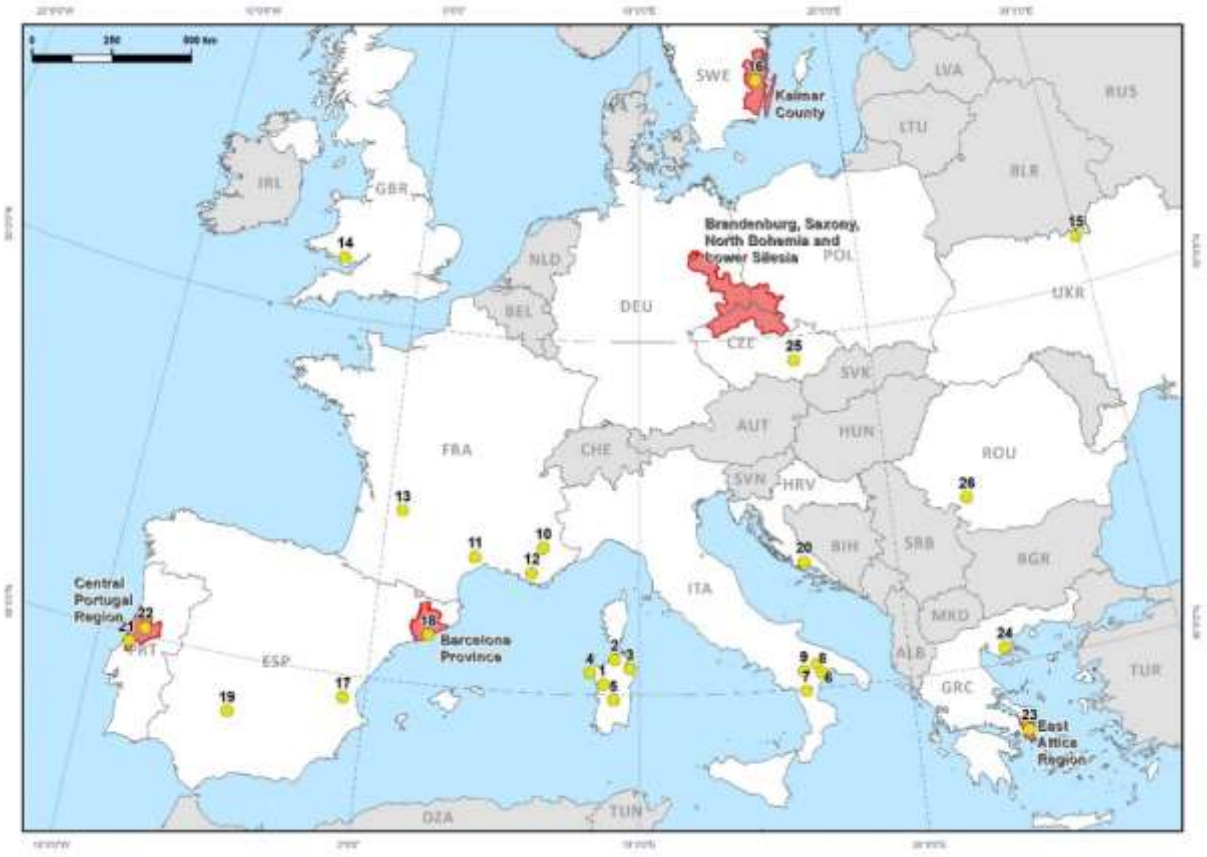


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Scope of the Product

- The product was originally developed in A1.1.1 for all the Pilot Sites. Switching to a RFR for inversion allowed us to extend it to cover the **European Territory**
- Daily product with latest cloud-free observations in the last 10-days

FirEURisk "Pilot Sites"



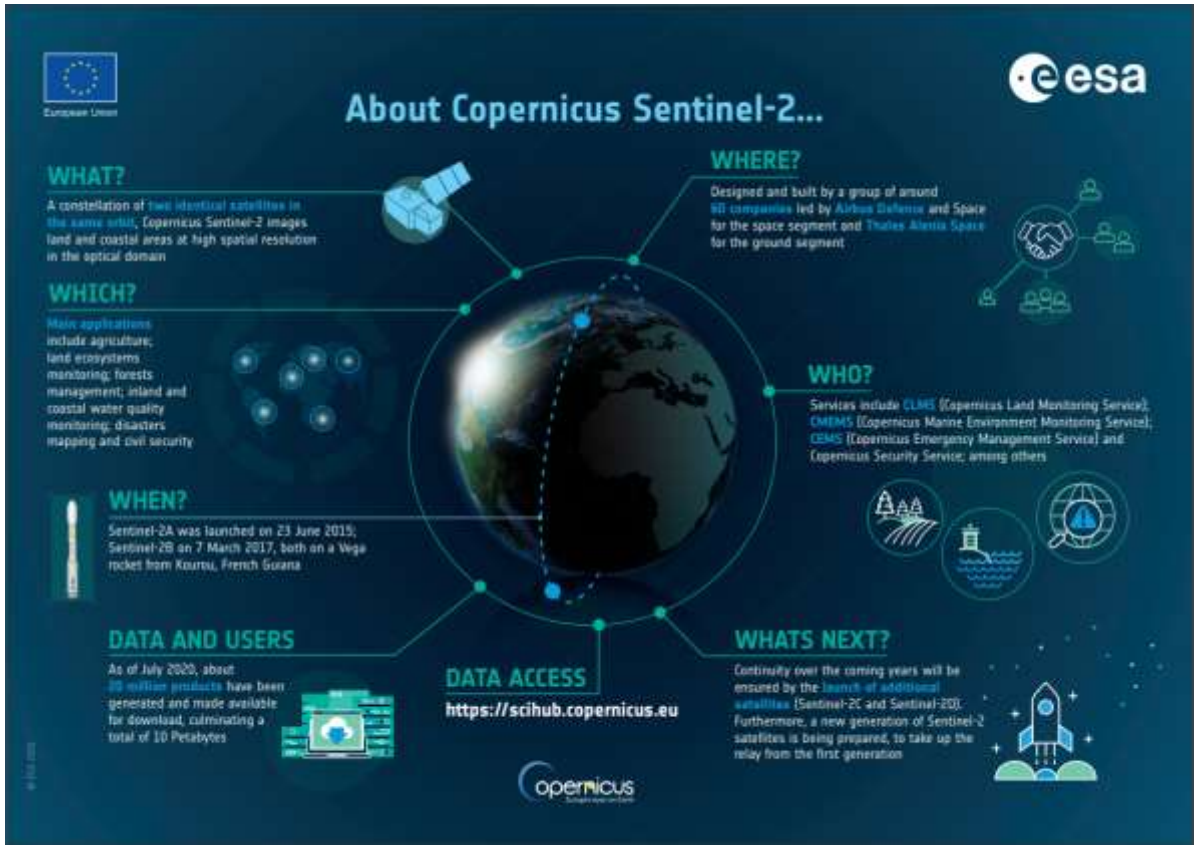
FirEURisk "European Territory"

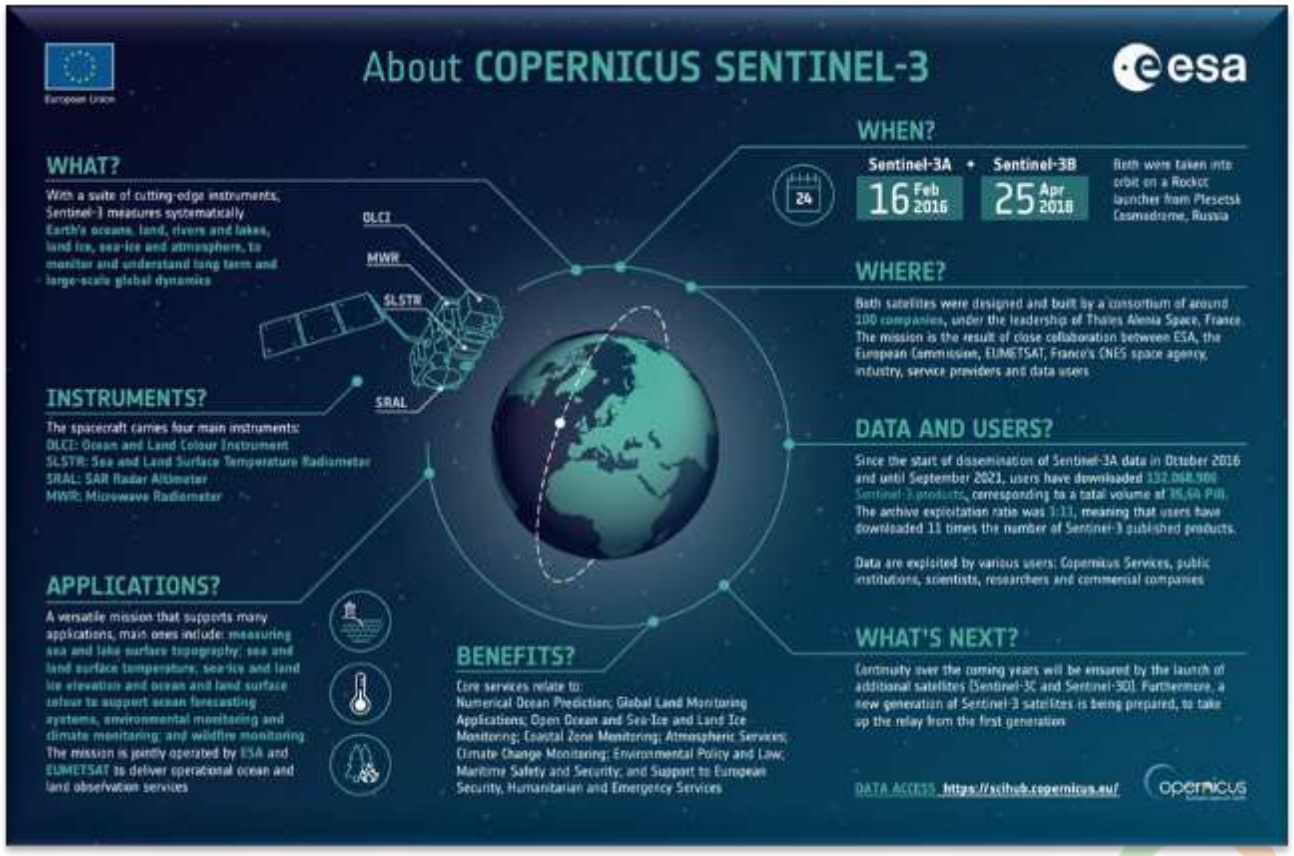


event

Target Satellite Platforms and Products

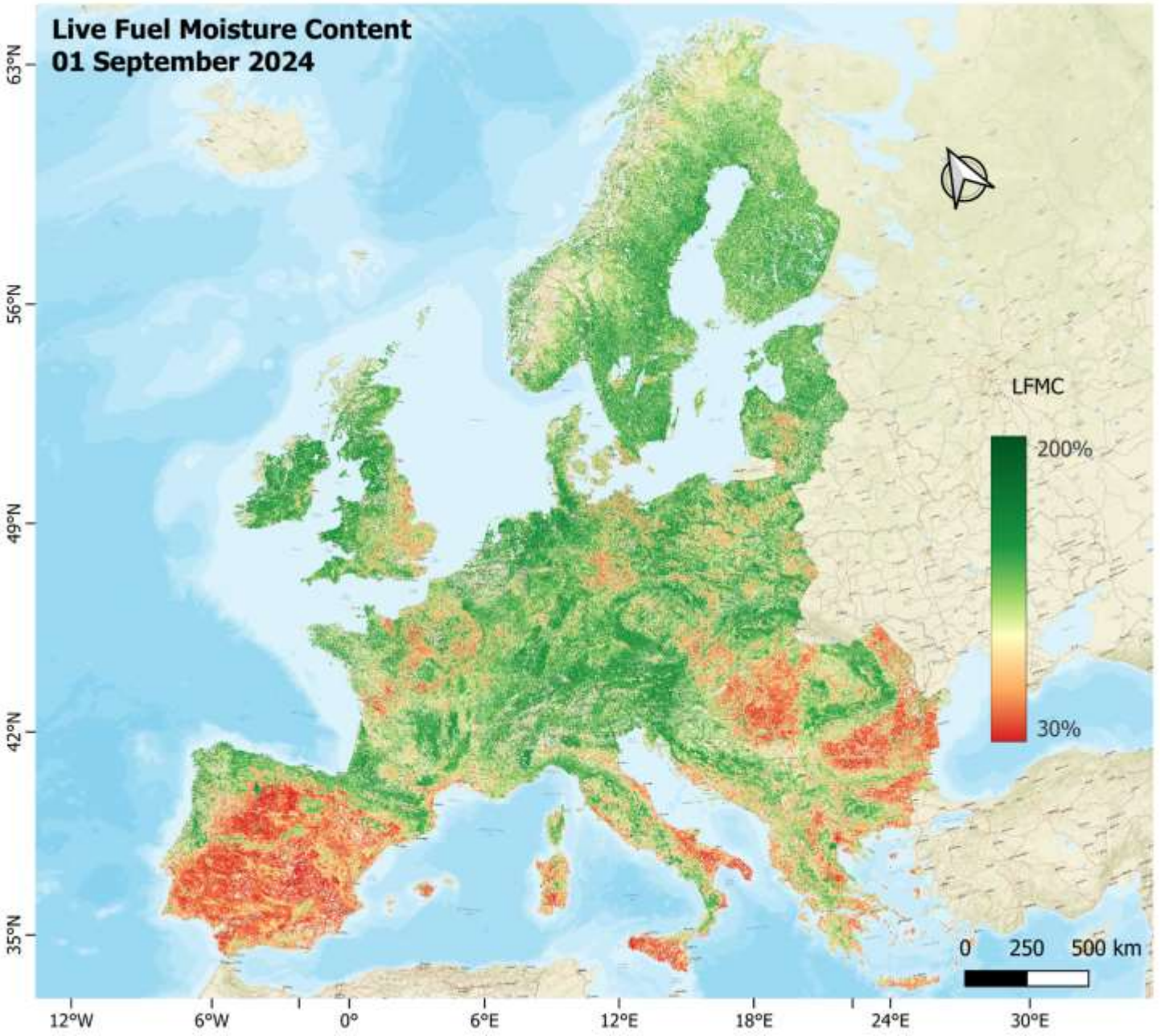
- **Sentinel-3 Synergy**: 300 m* resolution, revisit time ~ 1 day → Regional, National, Continental scale
- **Sentinel-2 L2A**: 10-20 m resolution, revisit time ~ 5 days → Local scale (Municipality, WUI…)





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S3 Product Sample



European Territory

Resolution:

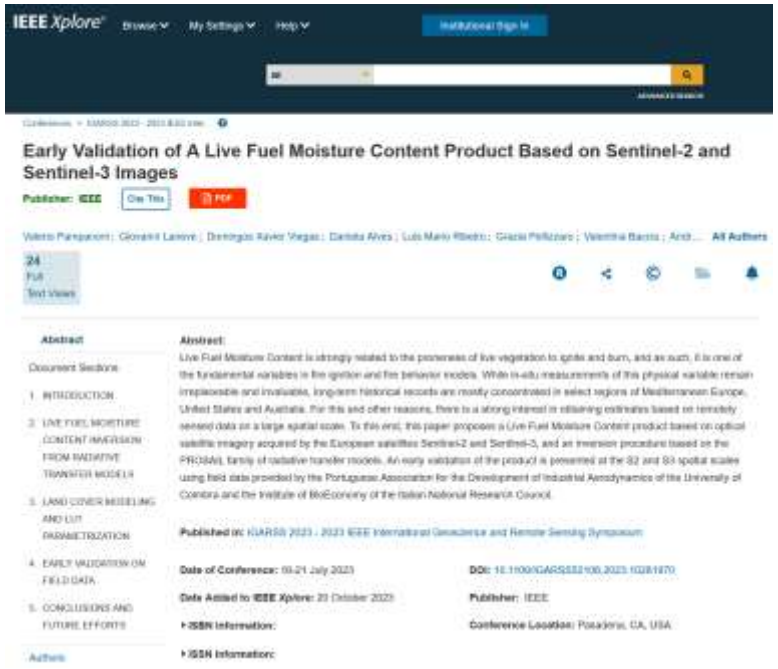
300x300 m

Date:

01 Aug 2024

(Latest cloud-free observations from previous 10 days)

Product Validation (ongoing)



Pampanoni, Laneve, Viegas, Alves, Ribeiro, Pellizzaro, Bacciu, Ventura

IGARSS 2023, Pasadena, CA, United States

"Early Validation of a Live Fuel Moisture Content Product based on Sentinel-2 and Sentinel-3 Images", 2023



Pampanoni, Laneve, Saquella, Ferrari

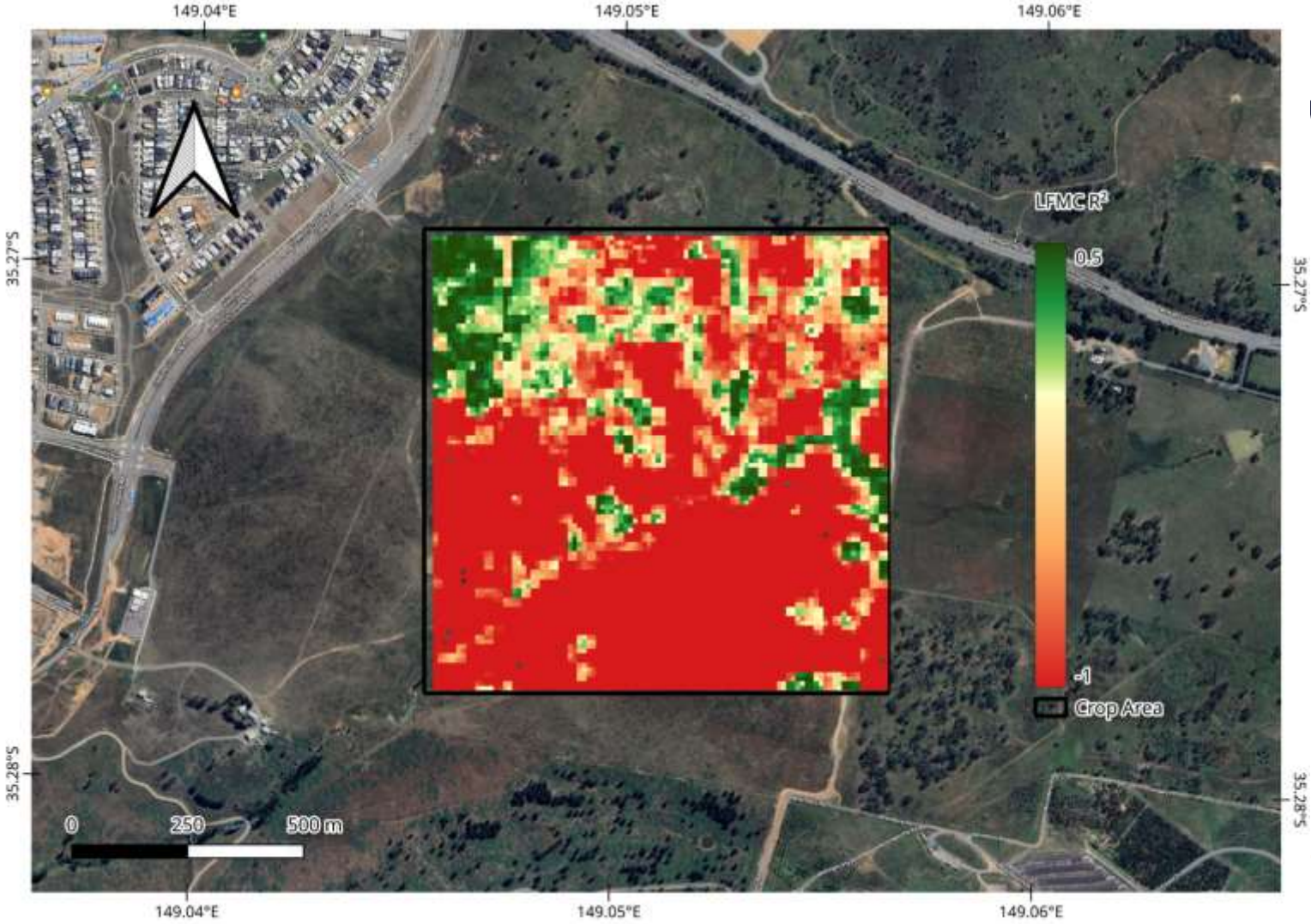
IGARSS 2024, Athens, Greece

"Using PROSAIL Look-Up Tables to Train Random Forest Regressors for Fast LFMC Retrieval", 2024

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Random Forest Regressor Results (in situ Data, GlobeLFMC 1.0)

- Example of a Globe-LFMC 1.0 automatically delimited test area (Sentinel-2): **Coppins**
- **Species**: *ania pumilio*,



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Conclusions

- The product will be finalized with a **global validation** of both Sentinel-2 and Sentinel-3 Products
  - ➢ The validation will be performed using the newly published (Apr. 2024) GlobeLFMC 2.0
- Validation procedure and results will be published in an Open Access paper
- Dataset will be publicly available through the **FirEURisk platform** and the **FirEURisk viewer**

- For inquiries send an email to
- **valerio.pampanoni@uniroma1.it**

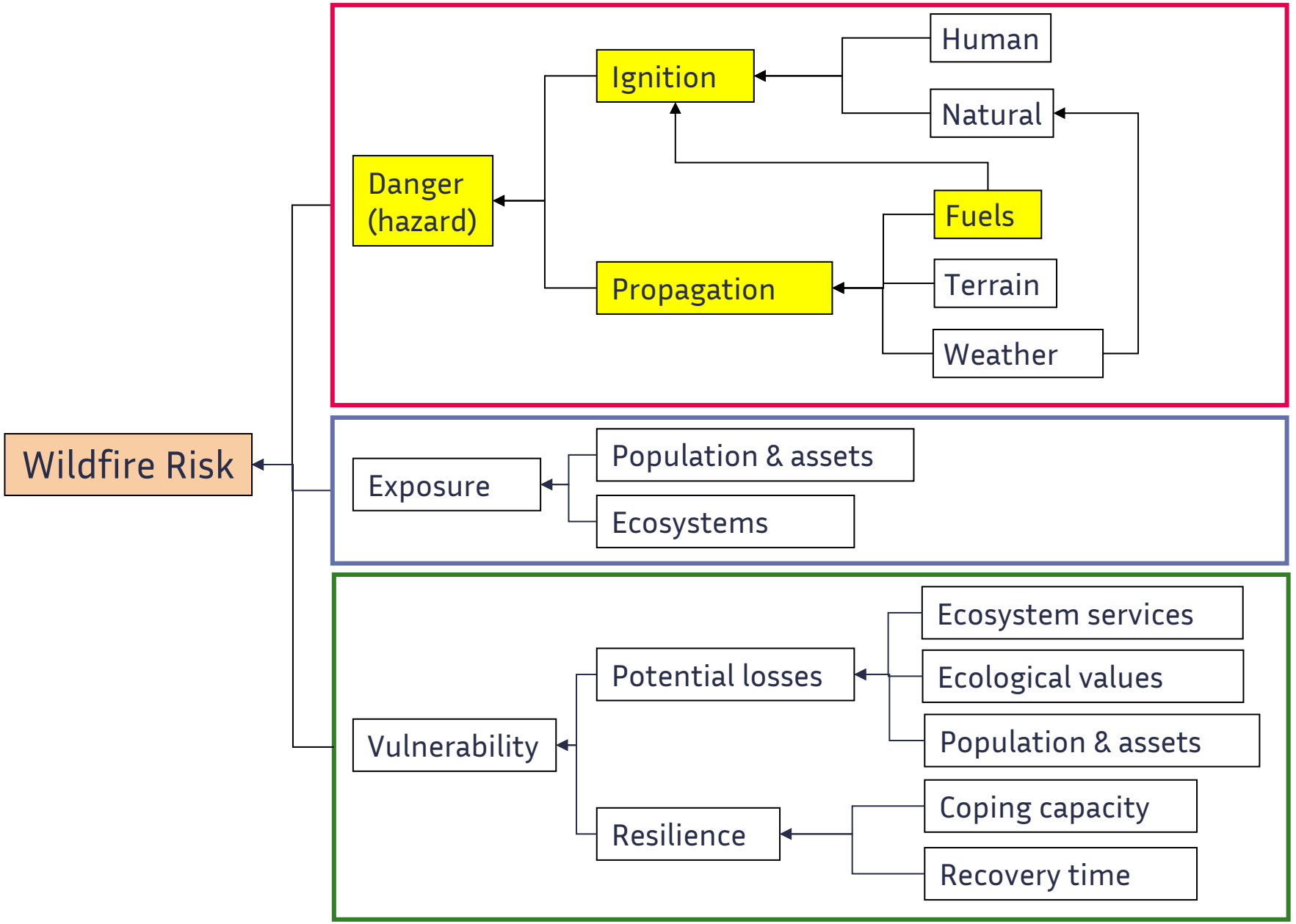
This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Fuel types and fuel parameters

Elena Aragoneses
(e.Aragoneses@uah.es)
University of Alcalá



This project has received funding from the European Union 's Horizon 2020 research and innovation programme under grant agreement No 101003890

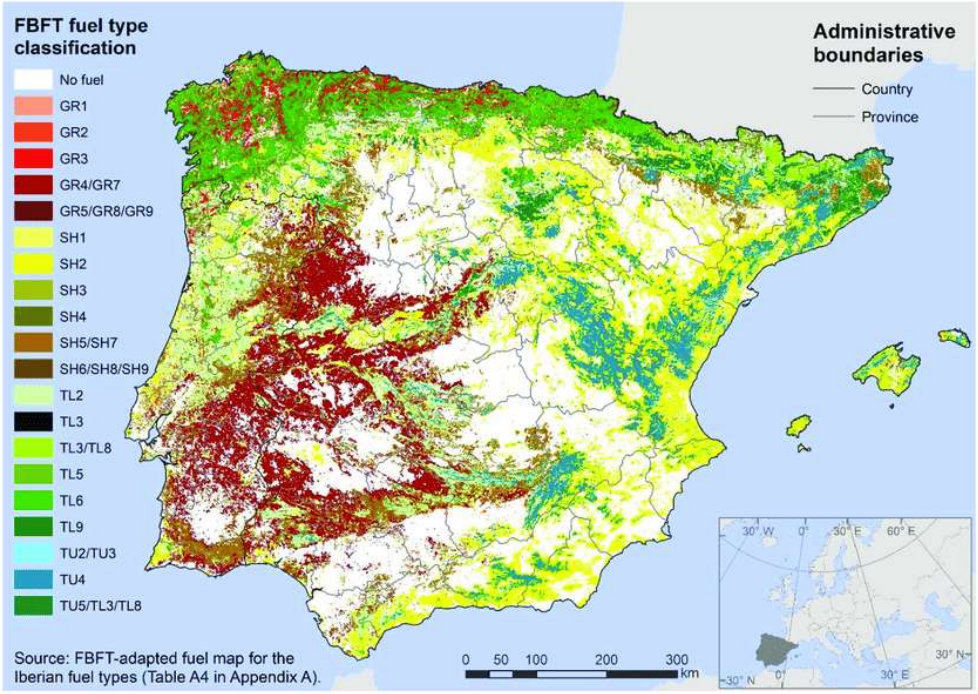


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Fuel types and fuel parameters

- **Fuel types:** vegetation with similar fire behaviour (categories)

- **Fuel parameters:** Numerical parameters required to model fire behaviour (height, load, particle size, etcetera).



Aragoneses and Chuvieco (2021): https://www.mdpi.com/2571-6255/4/3/59

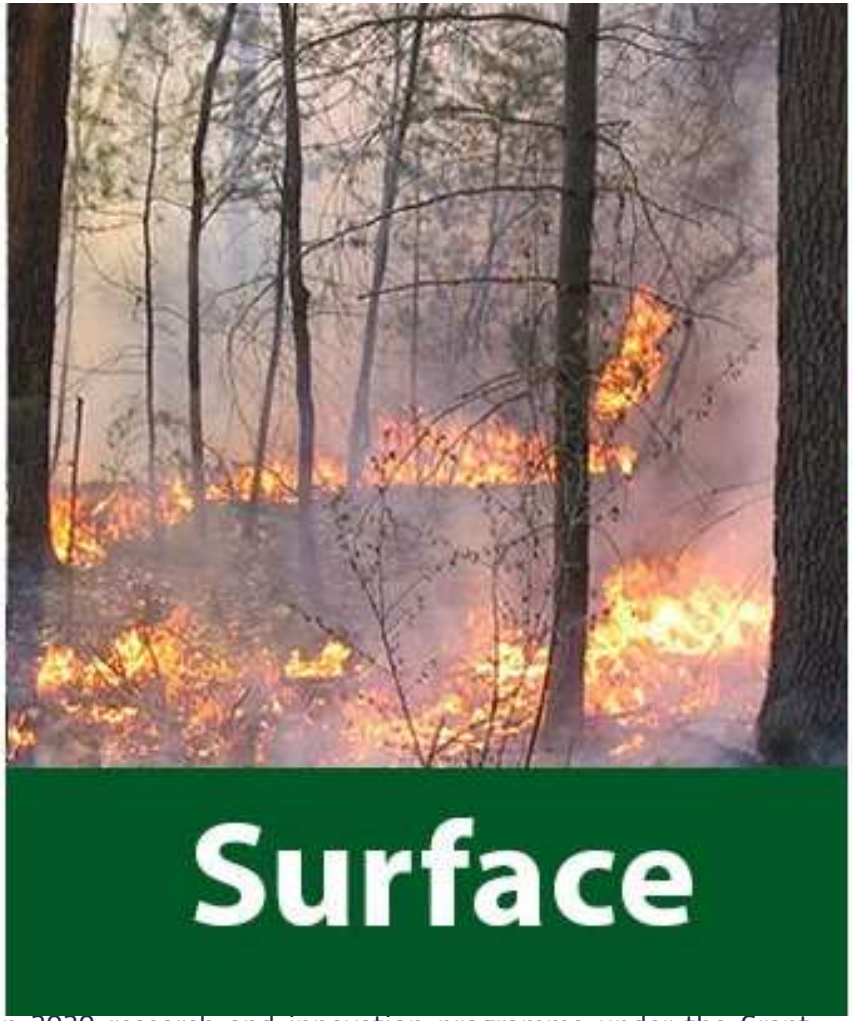
Fuel Model	Typical Fuel Complex	Fuel Loadings		
		Fuel 1-Hr	Fuel 10-Hr	Fuel 100-Hr
2	Timber (grass and understory)	2	1	0.5
3	Tall grass (2.5 feet)	3.01	0	0
4	Chaparral	5.01	4.01	2
6	Dormant brush, hardwood slash	1.5	2.5	2
7	Southern rough	1.13	1.87	1.5
8	Closed timber litter	1.5	1	2.5
9	Hardwood litter	2.92	0.41	0.15

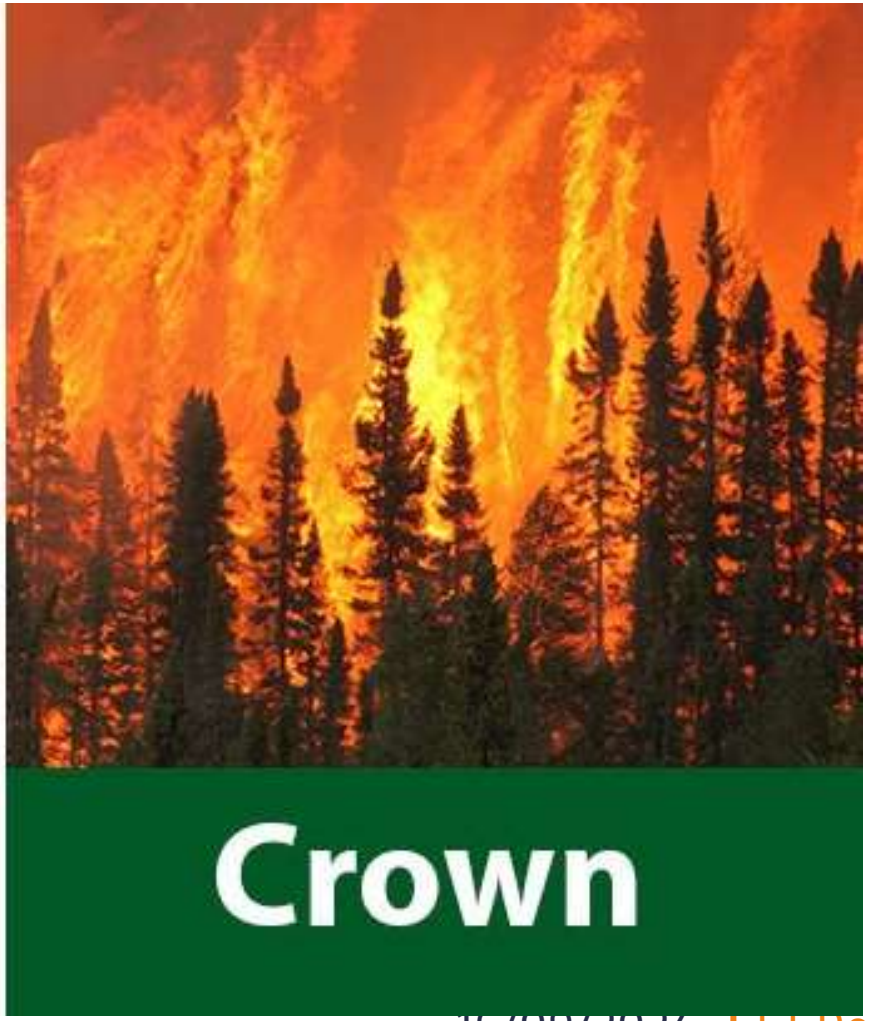
Kabli et al (2015): https://www.mdpi.com/1999-4907/6/6/2148/htm

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2% of European fires are **crown fires** → extreme → most damages. Our study:

- Surface fuels
- Crown/canopy fuels



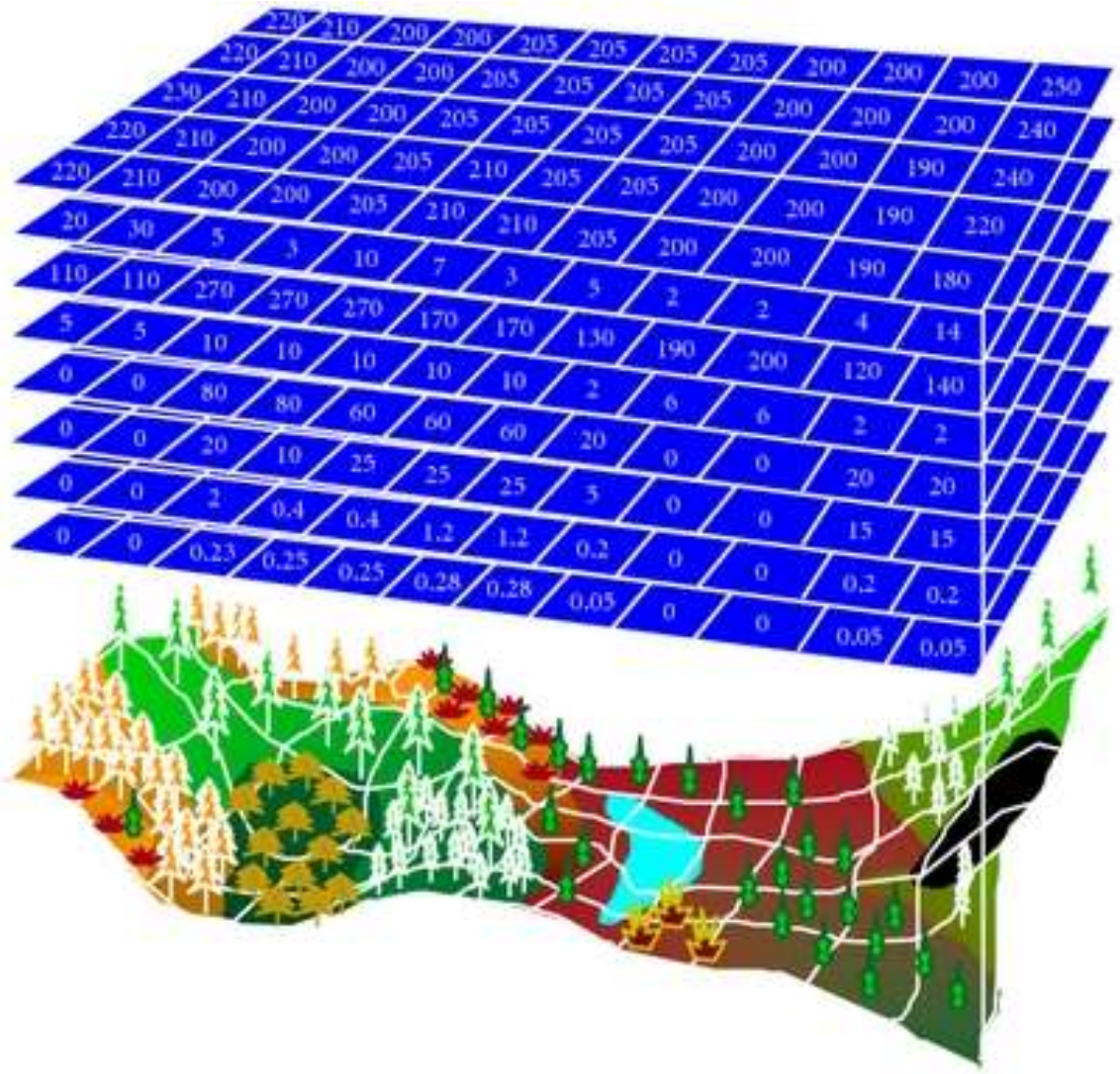


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Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Modelling fire behaviour

Fuel parameters

Fuel types



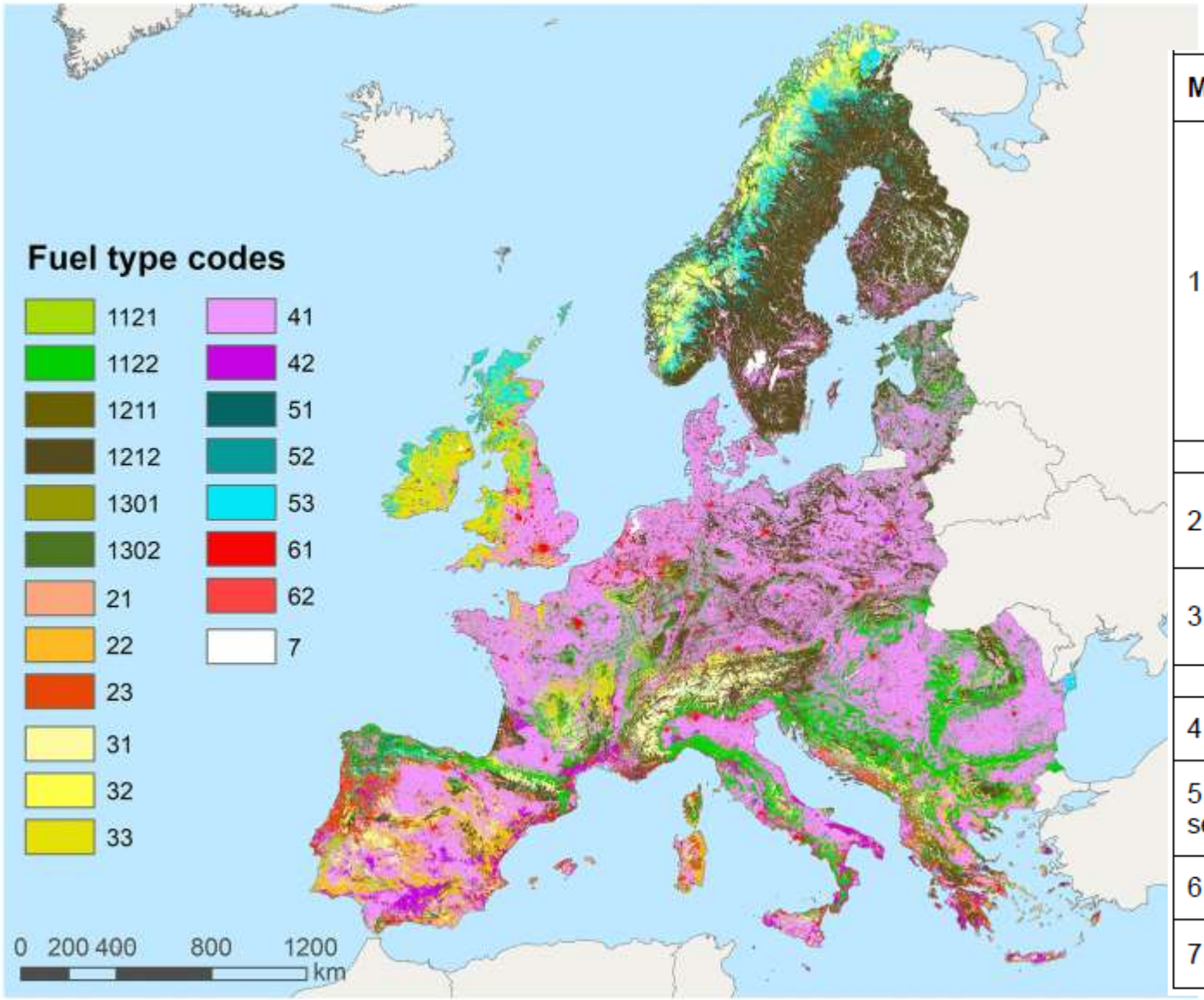
- **Surface fuels**
- **Canopy fuels**

What we did

- **Full set of fuel information at the European scale → fire behaviour modelling**
- 1 fuel type map: surface and crown fuels
- 1 fuel model map: surface fuels parameters (Scott and Burgan)
- 5 maps of custom canopy fuel parameters: canopy height (CH), canopy cover (CC), canopy base height (CBH), canopy fuel load (CFL), canopy bulk density (CBD)
  - 1 km
  - Circa 2019-2020

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European fuel type map



Main fuel type	Leaf type/ Type	Phenology	Fractional cover (%)
1. Forest	11. Broadleaf	111. Evergreen	1111. Open [15-70%)
			1112. Closed [70-100%)
		112. Deciduous	1121. Open [15-70%)
			1122. Closed [70-100%)
	12. Needleleaf	121. Evergreen	1211. Open [15-70%)
			1212. Closed [70-100%)
		122. Deciduous	1221. Open [15-70%)
			1222. Closed [70-100%)
	13. Mixed		1301. Open [15-70%)
			1302. Closed [70-100%)
	Fuel depth		
2. Shrubland	21. Low [0-0.5m)		
	22. Medium [0.5-1.5m)		
	23. High (≥ 1.5m)		
3. Grassland	31. Low [0-0.3m)		
	32. Medium [0.3-0.7m)		
	33. High (≥ 0.7m)		
	Type		
4. Cropland	41. Herbaceous		
	42. Woody (shrub-tree)		
5. Wet and peat/ semi-peat land	51. Tree		
	52. Shrubland		
	53. Grassland		
6. Urban	61. Continuous fabric: urban fabric (≥ 80%)		
	62. Discontinuous fabric: vegetation and urban fabric [15-80%)		
7. Nonfuel			

Hierarchical

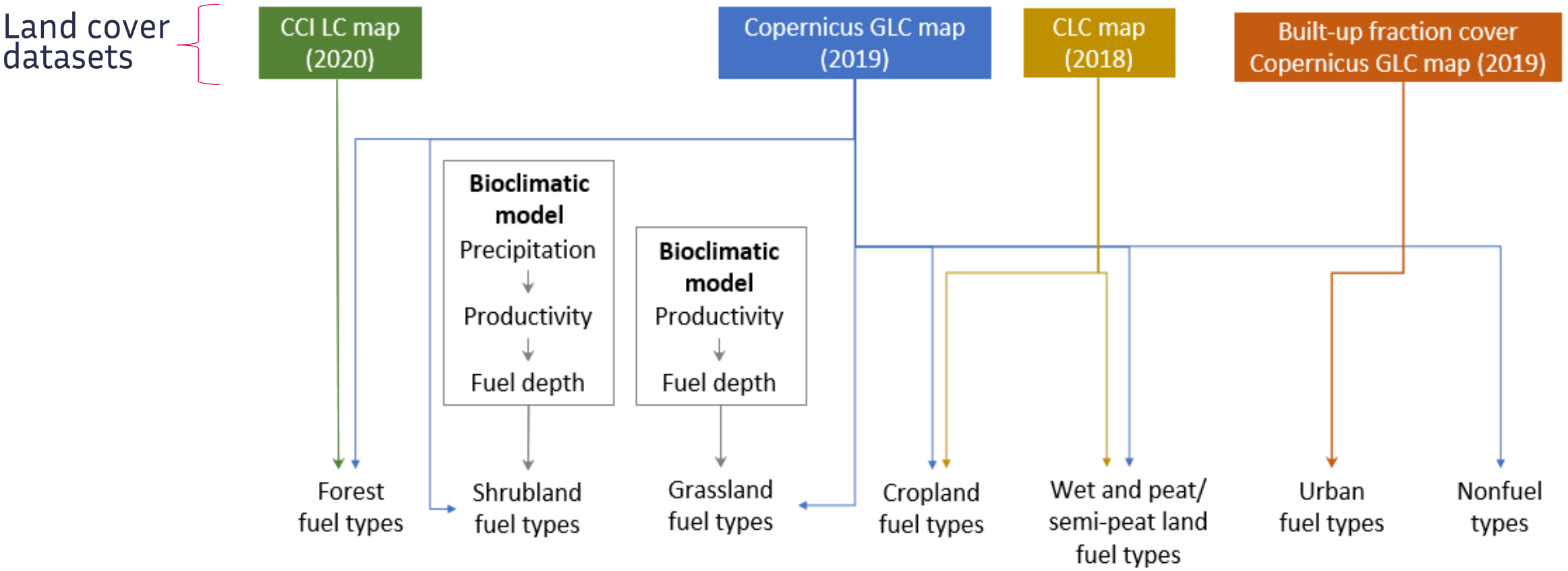
Europe's diversity

Surface and crown fuels

1 km resolution

Aragoneses et al. 2023 https://doi.org/10.5194/essd-15-1287-2023

Generation of European fuel map

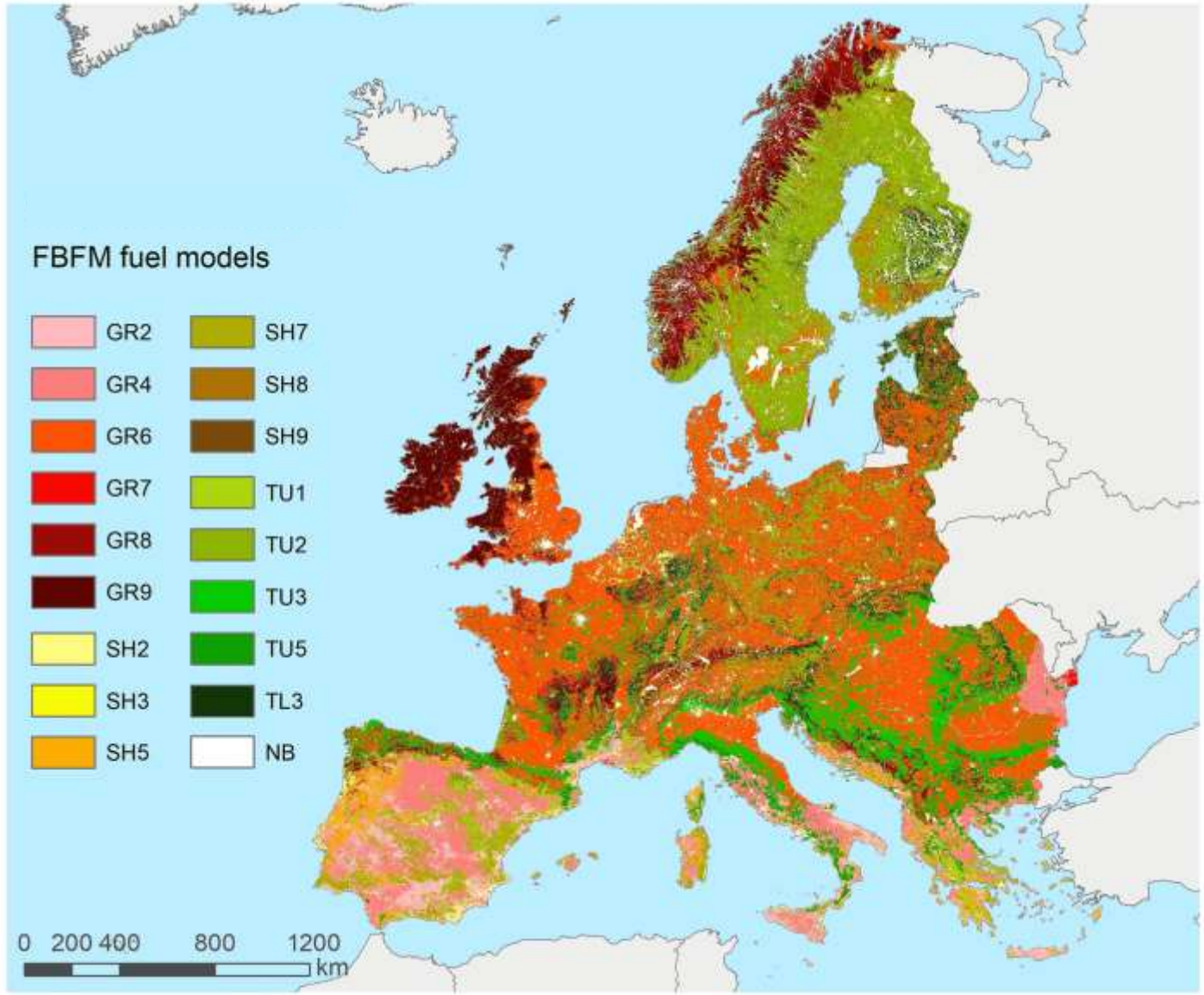


Input sources for the generation of the European fuel map: Aragoneses et al. 2023 https://essd.copernicus.org/articles/15/1287/2023/essd-15-1287-2023.html

This project has
Horizon 2020 r
Agreement no. 1

First assignment of standard fuel models

- Crosswalk from FirEUrisk fuel types to FBFM fuel models (Scott and Burgan, 2005)
- Use of expert knowledge
- Only **surface** fuels

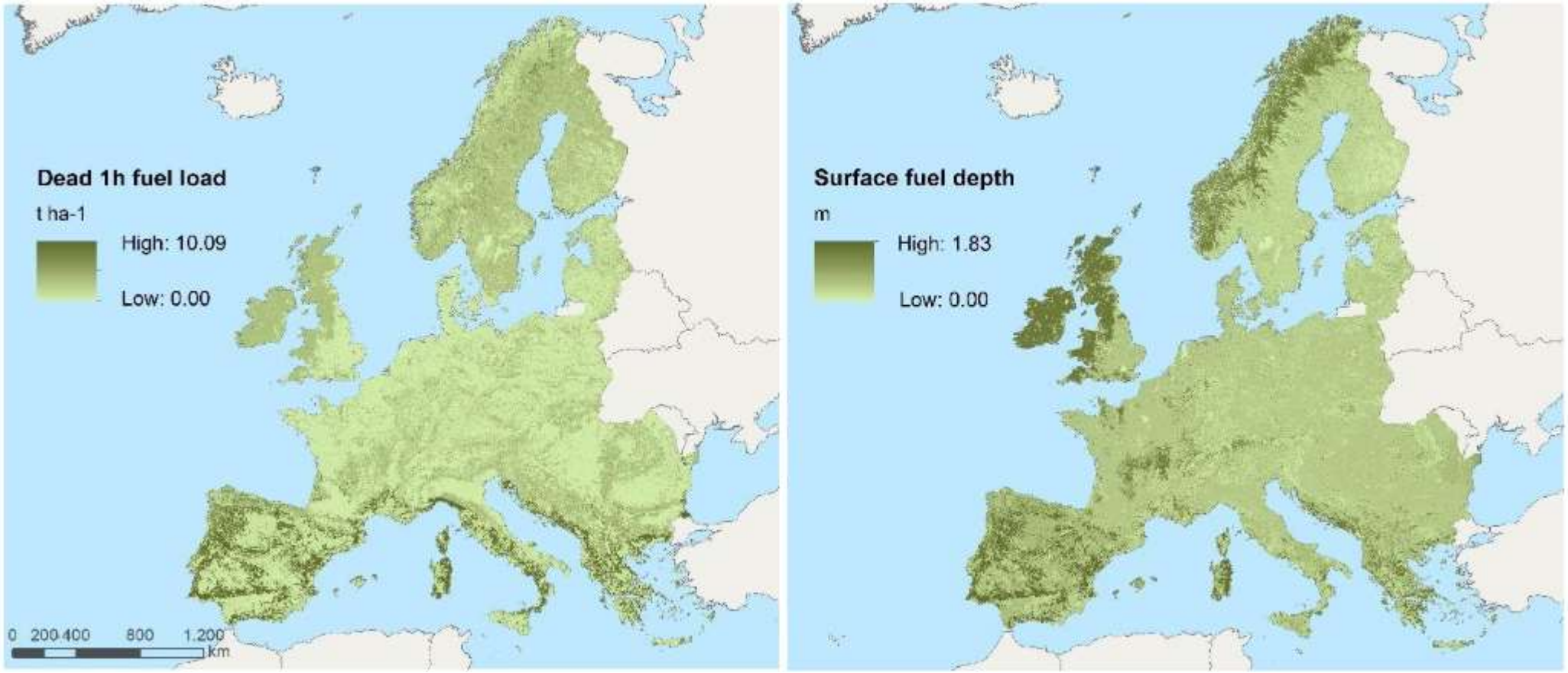


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Horizon 2020 research and innovation programme u
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Aragoneses et al. 2023 https://doi.org/10.5194/essd-15-1287-2023

Estimated surface fuel parameters from S&B models

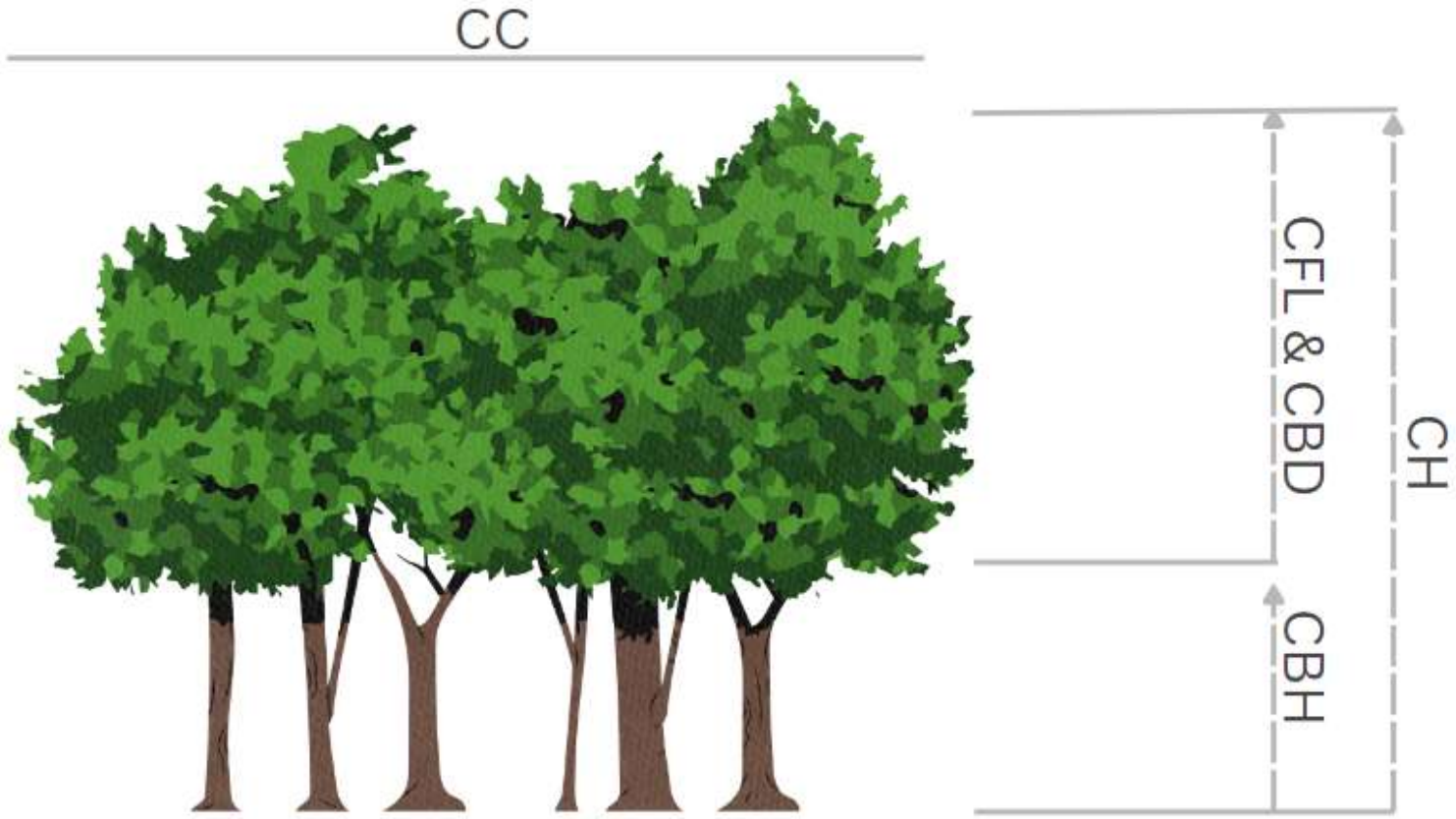
- Each fuel type → standard <u>surface</u> parameters



Aragoneses et al. 2023 https://essd.copernicus.org/articles/15/1287/2023/essd-15-1287-2023.html

Crown fuel parameters and used data

- Forest canopy fuel parameters to be estimated – useful for fire behaviour modelling:
  - Canopy mean height
  - Canopy cover
  - Canopy base height
  - Canopy fuel load
  - Canopy bulk density



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Crown fuel parameters and used data

- Forest canopy fuel parameters to be estimated – useful for fire behaviour modelling:

• Canopy mean height • Canopy cover • Canopy base height	**METHOD 1:** Derived metrics from GEDI LiDAR
• Canopy fuel load • Canopy bulk density	**METHOD 2:** Raw GEDI LiDAR waveforms

MORE COMPLEX PARAMETERS:
Vertical distribution of fuel

- Forest inventory data
- Discrete waveforms: airborne LiDAR → calibration of models
- Full-waveforms (continuous pulse of energy): satellite LiDAR (GEDI mission) → interpolation for wall-to-wall maps
  - Almost global coverage

GEDI ECOSYSTEM LIDAR

https://gedi.umd.edu/

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Method 1: Calibration of GEDI-based models from GEDI metrics

Forest inventory data and input airborne LiDAR (ALS)

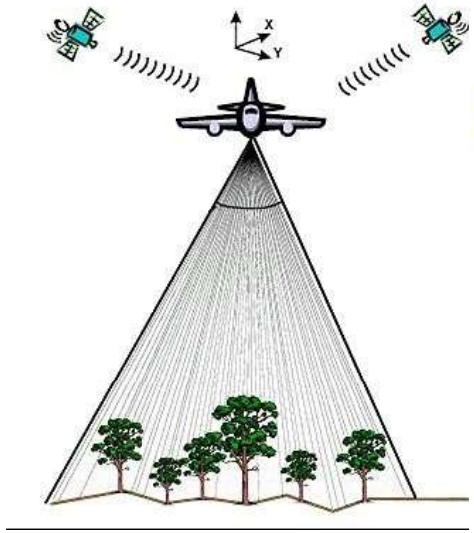
Spain -> 4 areas
Germany -> 2 areas
Slovenia -> 1 area

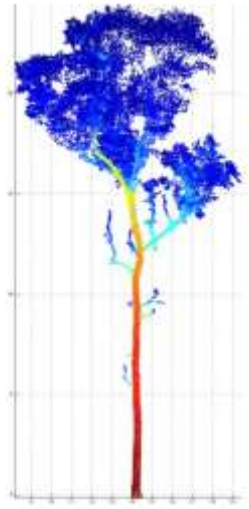
Clip by forest plots

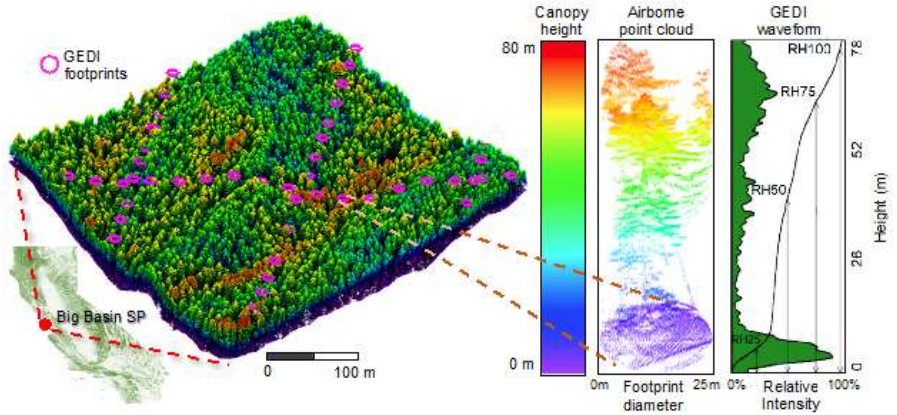
Simulate satellite GEDI-like waveforms

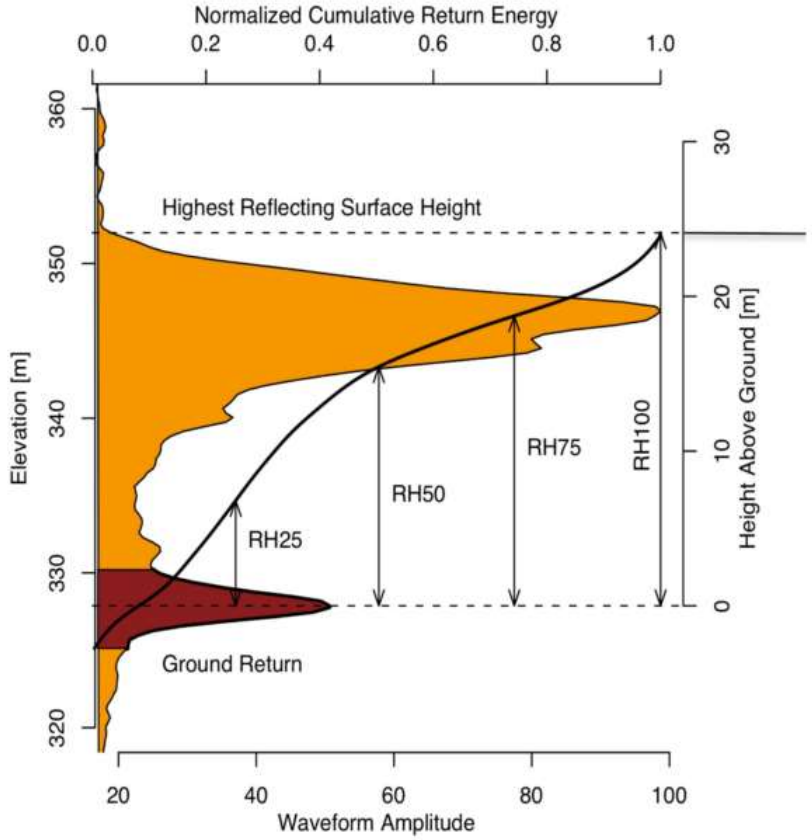
Simulation -> Extract metrics (RHs, ground, canopy cover,...)

GEDI-based model using reference data from ALS and forest inventory



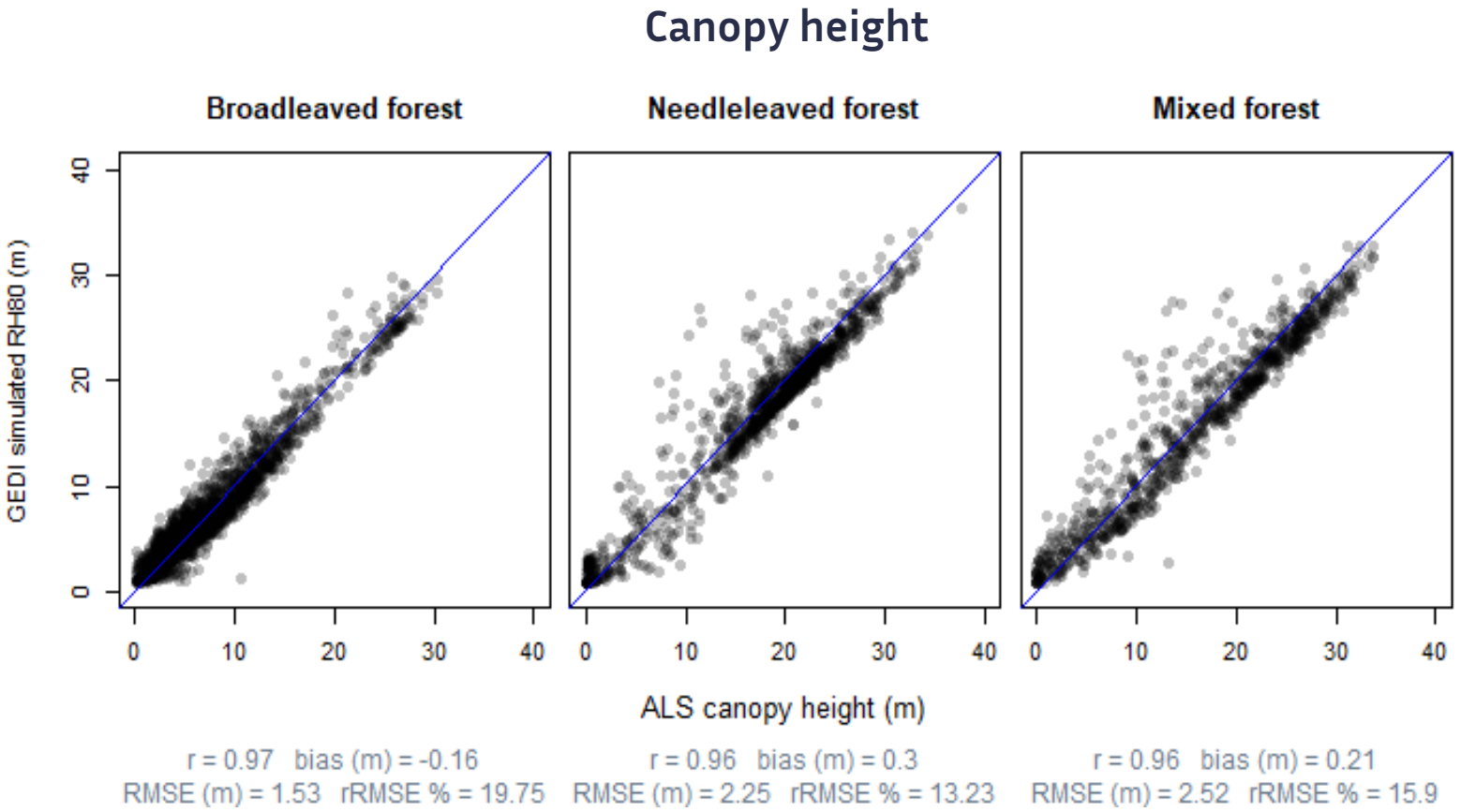


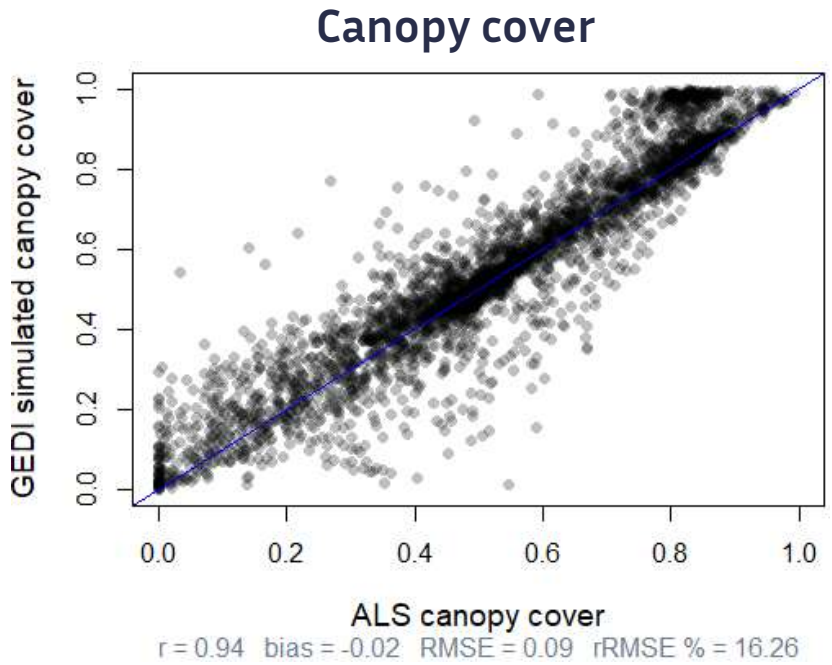


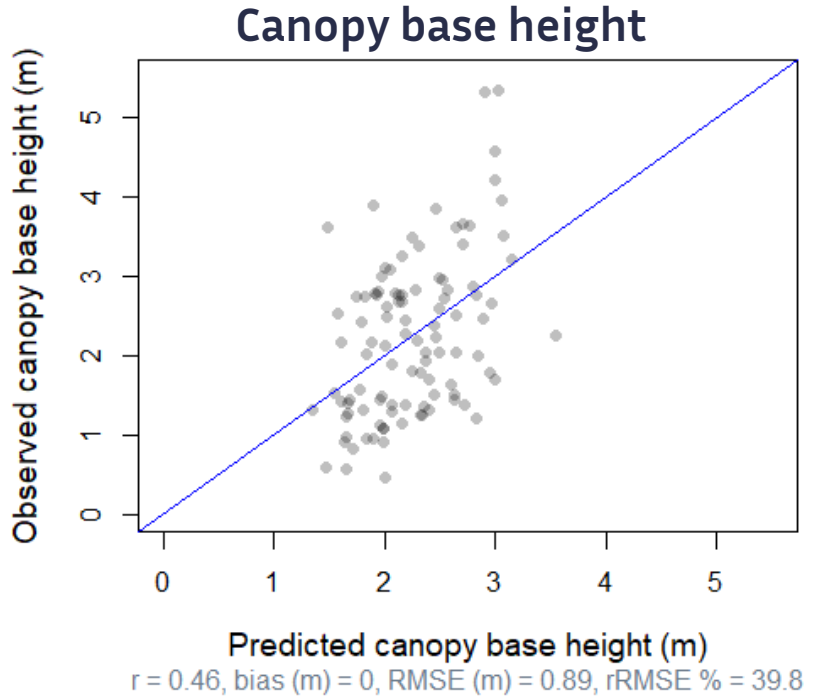


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Results: calibration of GEDI with reference data from forest inventory







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GEDI ECOSYSTEM LIDAR

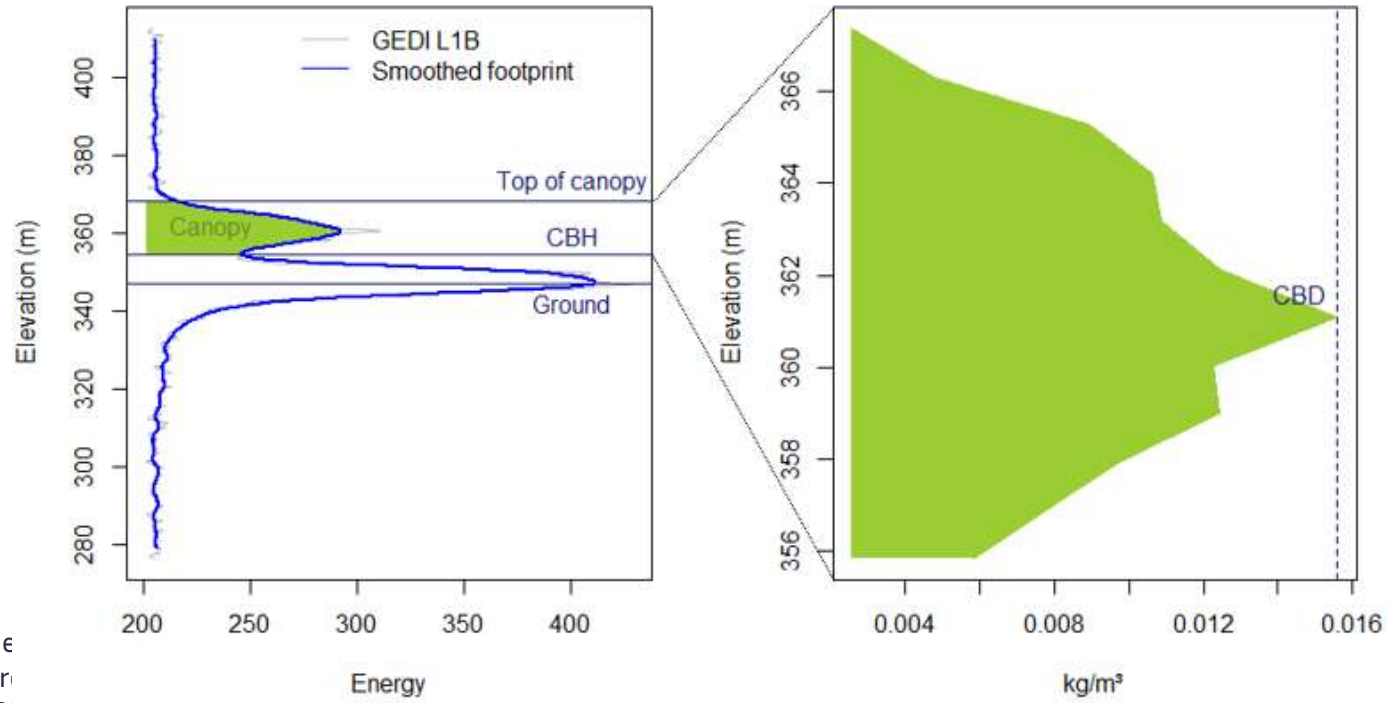
https://gedi.umd.edu/

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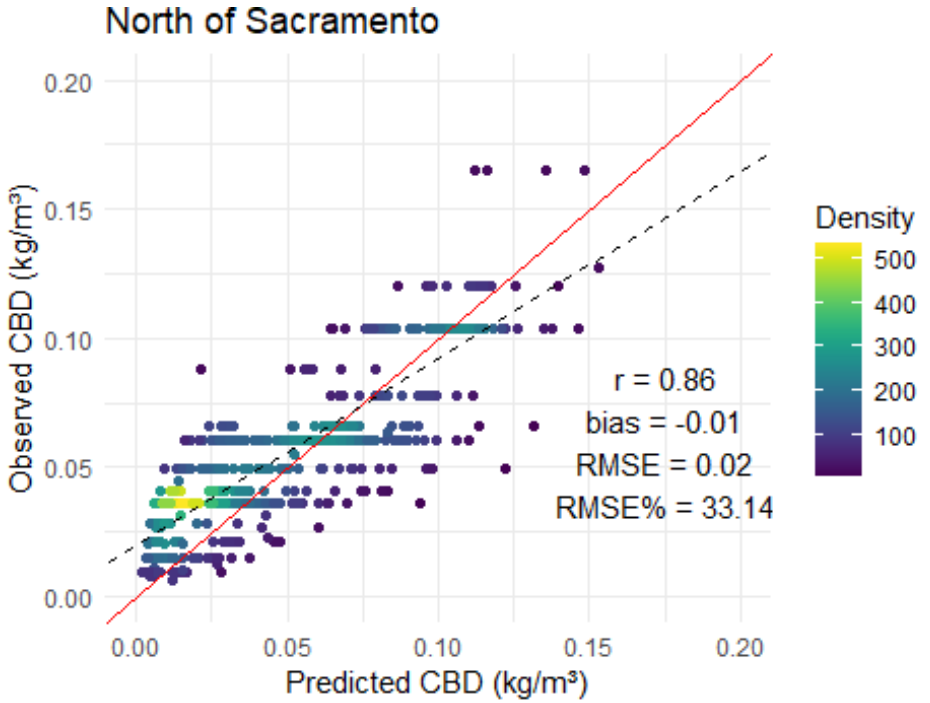
Method 2 : Analysis of raw GEDI waveform

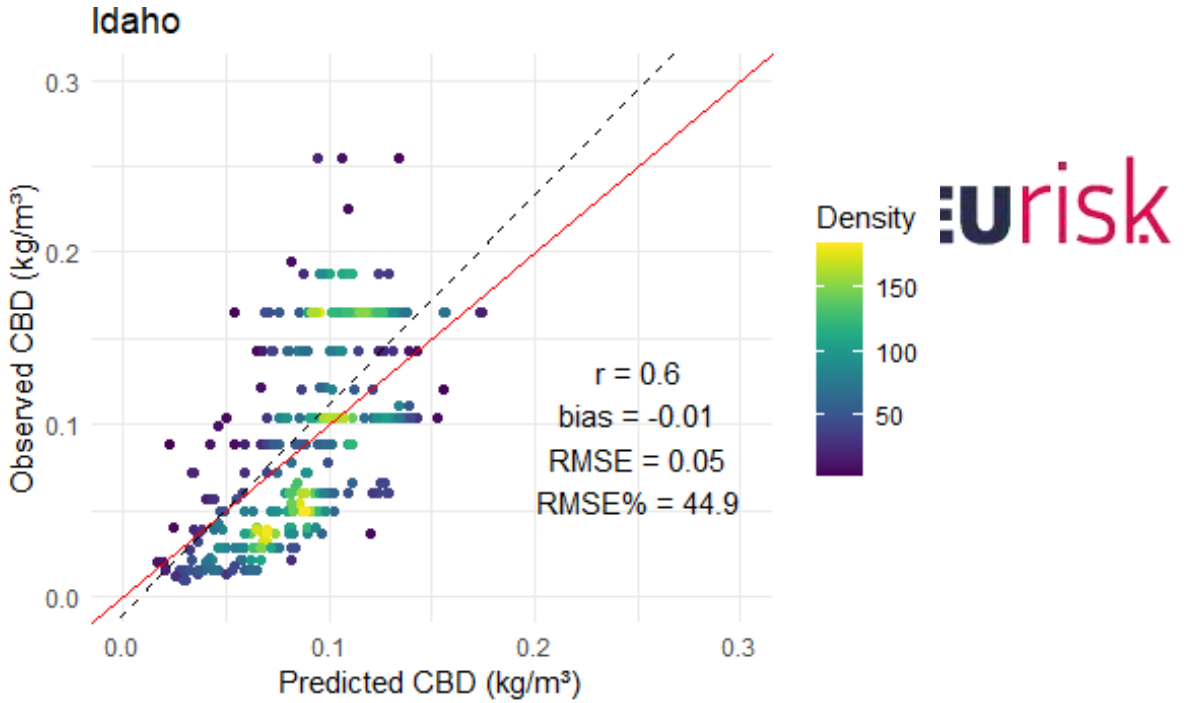
- **Canopy fuel load**
- LAI/ SLA (speficif Leaf Area)

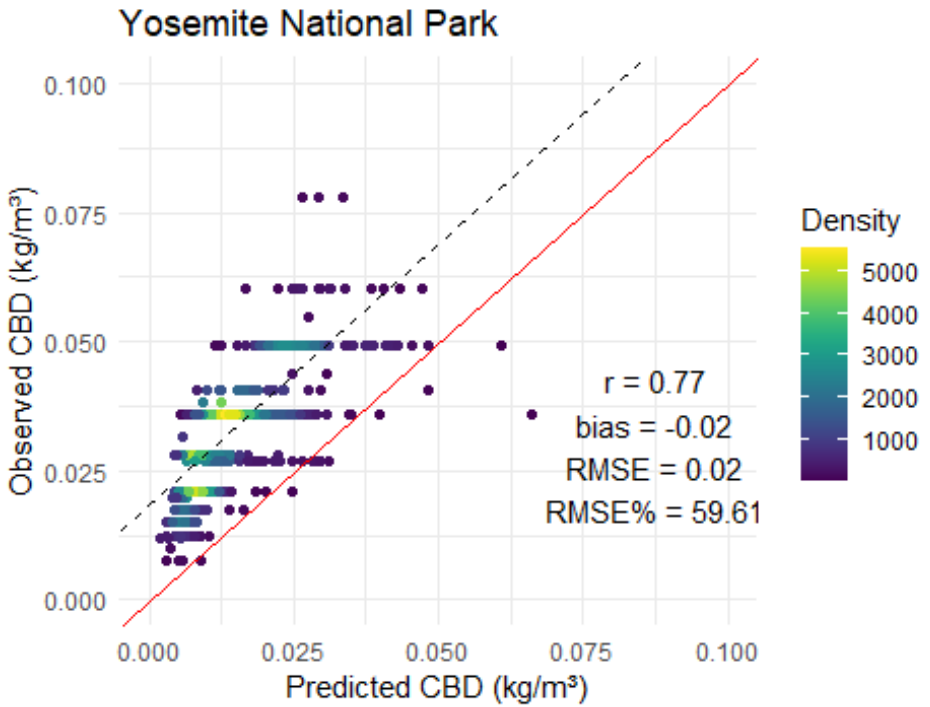
- **Canopy bulk density**
- Get canopy Fuel Vertical Profile (FVP)
- CBD as maximum of the FVP/SLA



This project has bee
Horizon 2020 resear
Agreement no. 10100







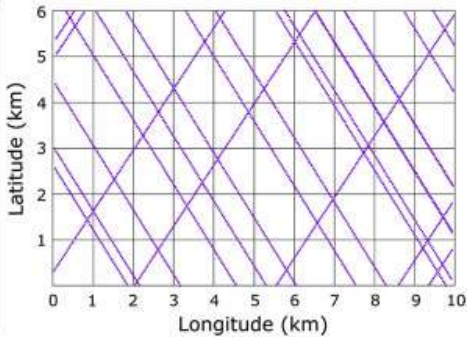
Results: Assessment using US LANDFIRE data for 3 different bioclimatic conditions

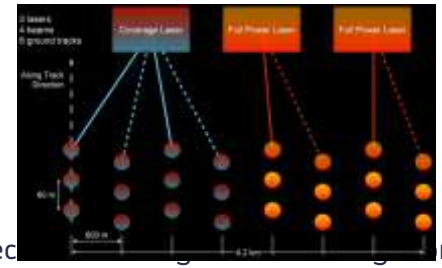
Final step: Interpolation model of GEDI data

Next step: Use spaceborne GEDI data to derive forest canopy height and cover

But we need to **interpolate** because GEDI data is not spatially continuous







1 **Inverse distance weight (IDW) interpolation** of GEDI data

Forest fuel polygons with spacebrone GEDI footprints

92 % forest under 51.6ºN

2 **Random forest & K-nearest neighbout regression models** of GEDI + multispectral+ RADAR data + biopysical variables

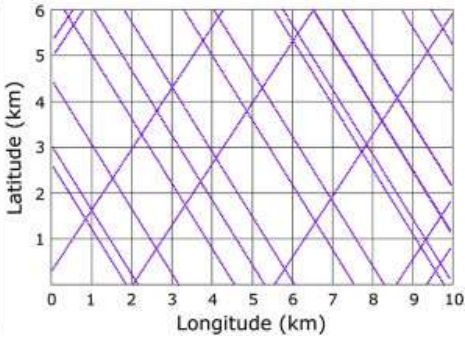
Forest fuel polygons without spaceborne GEDI footprints

(small polygons under 51.6ºN and all polygons above 51.6ºN, GEDI coverage)

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Methodology: regression models





https://www.sciencedirect.com/science/article/pii/S2666017220300018

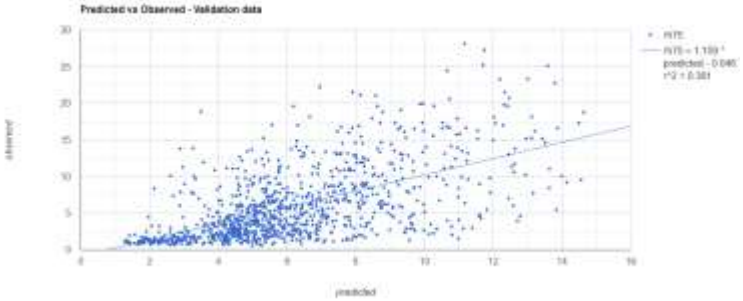
Input layers

- **Optical imagery**
- Landsat 8 composites' (May-September) statistics
- 6 spectral indices
- **RADAR imagery**
- PALSAR
- **Biophysical variables**
- Temperature
- Precipitation
- Biogeographic regions
- Elevation
- Slope
- Net primary production
- Tree cover
- Top canopy height
- Biomass
- Digital surface model

Training (70%)



Validation (30%)



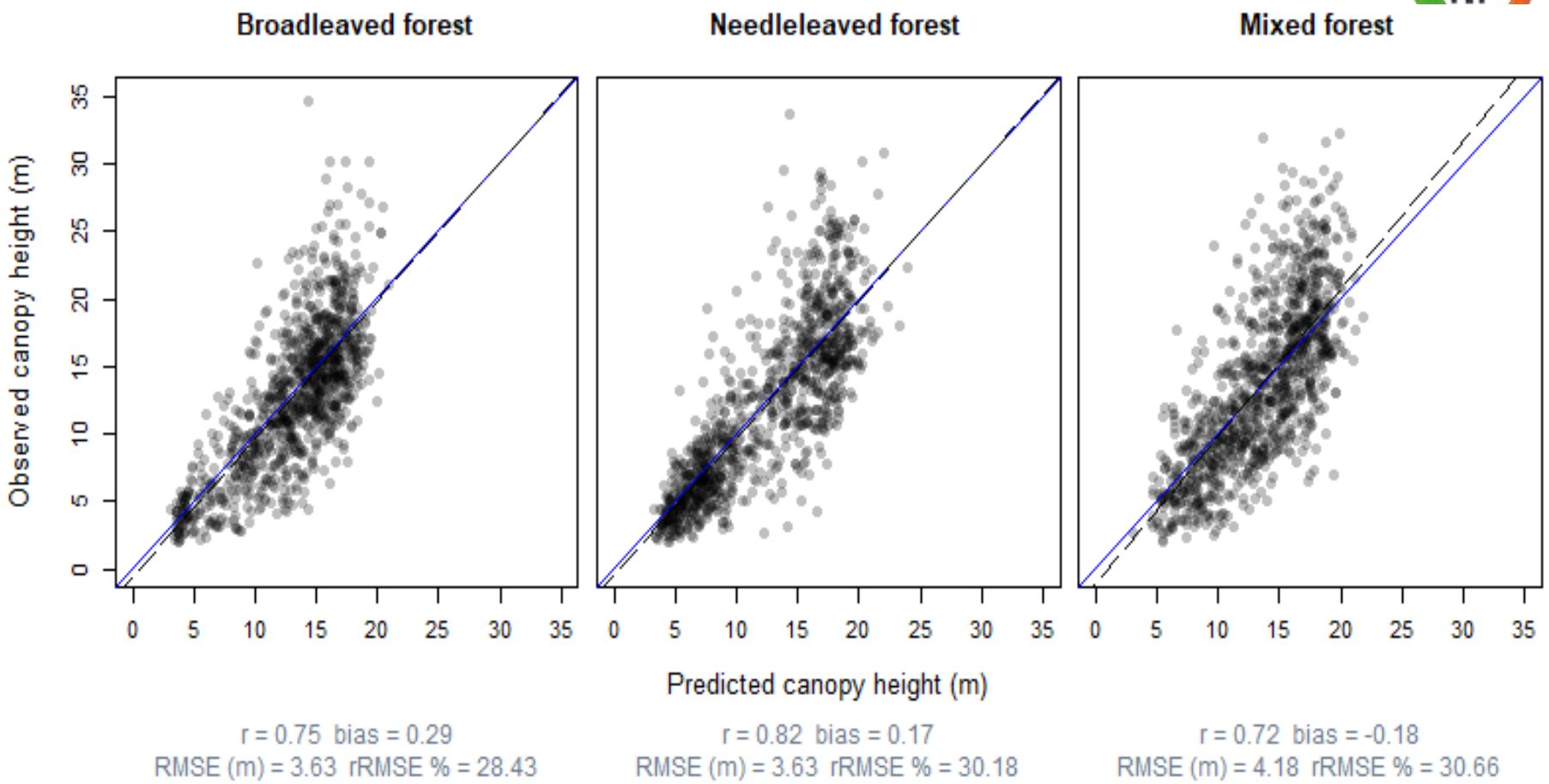
Regression model

Continuous map for forest canopy parameters (1 km)



nding from the European Union's
ation programme under the Grant

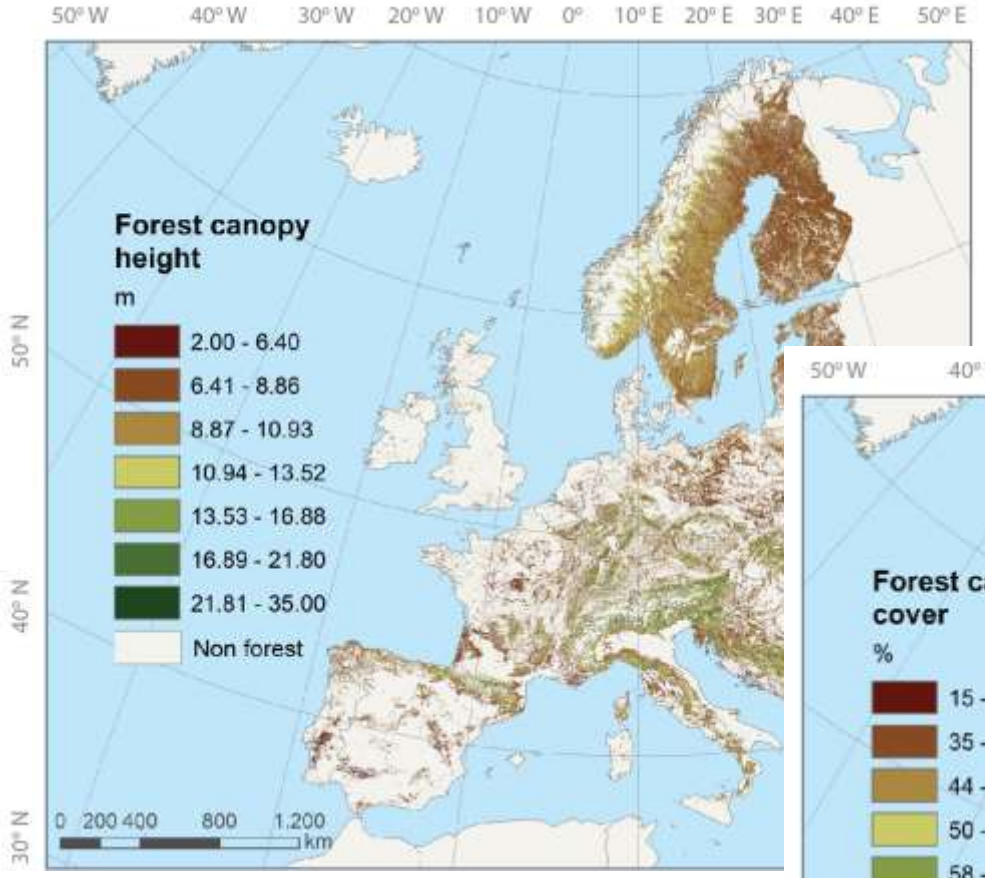
Results regression models: Example for canopy height

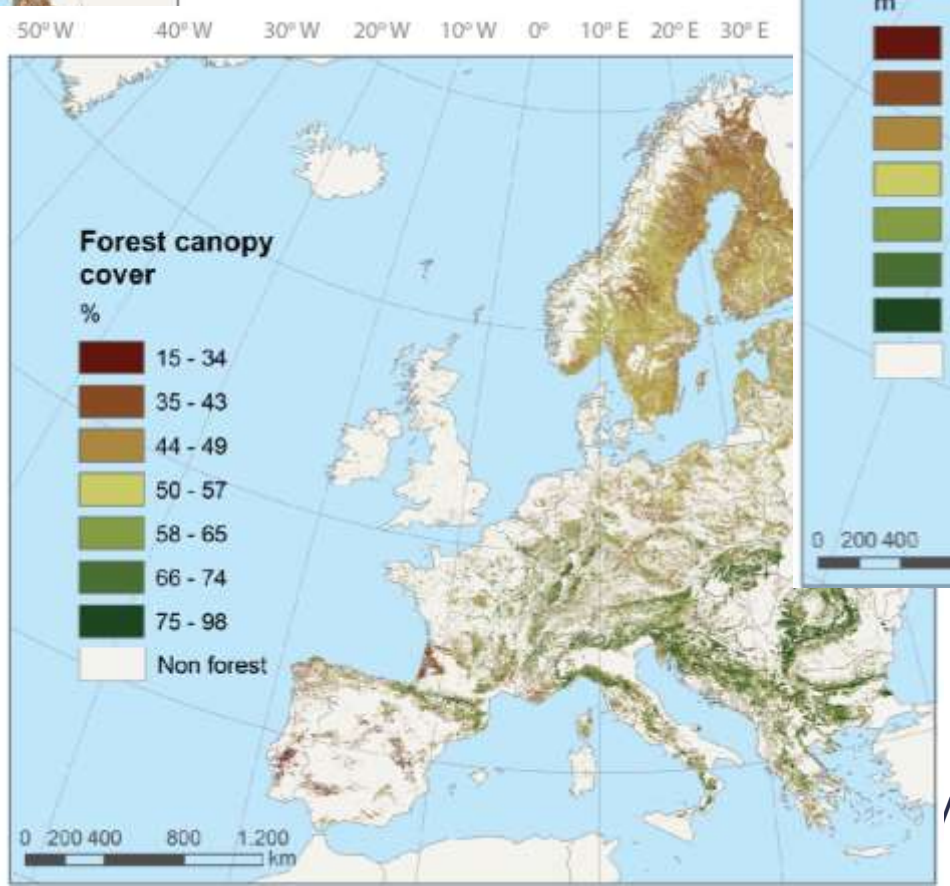


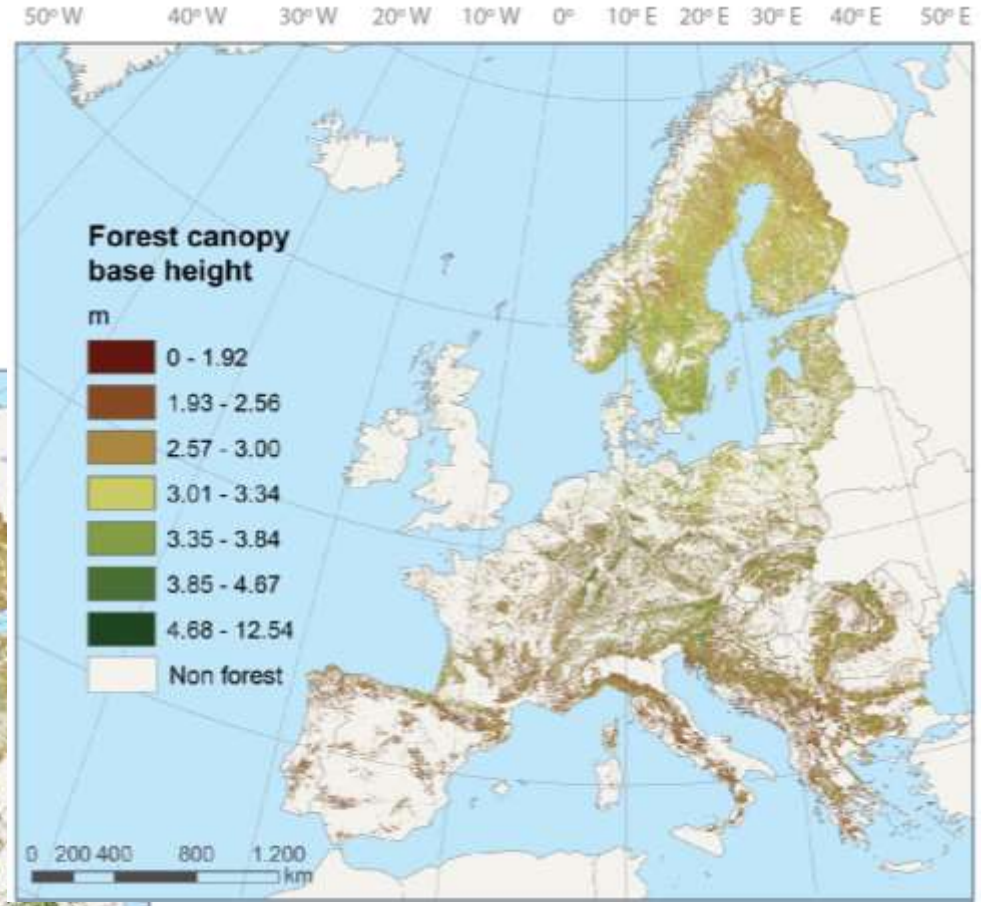
Most important variables for the canopy parameters

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Final results: wall-to-wall maps on canopy parameters

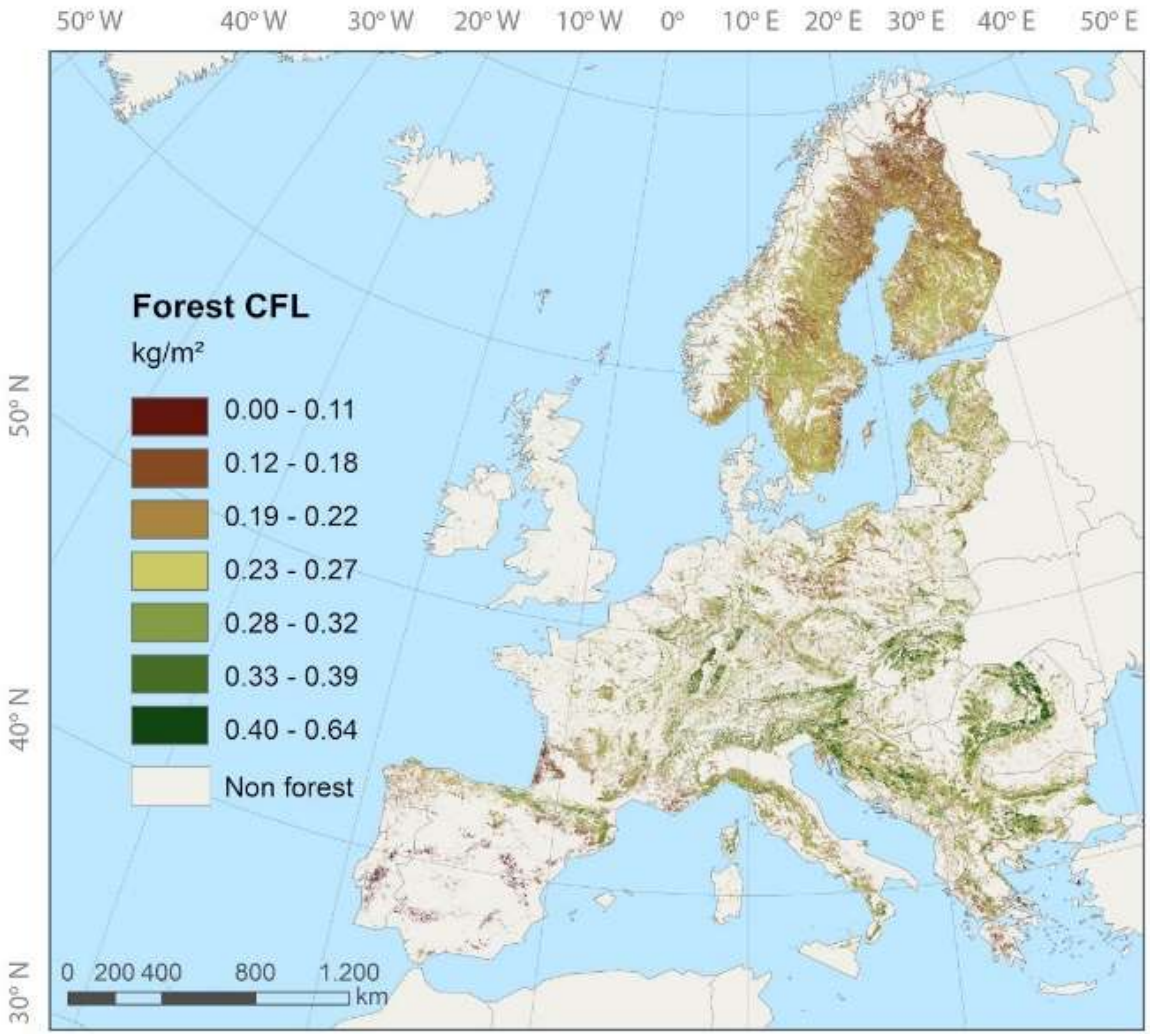


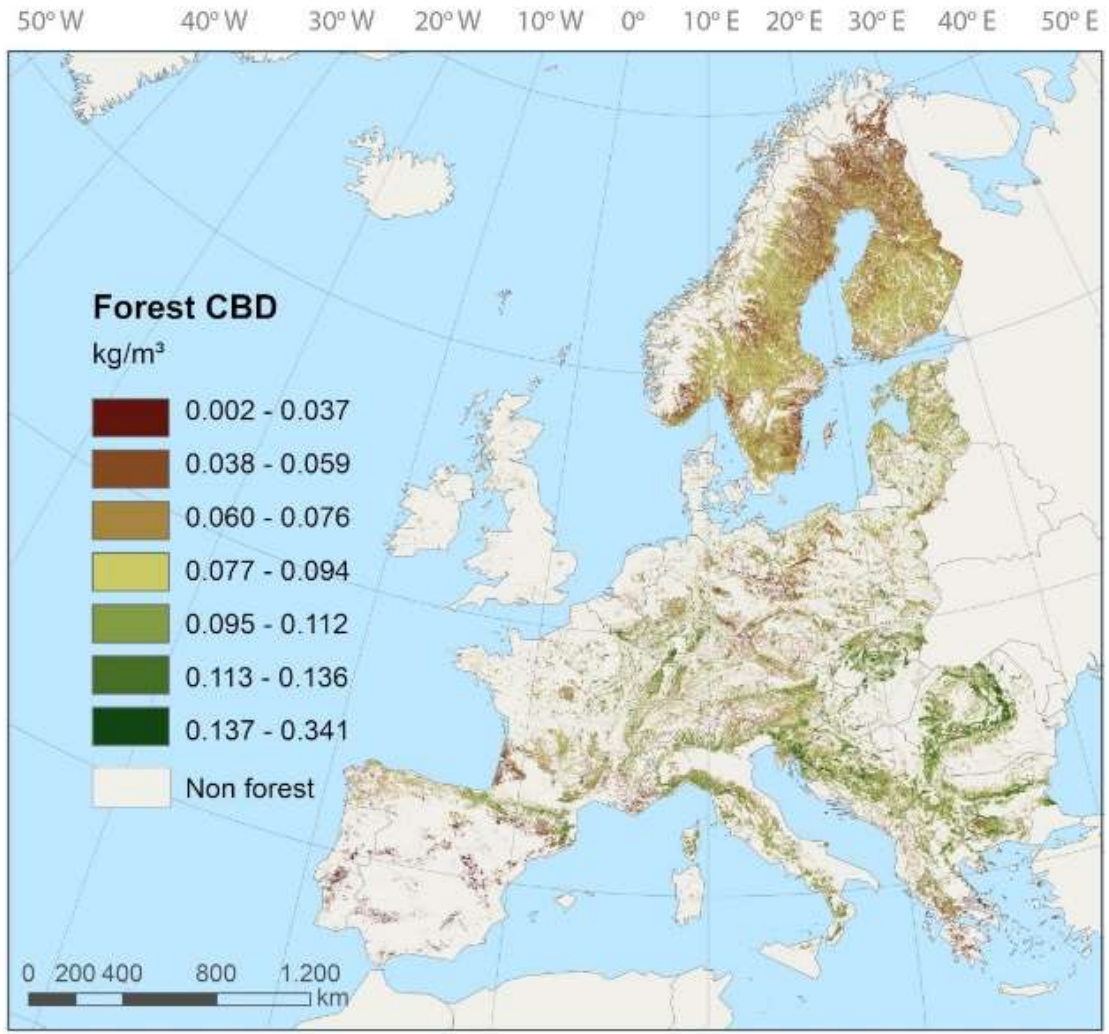




This project has been granted fundir
Horizon 2020 research and innovatio
Agreement no. 101003890

Final results: wall-to-wall maps on canopy parameters





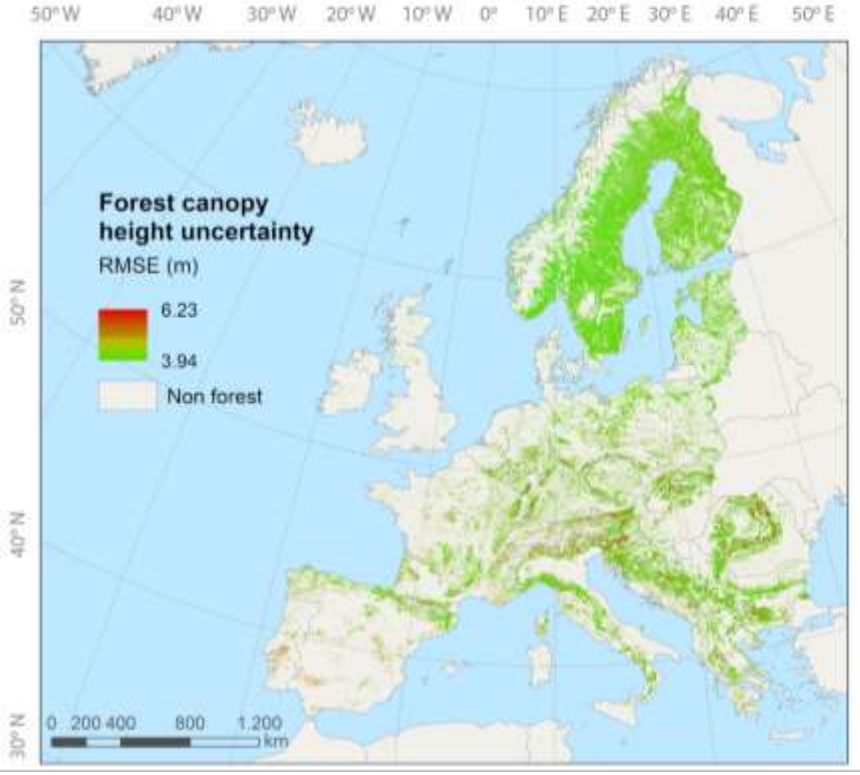
This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

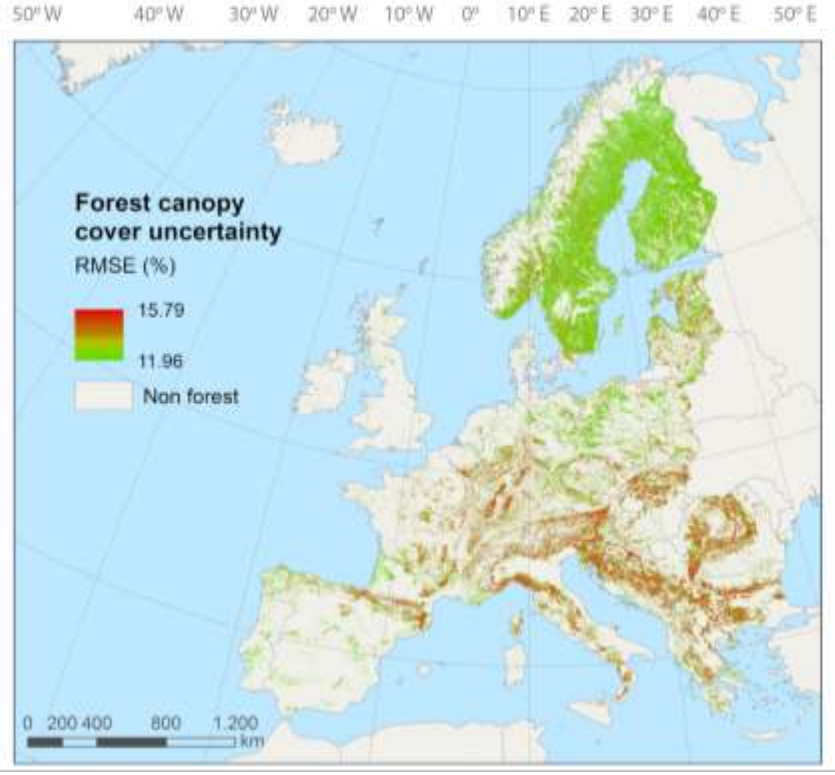
Generation of uncertainty maps

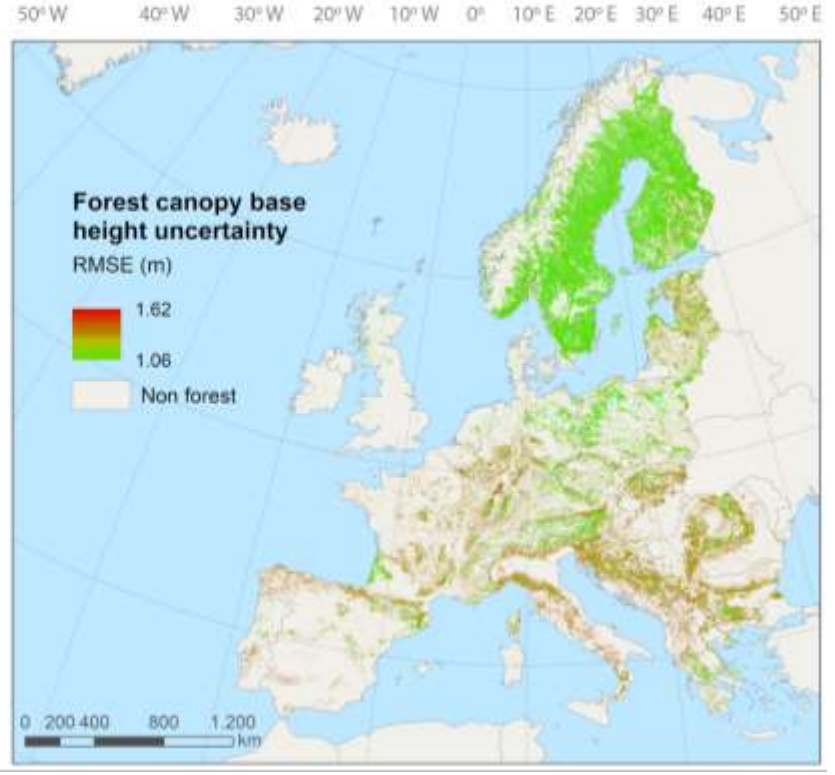
Steps

- Generation of reference data
- Calibration of GEDI models
- Extrapolation (IDW or RF)

→ Propagation of independent errors

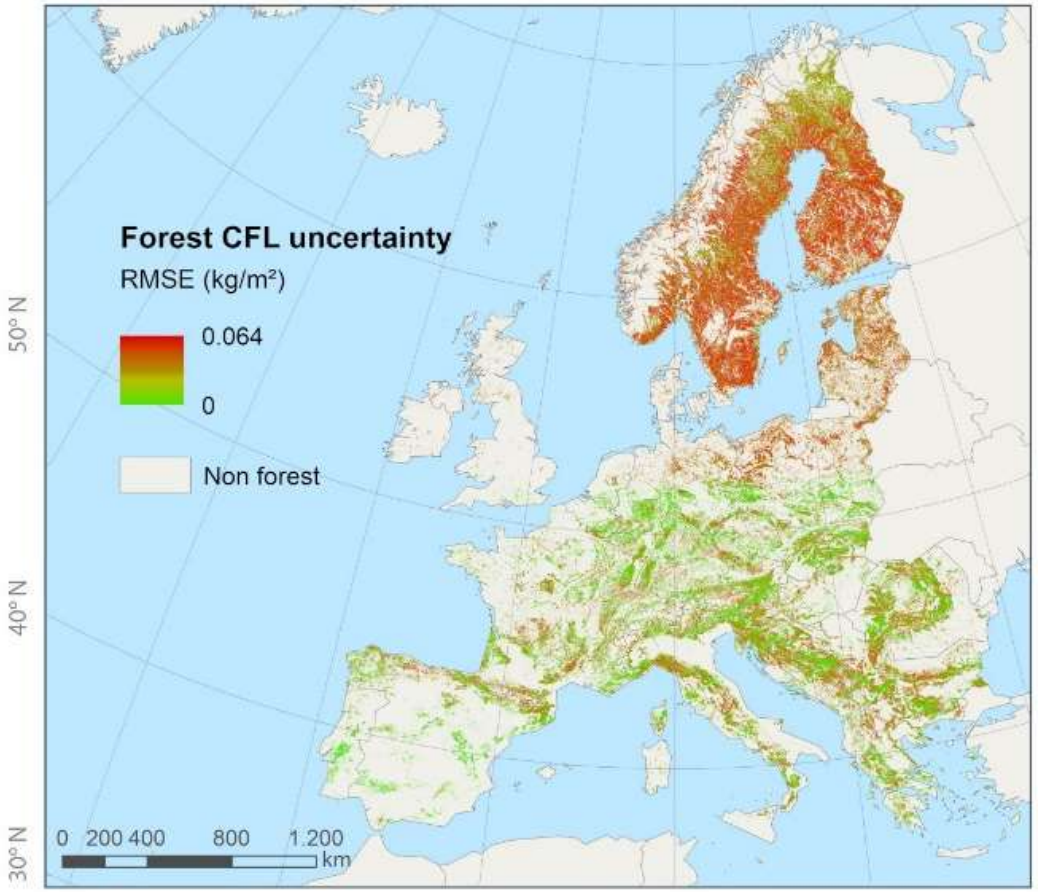


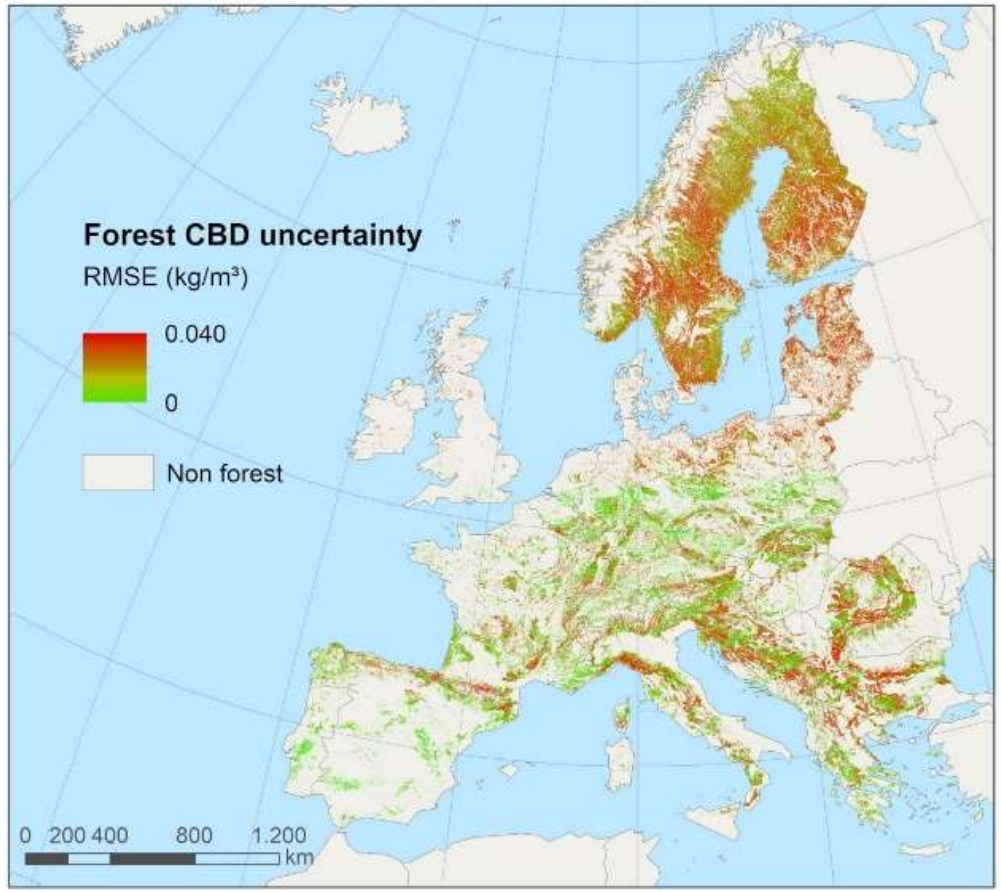




Generation of uncertainty maps

- Extrapolation → Propagation of independent errors





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Conclusions

- Our results can be used to help managers with **fire risk prevention strategies**
- Approach: **remote sensing and geospatial images**
- Novelty: **hierarchical multipurpose framework adapted to European conditions**
- Key technology: **GEDI LiDAR** (vertical structure of fuel types) both discrete and full-waveform. Using the raw GEDI waveform is key to estimate complex parameters

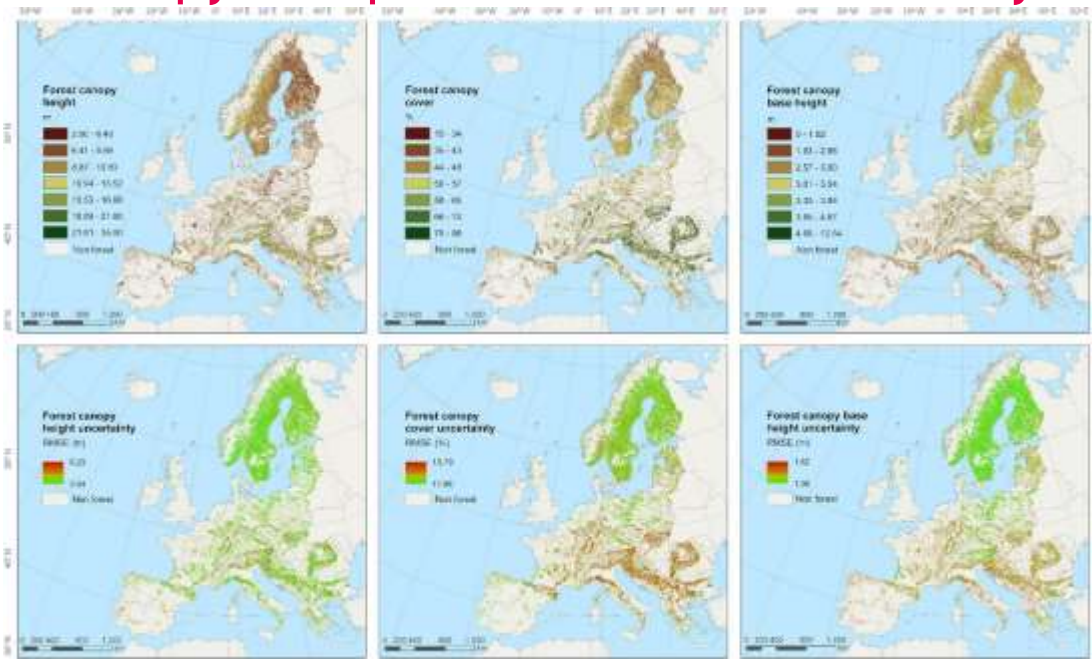


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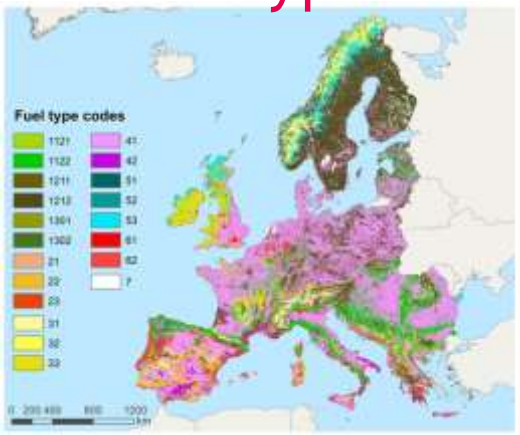
Final set of available layers

- **Open Access in public repository**
  - https://doi.org/10.21950/YABYCN
  - https://doi.org/10.21950/KTALA8
- **Methodology and details in scientific papers**
  - https://doi.org/10.5194/essd-15-1287-2023
  - https://doi.org/10.1016/j.rse.2024.114005
  - 3rd paper under review

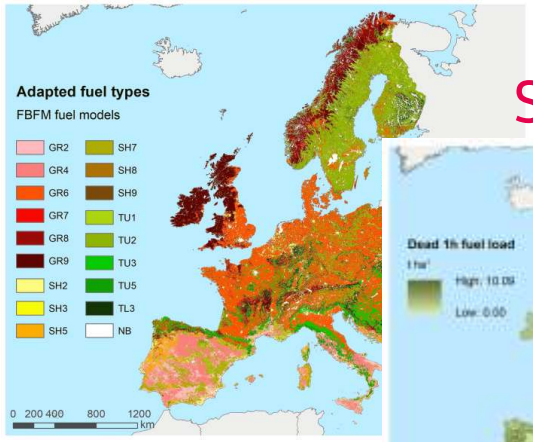
Canopy fuel parameters + uncertainty



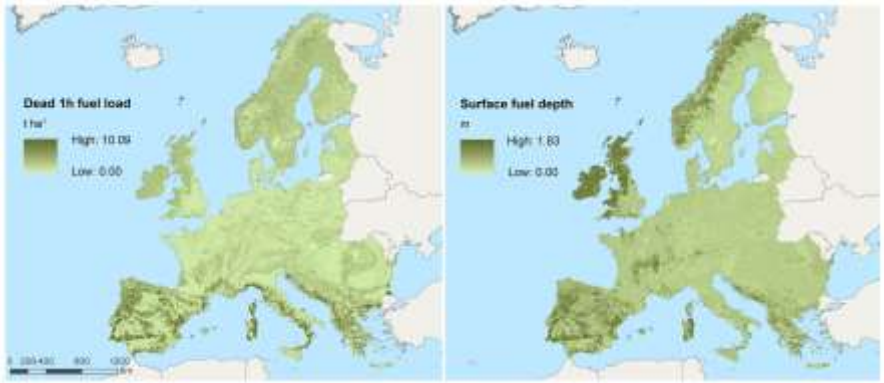
Fuel types

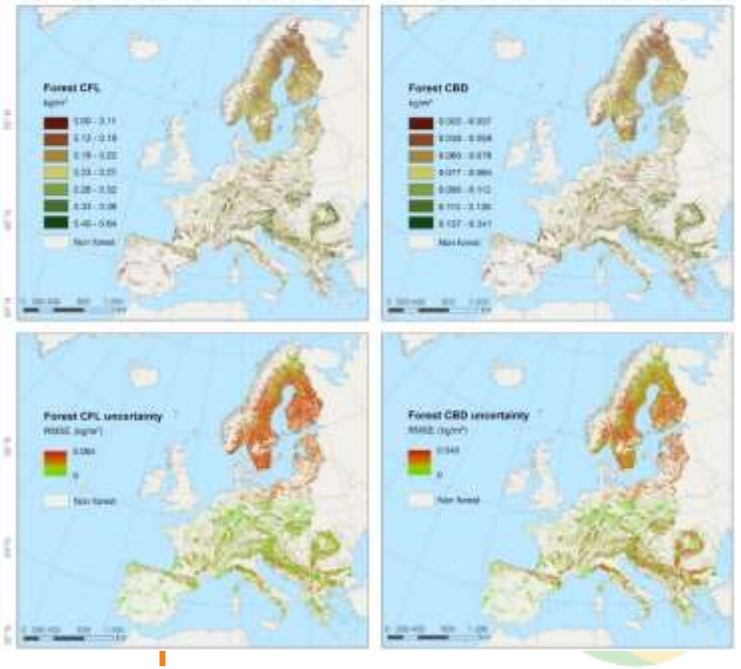


S&B fuel Models



Surface fuel parameters







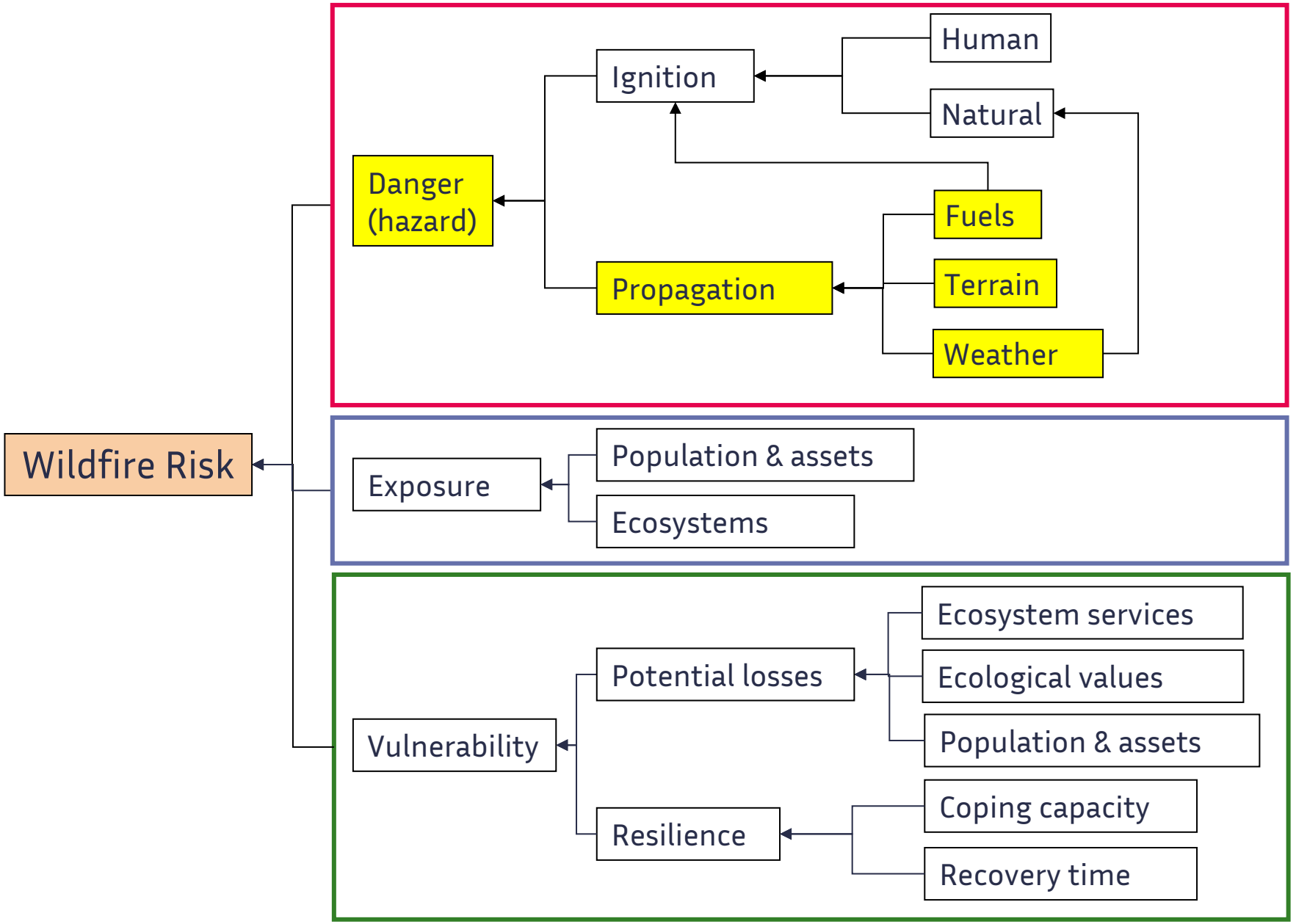
Elena Aragoneses: e.aragoneses@uah.es

Propagation potential

Darko Stipaničev
FESB University of Split, Croatia



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Topics

What is wildfire propagation potential?

Why it is important?

Calculation methodology for European territory

Results

How propagation potential maps could be used

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What is wildfire propagation potential?

- Wildfire propagation potential refers to a probability of wildfire spread in certain area. Its inputs are factors that affect the likelihood and intensity of wildfire spread, usually divided into three groups:
  - The type of vegetation,
  - Landscape topography and
  - Weather conditions.

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What are wildfire propagation potential variables?

Wildfire propagation potential variables are derived from wildfire propagation models.

We divide them into two groups connected with:



- Surface wildfire propagation
- Crown wildfire propagation.

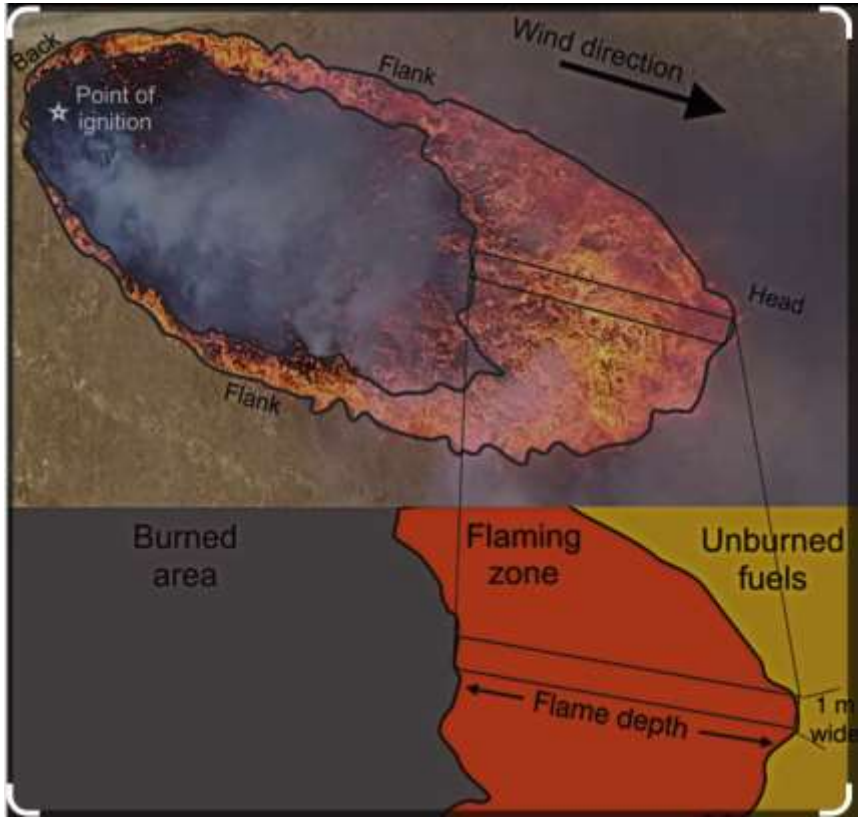
For both wildfire propagation types same propagation variables are calculated.



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What are wildfire propagation potential variables?

Fireline Intensity (FI) [kW/m] [kJ/(m s)]

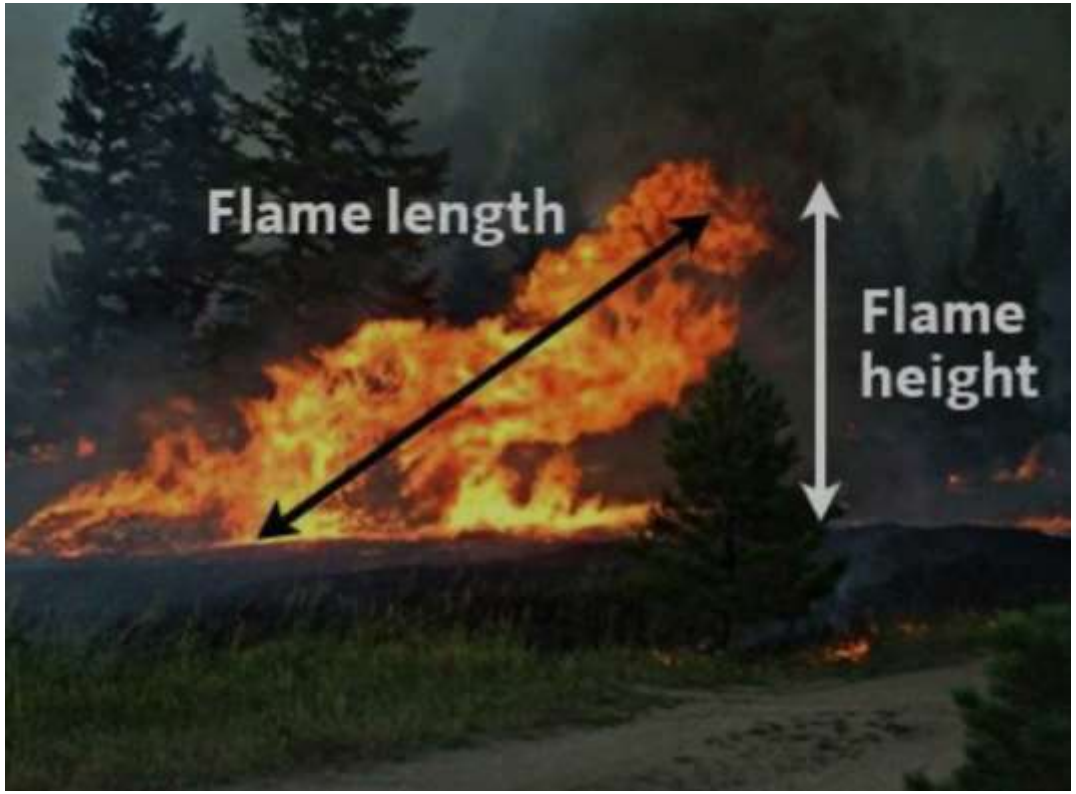


- Also called Byram's fire intensity
- Fundamental fire characteristic: *"… it gives as much information about a fire's behaviour as can be crammed into one number."*
- Heat energy released per unit time from a one-meter-wide section of the fuel bed extending from the front to the rear of the flaming zone.
- Fireline intensity is a function of rate of spread and heat per unit area. It is directly related to **flame length**.

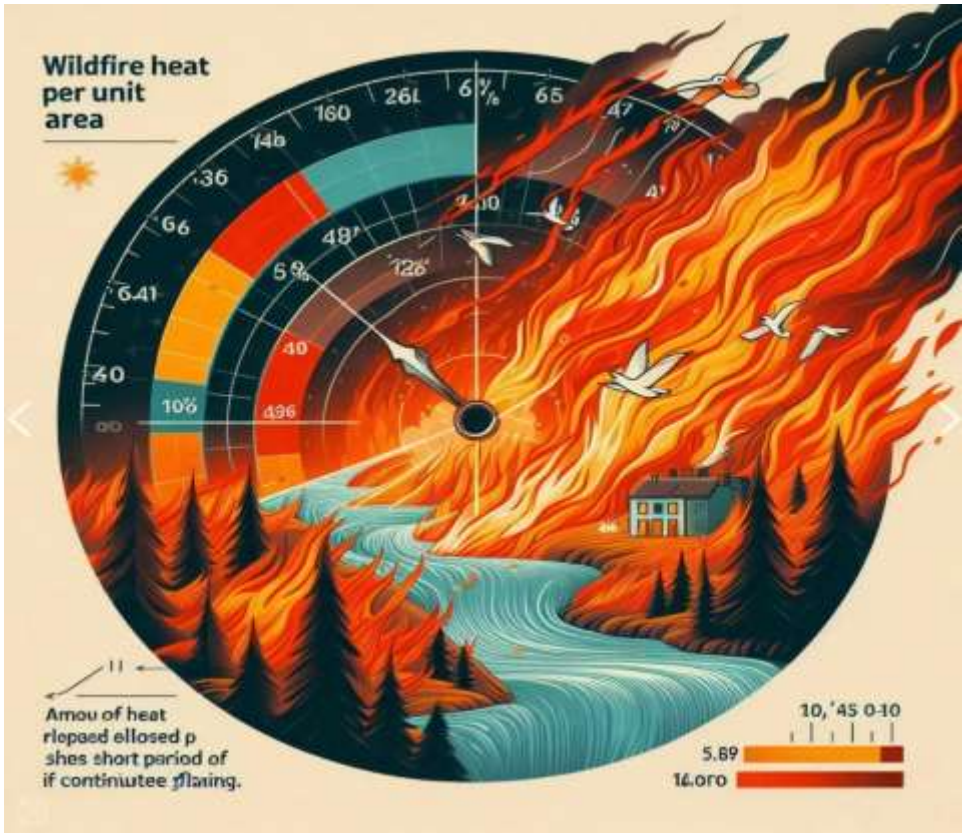
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What are wildfire propagation potential variables?

Flame Length (FL) [m]



Heat per Unit Area (HA) [kJ/m²]



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What are wildfire propagation potential variables?

Reaction Intensity (RI) [kJ/(m² s)]



Rate of Spread (ROS) [m/s]



... and the same for crown fire propagation.

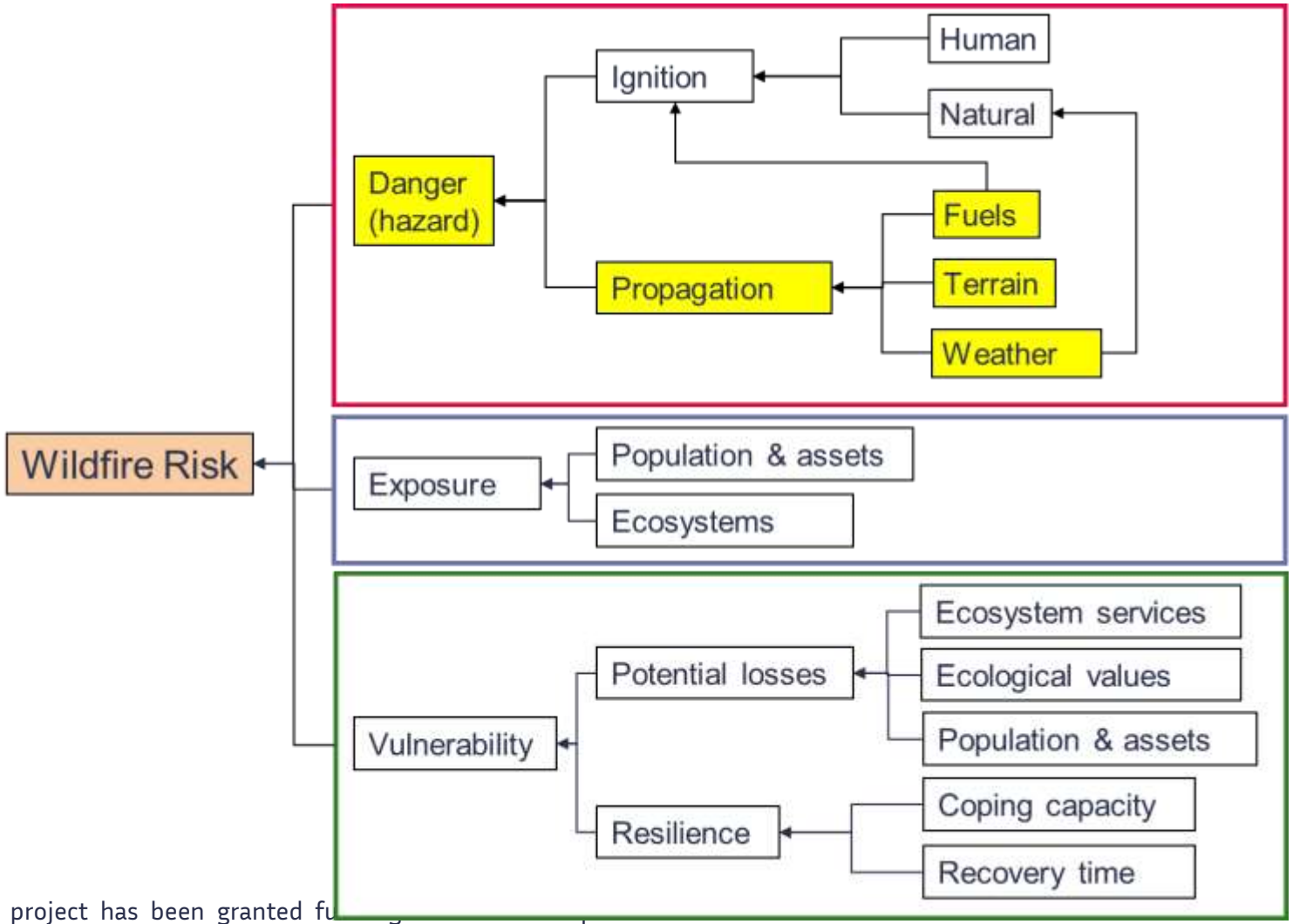
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Why propagation potential variables are important?

- Propagation potential variables could be typically used by wildfire managers **to assess the potential risk of a wildfire in a particular area**.
- Propagation potential maps are useful for prevention and preparedness planning.
- In **FirEURisk** project propagation potential variables are used, not only for **wildfire danger (hazard) estimation**, but also for **wildfire exposure risk estimation**.

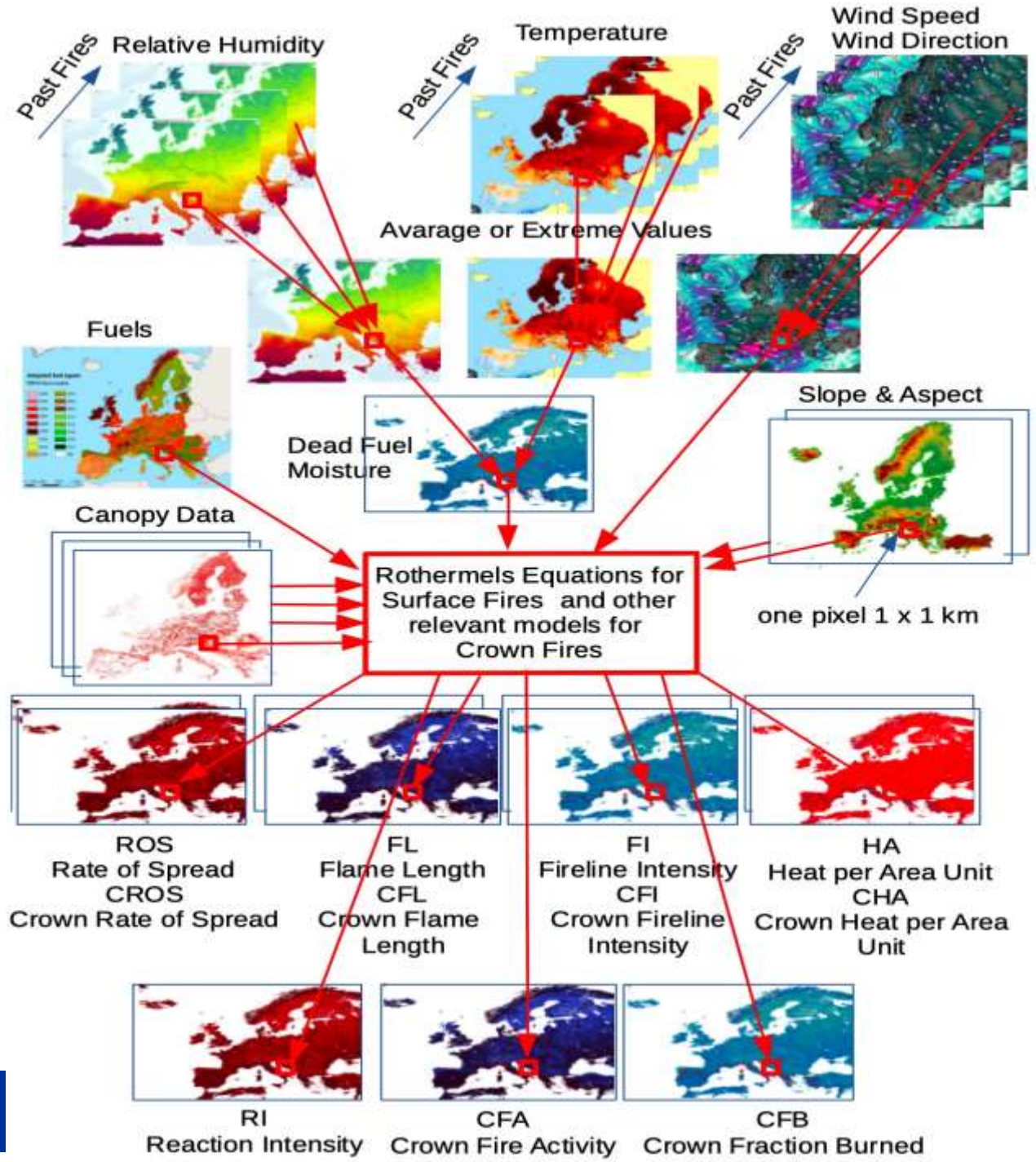
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Why propagation potential variables are important?



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Calculation methodology for European Territory (ET)

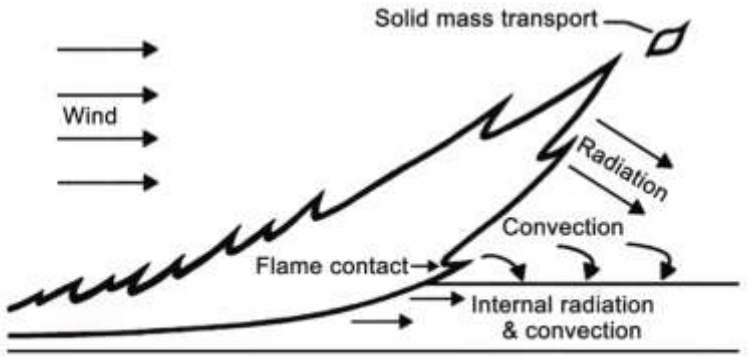


Calculation methodology

- Propagation potential for EU territory was calculated in 1 km resolution, based on **custom implementation of**
  - **Rothermel's model** (1972, Rothermel) **for surface fire** and
  - **standard crown fire models** (1977 Van Wagner's crown fire initiation model, 1991 Rothermel's crown fire spread model, 1998 Finney's crown fire behaviour model and 2001 Scott and Reinhardt's crown fire behaviour model.)

  in Python **for cell-based wildland landscape fire growth simulations**.

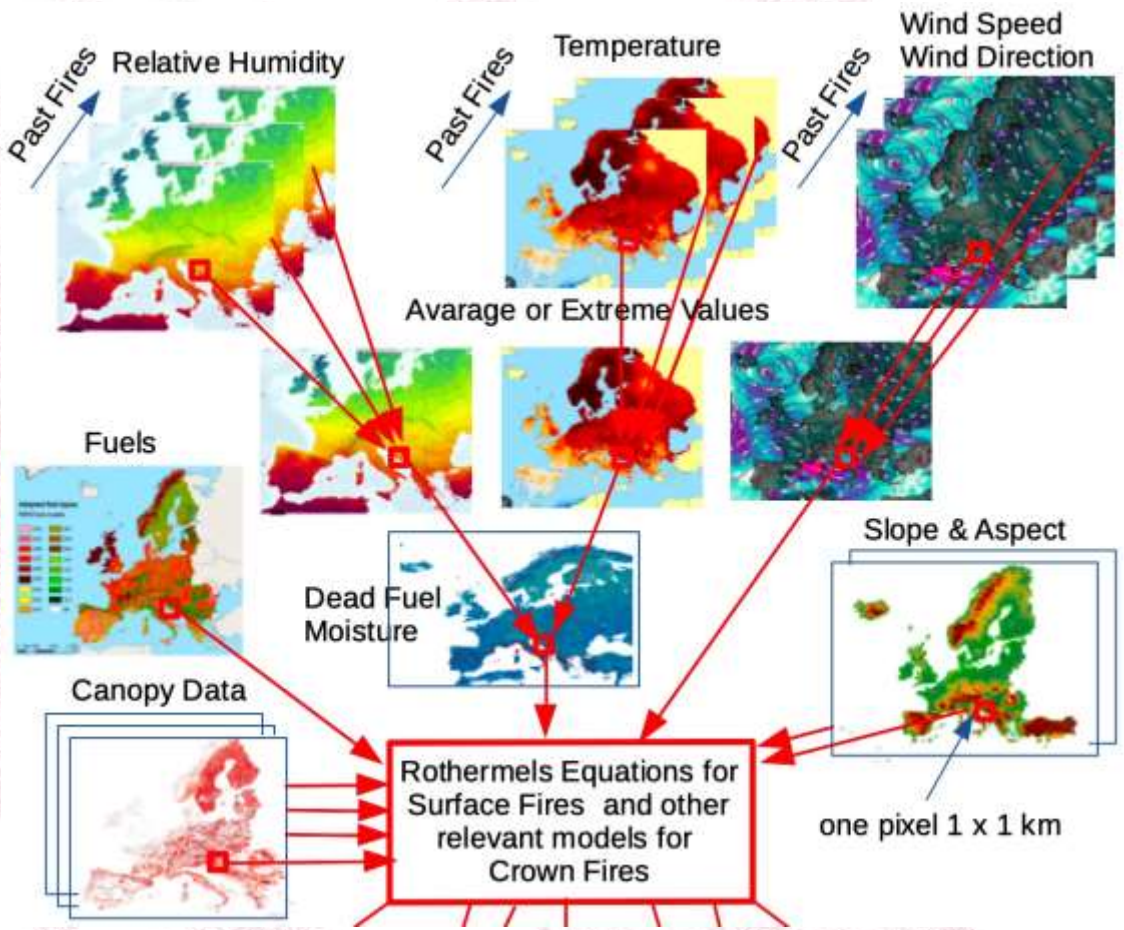
$$R = \frac{I_R \xi (1+\phi_w+\phi_s)}{\rho_b \epsilon Q_{ig}}$$



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Calculation methodology

- Inputs are:
  - **Fuel Maps** according to FirEUrisk Fuel Models
  - **Terrain Topology** (Slope & Aspect)
  - **Canopy Data** (Canopy Cover, Canopy Height, Canopy Base Height, Canopy Bulk Density)
  - **Meteorological Data** (Wind Speed and Direction, Temperature & Relative Humidity used to calculate Dead Fuel Moisture) based on historical fires larger then 2000 from 2001 to 2019. There were 403 of such fires.



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Meteorological Input Data

- For their dates, maps of meteorological parameters were extracted from ERA5 by MeteoGrid.
- **10h Fuel Moisture Content** and **wind speed and direction** 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 the wind speed).

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Results

- Final results were two sets of maps for European territory in 1 km resolution, one for average and one for extreme conditions (22 maps)

SURFACE FIRE

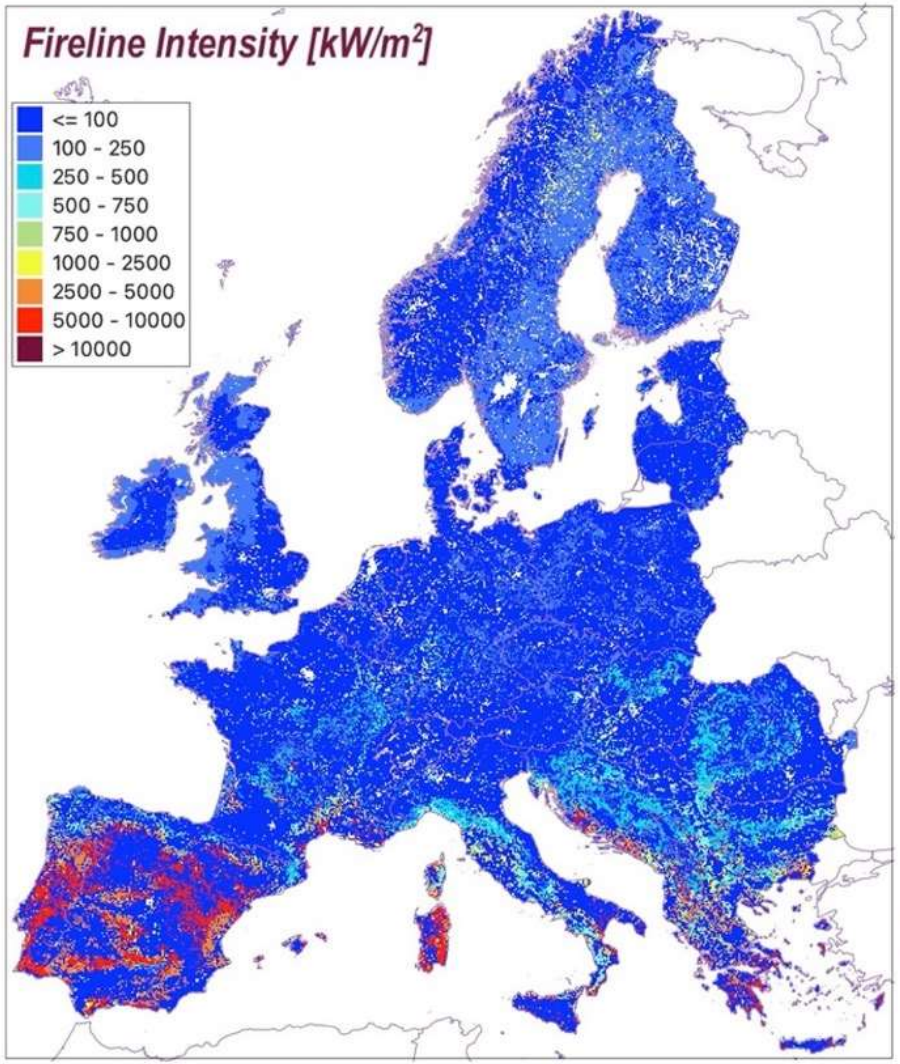
Rate of Spread – R [m/s]
Reaction Intensity – RI [kW/m^2]
Fireline Intensity – FI [kW/m]
Flame Length – FL [m]
Heat per Unit Area – HA [kJ/m^2]

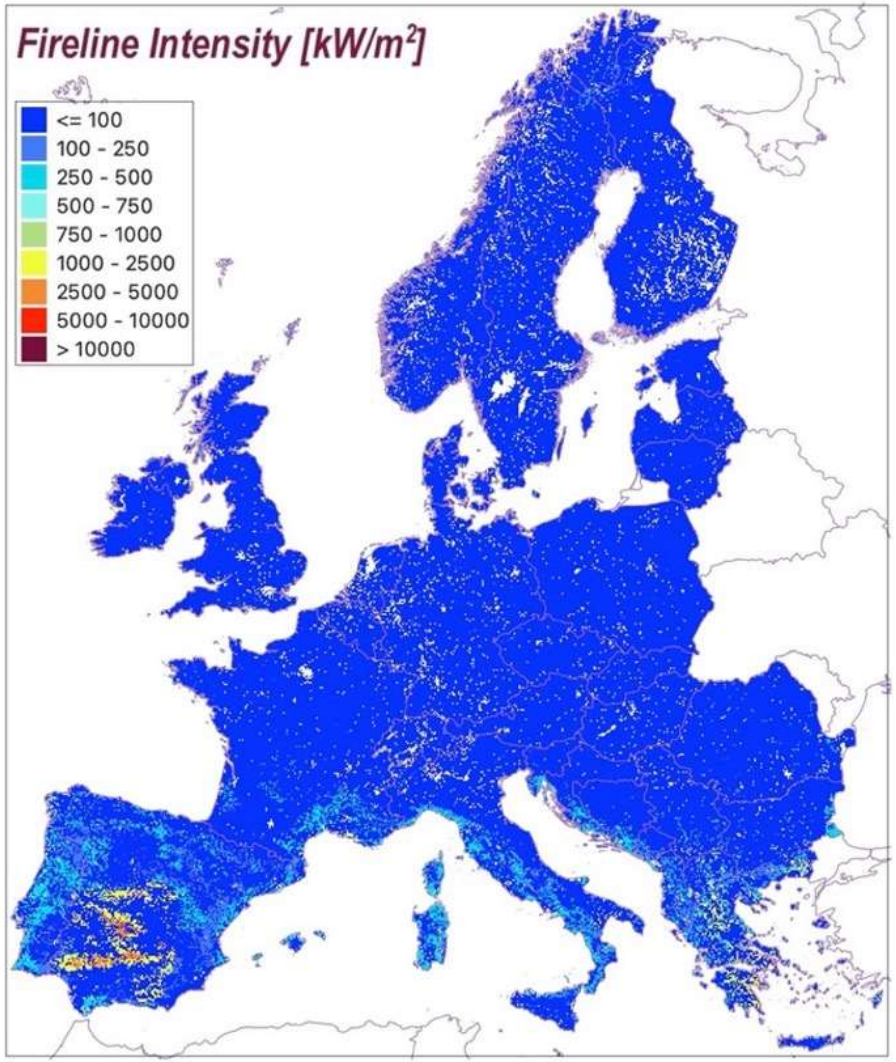
CROWN FIRE

Crown Fire Activity – CFA [indicator]
Crown Factor Burned – CBA [fraction]
Crown Fire Rate of Spread – R [m/s]
Crown Fire Fireline Intensity – FI [kW/m]
Heat per Unit Area – HA [kJ/m^2]
Flame Length – FL [m]

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Results





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How propagation potential maps could be used

- Propagation potential maps could be easily implemented in wildfire management system. Operator could have two options considering propagation potential danger (hazard) and other wildfire risk indicators:
  1. The first one is **based on these historic fires**, so for example if southwest wind is blowing, firefighter operator could see which part has the most severe danger considering propagation potential indicators.

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How propagation potential maps could be used

- 2. The second one is even more interesting and important. Propagation potential danger indicators (beside others wildfire risk indicators) could be also **calculated dynamically on daily bases using daily meteorological data,** so operators could have insight in daily real time wildfire propagation potential risk indicators, **as it was done in FirEURisk project during summer 2024**.

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Ecological Values

Fátima Arrogante Funes

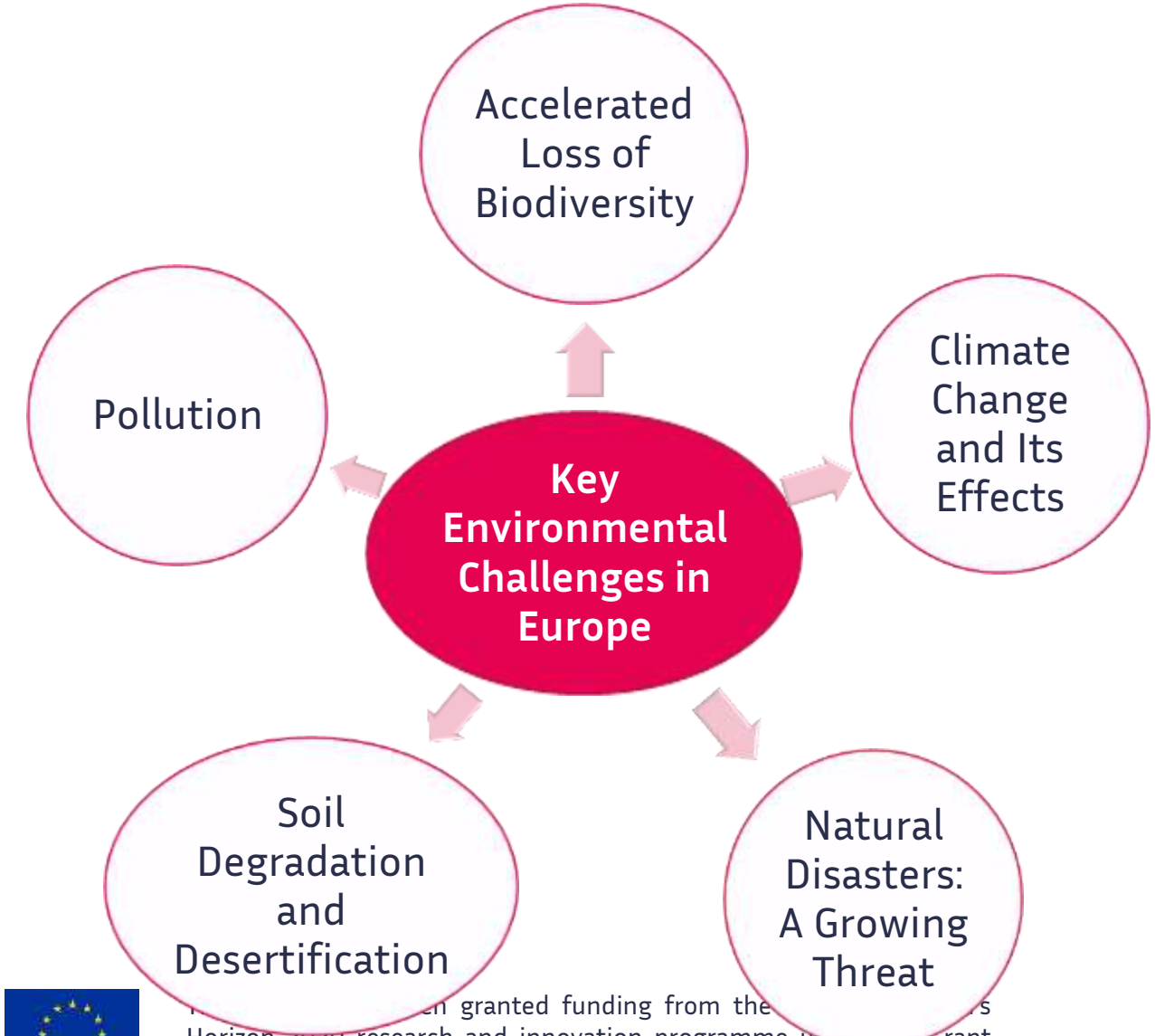
Universidad de Alcalá

fatima.arrogante@uah.es



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1. Context and Product Need



Need for Data-Driven Planning and Management…

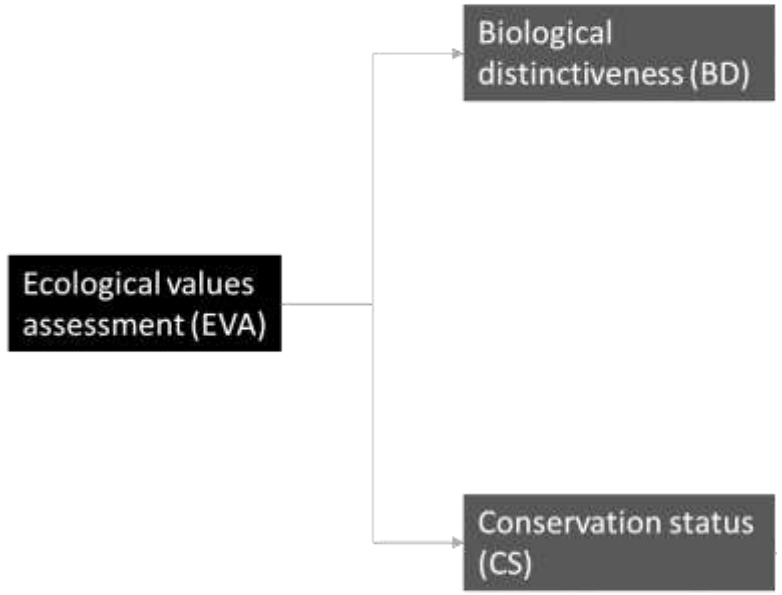
- It is essential to have **tools that allow for effective planning and decision-making** based on accurate, up-to-date data.
- A **map of ecological values at a European scale** provides a critical tool for assessing risks, identifying vulnerable areas, and prioritizing conservation actions.

…n granted funding from the …s Horizon 2020 research and innovation programme un… Grant Agreement no. 101003890

2. Product Description

- **What is the Ecological Values Map?**

The **Ecological Value Map (EVA)** is a tool designed to assess and represent the ecological importance of different areas by evaluating two primary factors: **Biological Distinctiveness (BD)** and **Conservation Status (CS)**.



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2. Product Description

Key Component: Biological Distinctiveness (BD)

Refers to the **uniqueness** and **structural biodiversity** of an ecosystem.

Ecosystems with **high BD** provide **critical ecosystem functions** and **contribute to biodiversity conservation**.

Species Richness

Input: vectorial layers of mammals (278 sp.), birds (711sp.) reptiles (156 sp.), amphibians (96 sp.), vascular plants (20.000 sp.)
Source: UICN
Method: Raster Spatialization of occurrence based on IUCN data. Sum.
Up-to-date: Last updated 27th June 2024

Density of Habitat

Input: raster layer of biomass (g/Cm²)
Source: JRC-Forest
Method: Transformed to 1 kilometre using a weighted average approach
Up-to-date: 2010

Forest Productivity

Input: raster layer of specific leaf area (mm2 mg−1), leaf dry matter content (g g−1), leaf nitrogen content and leaf phosphorus content (mg g−1)
Source: Moreno-Martínez et al., (2018)
Method: normalising each variable, sum at the pixel level of the carbon, nitrogen and phosphorus cycle production values
Up-to-date: 2018

Key Biodiversity Areas

Input: vectorial layer
Source: Potapov et al., (2008)
Method: to 1km resolution
Up-to-date: 2020

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2. Product Description

Key Component: Conservation Status (CS)

Assesses the current condition of ecosystems and the threats they face.

Exceptional forests

Input: vectorial layer of intact forest landscapes
Source: Potapov et al., (2008)
Method: to 1km resolution
Up-to-date: 2016

Places of special conservation

Input: vectorial layer of protected areas
Source: UNEP, IUCN, WCMC
Method: protected areas classified under IUCN categories I–IV, assigning 1 where a WDPA was located and 0 where it was not
Up-to-date: 2023

Human pressures

Input: vectorial layer of fragmentation of the territory due to human infraestructures, road, railways and human assessments
Source: UNEP, Oak Observatory
Method: Density of railways, roads and population density
Up-to-date: 2021

Loss of forest

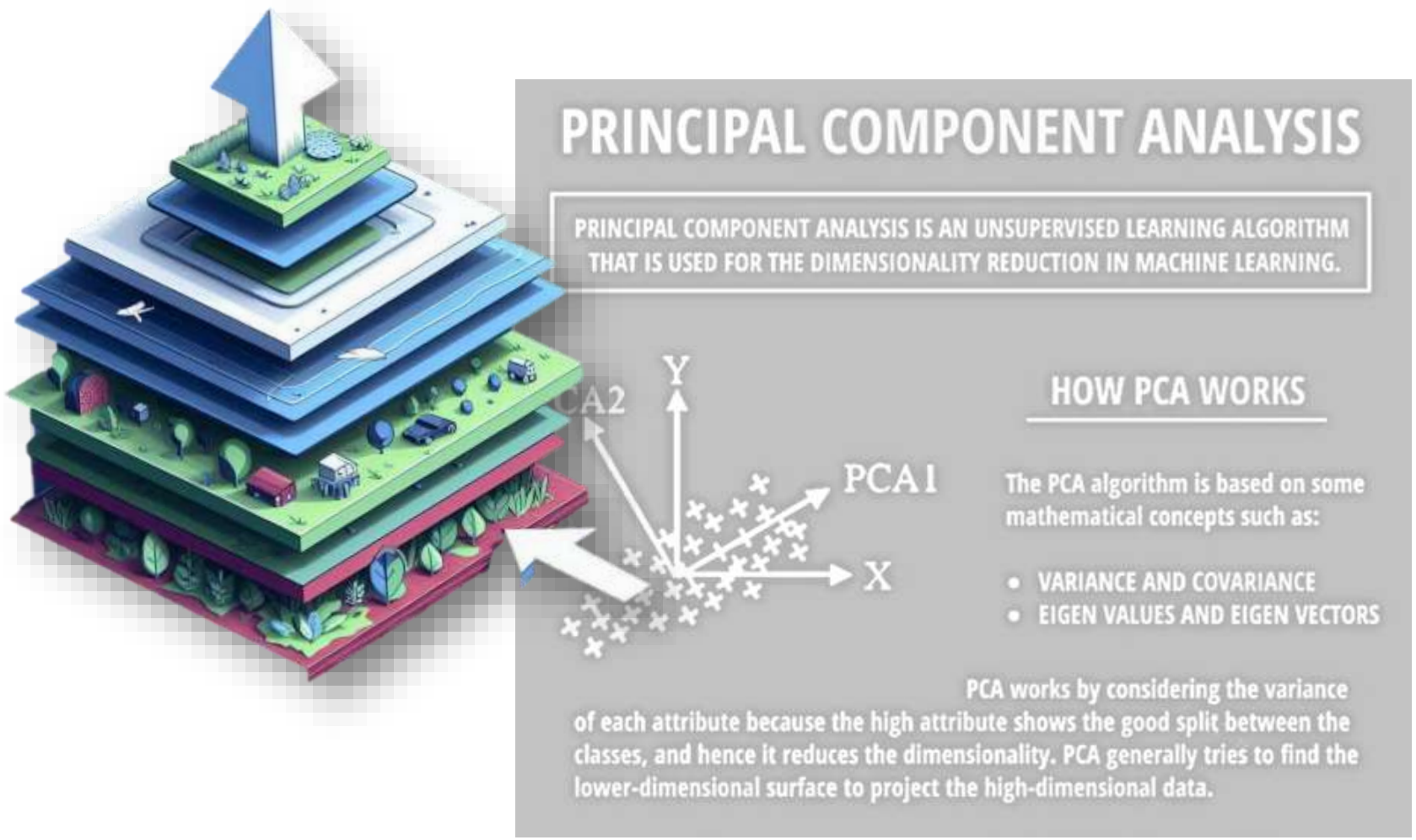
Input: raster layers of vegetation loss
Source: Hansen et al., (2013)
Method: Sum of the pixels that contain forest losses
Up-to-date: 2013

Unique habitat preservation

Input: vectorial raster of species from the Red List
Source: IUCN
Method: category of "critically endangered", "endangered", and "vulnerable", aggregated at pixel level
Up-to-date: 2020

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2. Product Description



INTEGRATION METHOD

- **First principal component** → Synergies between BD and CS
- *For example*,
  zones with fewer roads and railways and a loss of forest cover conserve better ecological values.

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3. Product and applicability

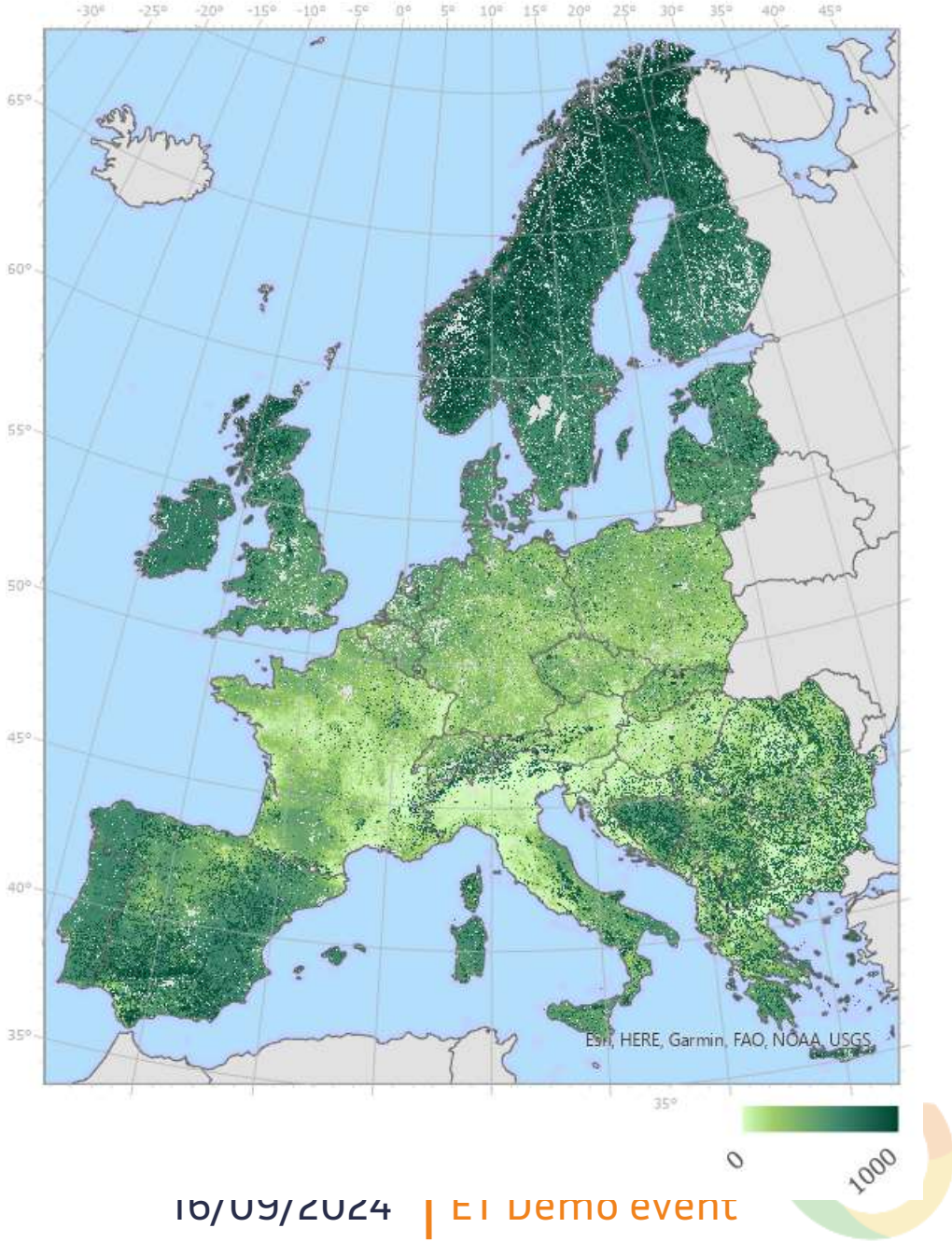
Scalability and geographic coverage

- **Ecological Value Map** → Continental level: 1km
- **Adapted to different spatial levels** → Versatile tool for various stakeholders
- **Up-to-date:** Depends of the refresh sources

Availability

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

Correspondence: fatima.arrogante@uah.es



This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

3. Product and applicability

Applications for different Users Types

- **Researches**
  - **Examples**: Biodiversity studies, climate change, ecosystem analyses, risk assessment
  - **Benefits**: Provides access to accurate and standardized data across Europe, enabling comparative studies and modeling
- **Businesses**
  - **Example:** Environmental Impact Assessments (EIA), sustainable infrastructure planning, or ecological offset strategie
  - **Benefits:** Facilitates compliance with environmental regulations and optimizes project planning
- **Governments Organizations**
  - **Example:** territorial planning, protection of natural areas, and public policy design
  - **Benefits:** Enhances decision-making based on updated scientific data

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4. Conclusions

- Data-driven tools are essential for tackling Europe's growing ecological challenges, such as biodiversity loss, climate change, and habitat degradation.
- The Ecological Value Map is a key resource that addresses this need by providing a comprehensive, scientifically grounded framework for analysing ecosystems.
- The map enables researchers, businesses, and governments to make informed, sustainable decisions by integrating diverse data layers- ranging from biodiversity hotspots to human pressure.
- Ultimately, this tool supports better planning, conservation efforts, and policy-making, ensuring that Europe's natural heritage is preserved for future generations.

- Fátima Arrogante Funes
- Universidad de Alcalá
- fatima.arrogante@uah.es

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Ecological Resilience: Coping Capacity & Recovery Time

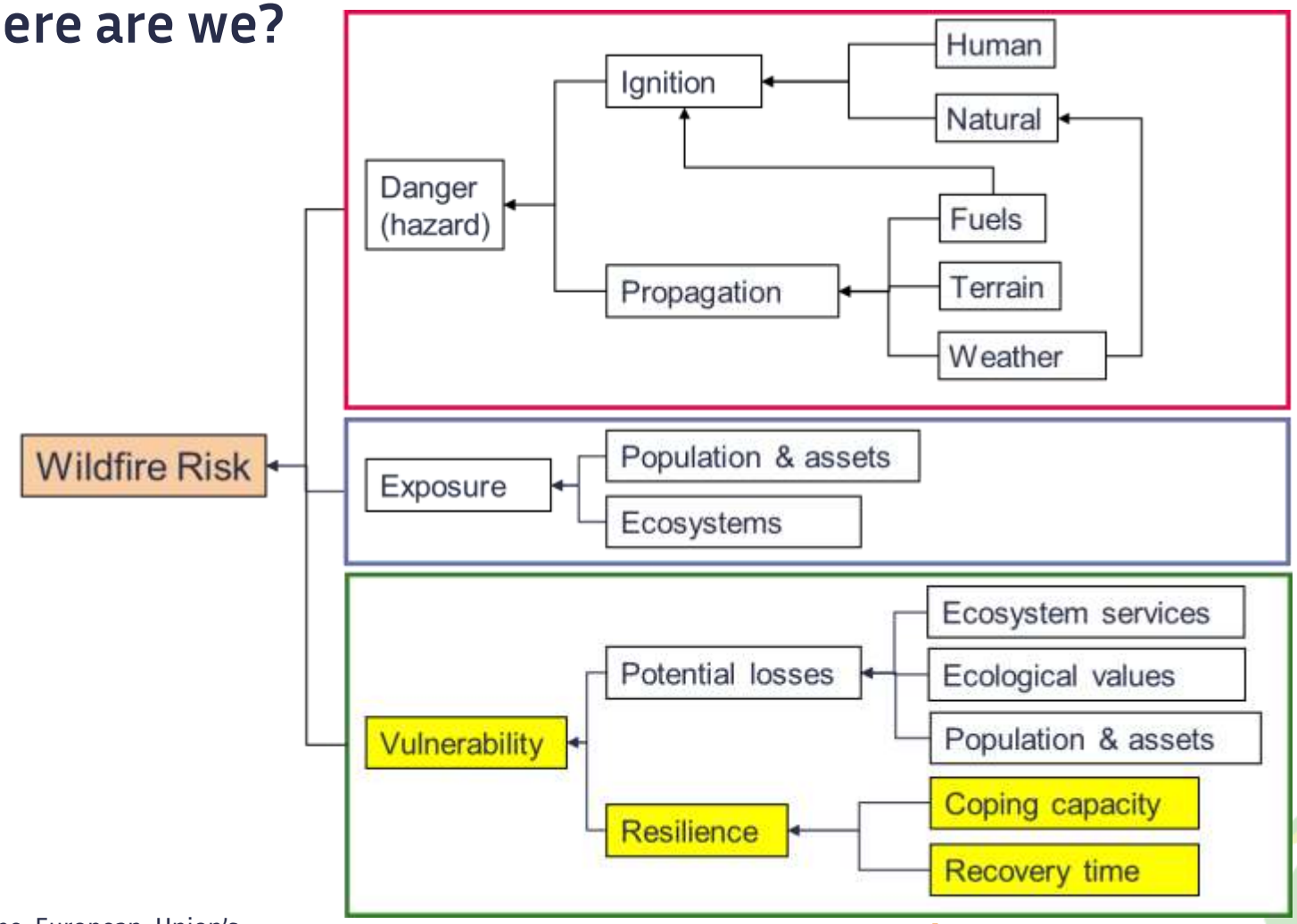
Florent MOUILLOT
IRD, France
florent.mouillot@ird.fr



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1. General concepts & background

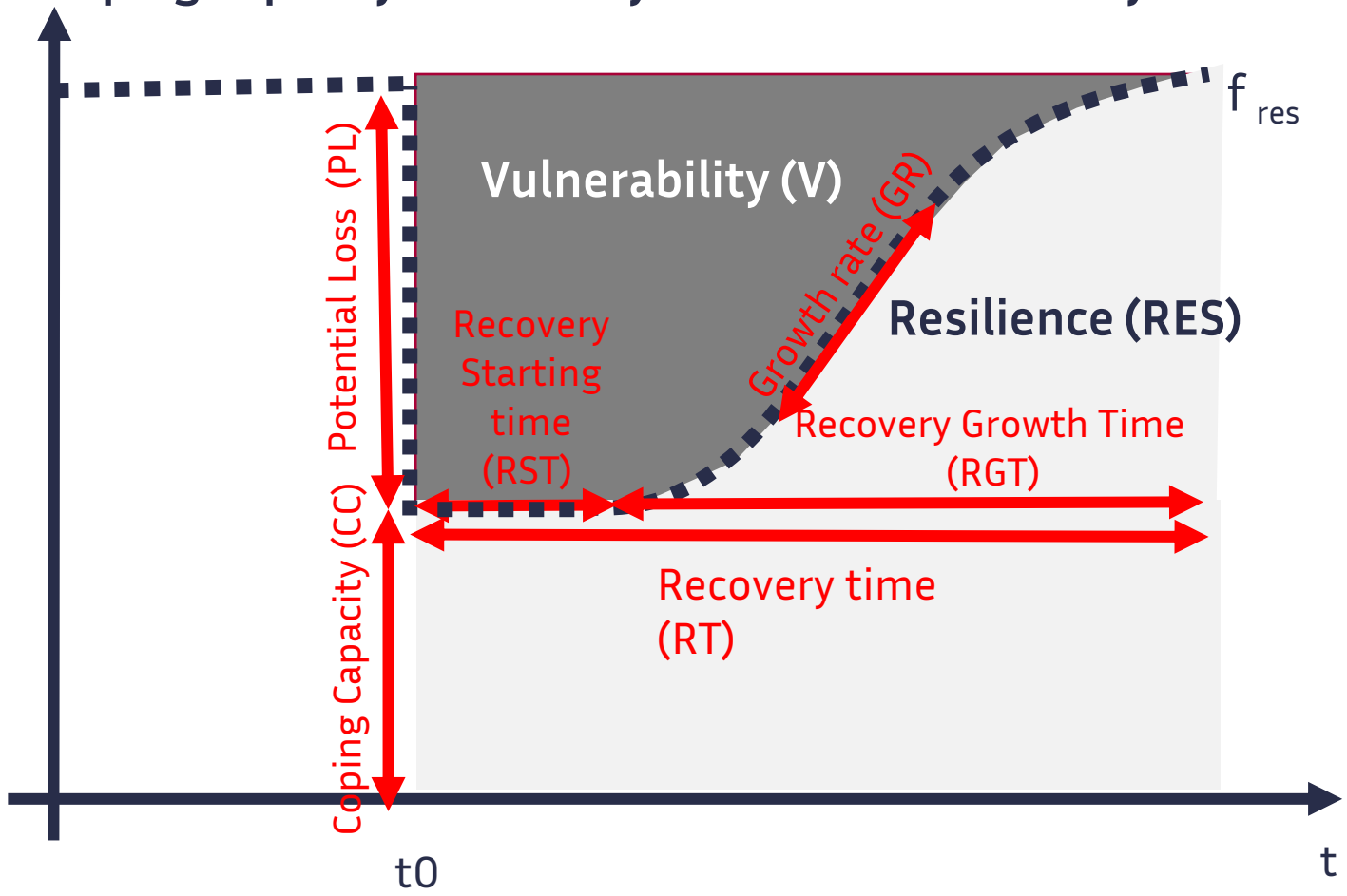
The Fireurisk Scheme: Where are we?



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1. General concepts & background

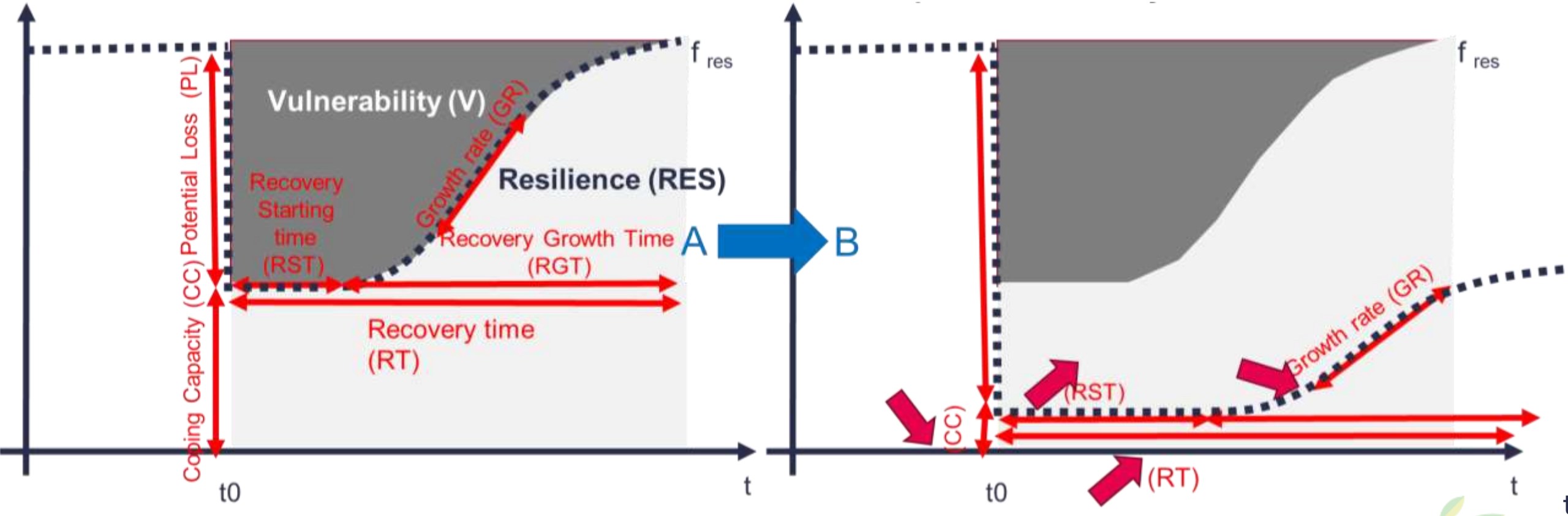
Concepts of Coping Capacity & Recovery Time for Vulnerability assessment



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1. General concepts & background

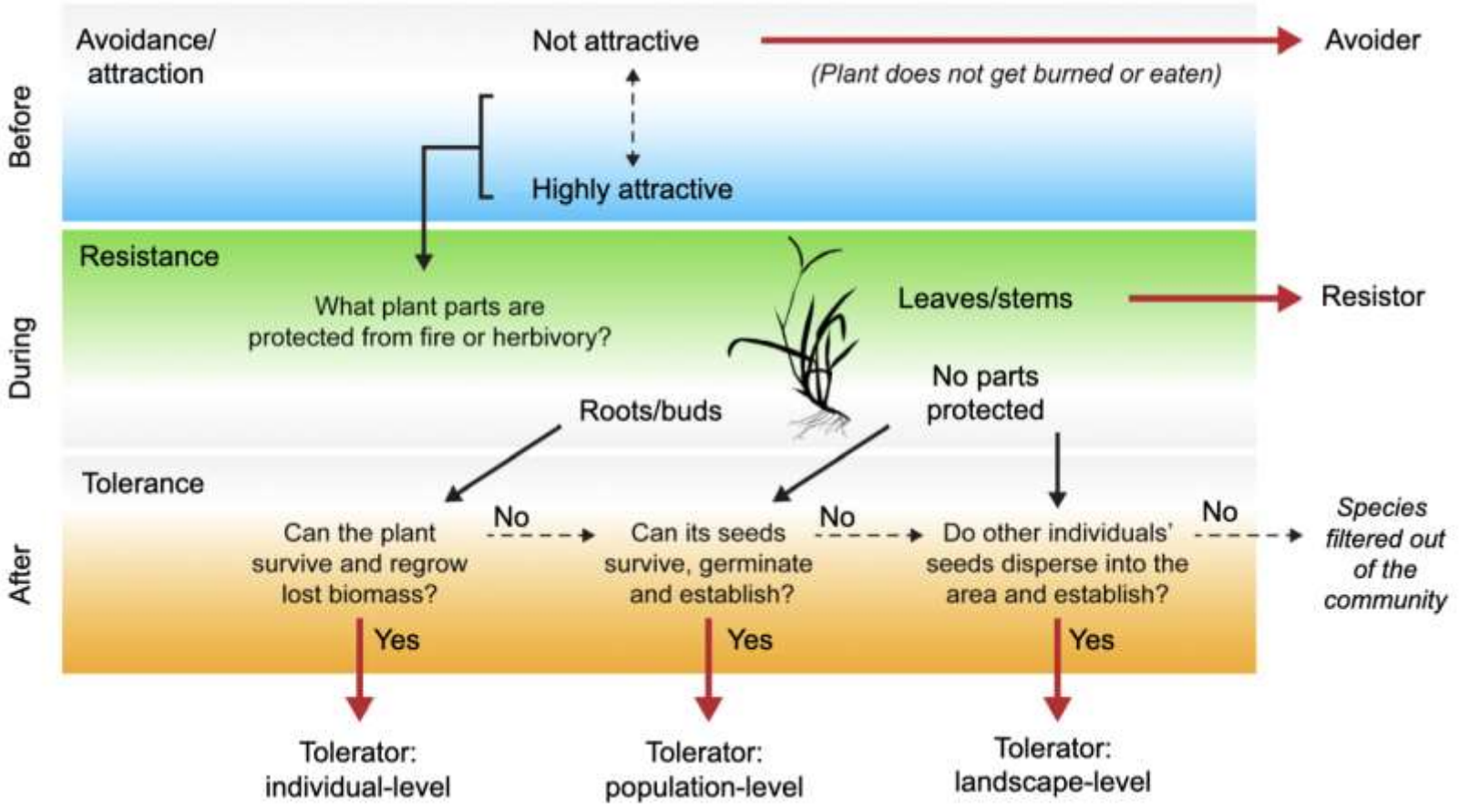
Potential variabilities in CC & RT and the subsequent Vulnerability



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1. General concepts & background

Ecological basis for post-fire resilience: Plant life-history strategies *(Archibald et al. 2019, New Phytol.)*



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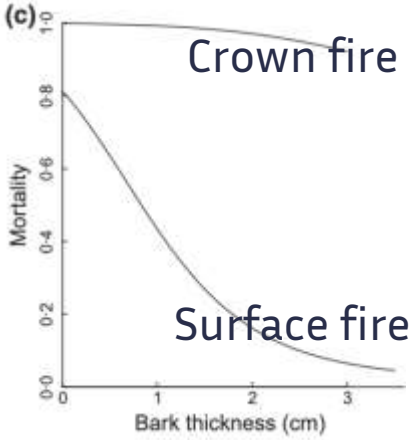
2. Plant Life-history strategies for fire

1. Coping Capacity

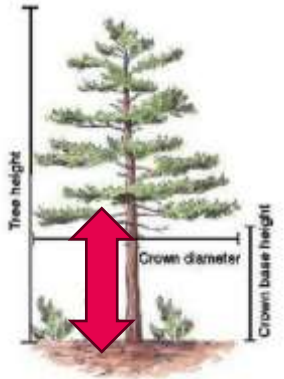
Bark Thickness



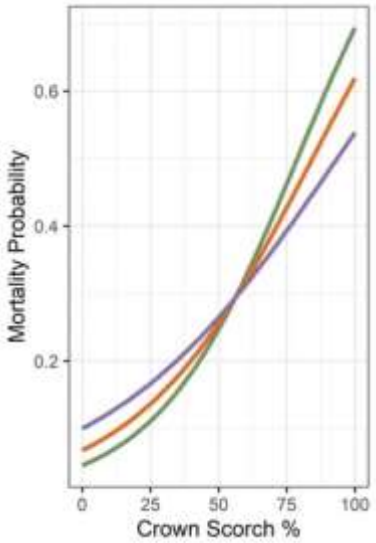
Pausas 2015, Functional Ecol.

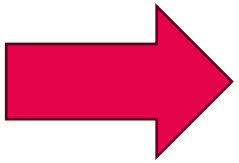


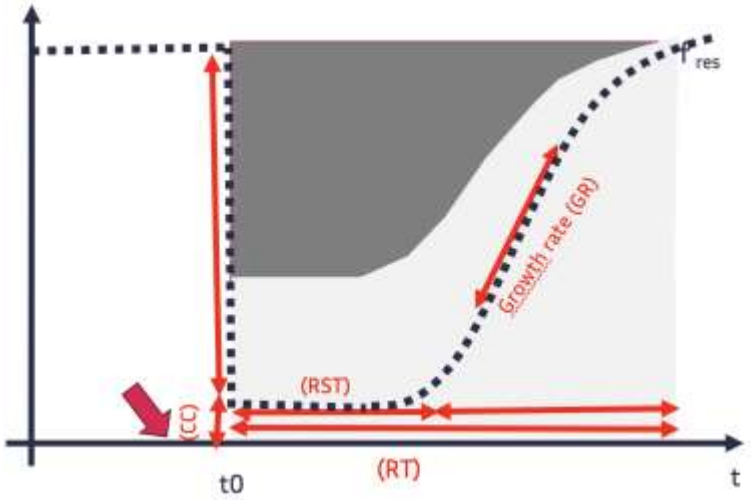
Basal Crown Height



Barker et al. 2022, Fire.







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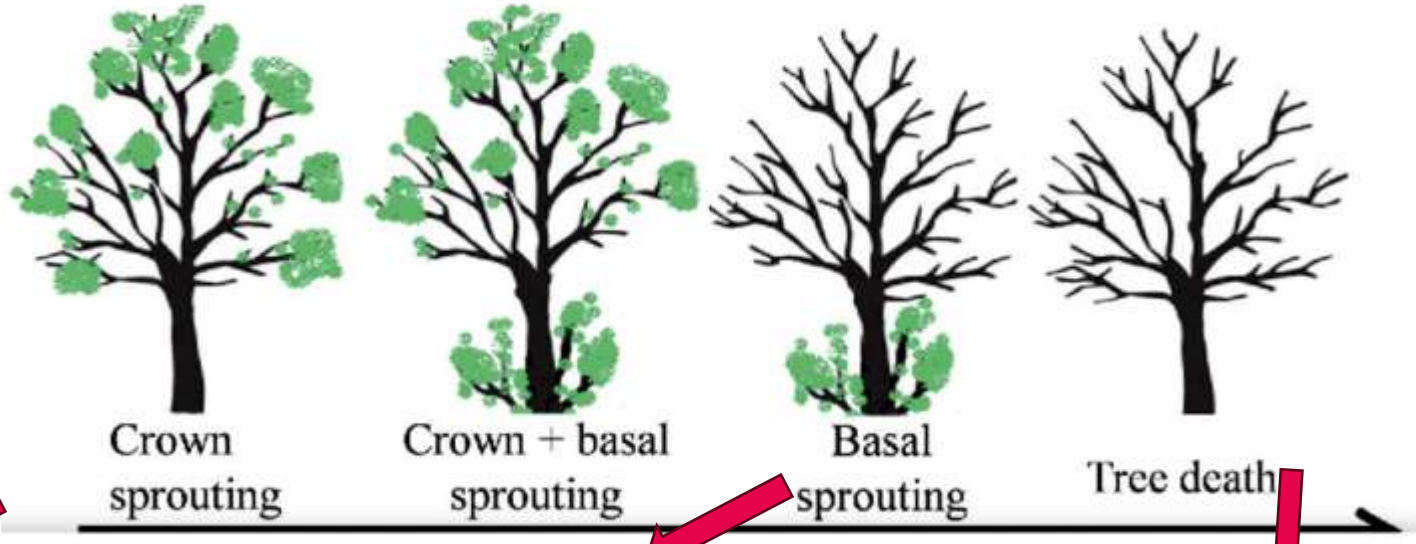
2. Plant Life-history strategies for fire

2. Regeneration

Resprouting:

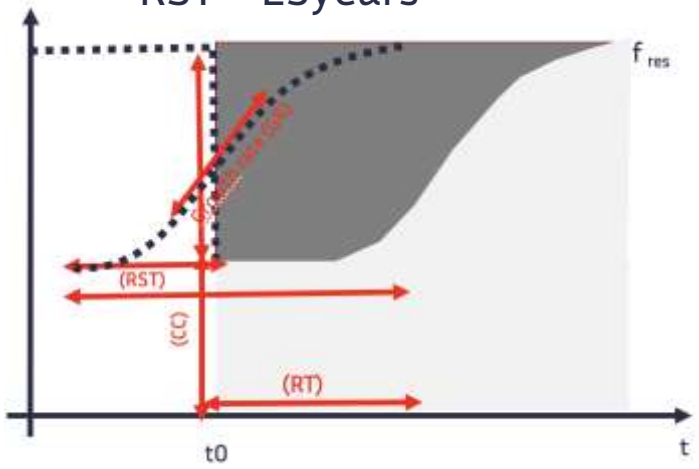
- Apical buds
- Basal buds



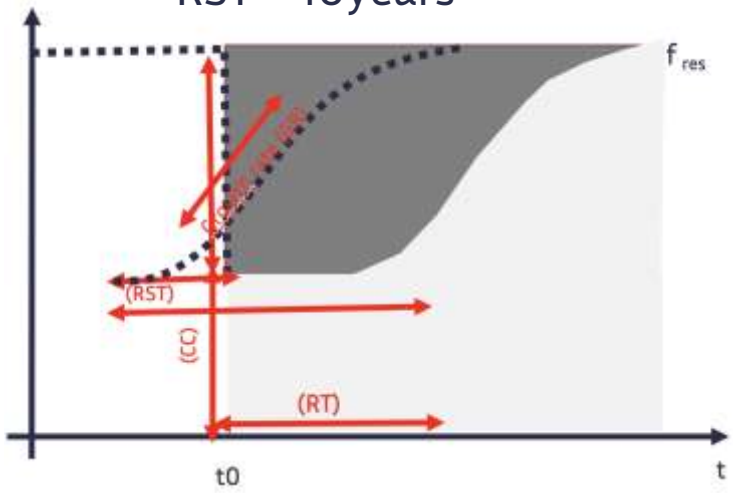


Moreira et al. 2008.

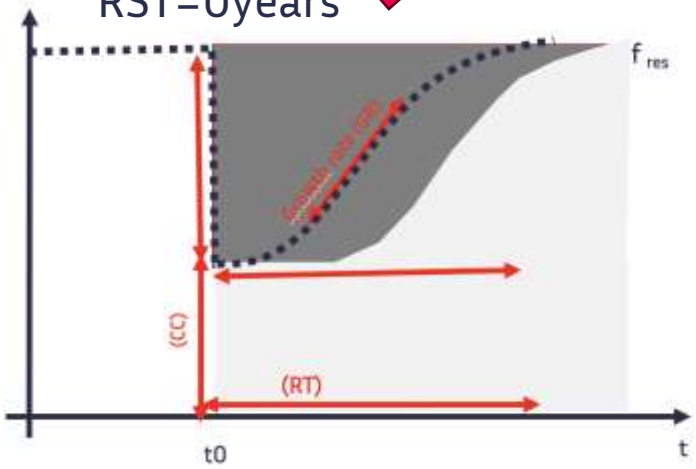
RST=-25years



RST=-10years



RST=0years



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2. Plant Life-history strategies for fire

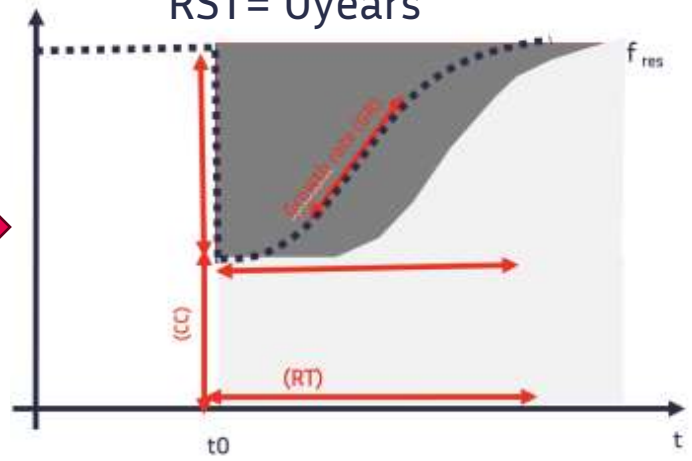
2. Regeneration

Germination:

Seed bank



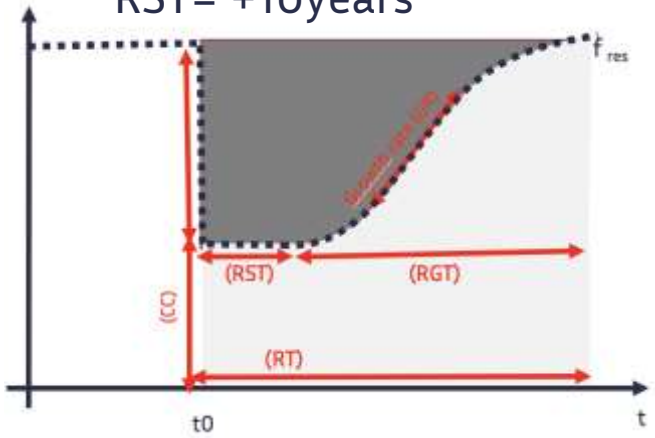
RST= 0years



Dispersal (long distance)



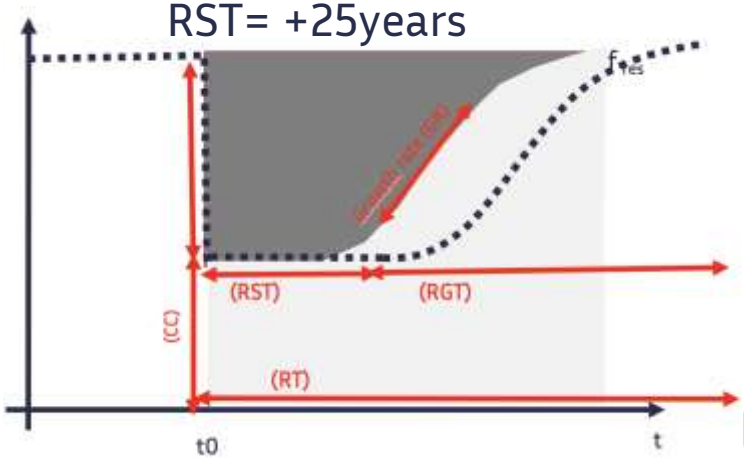
RST= +10years



Dispersal (short distance)



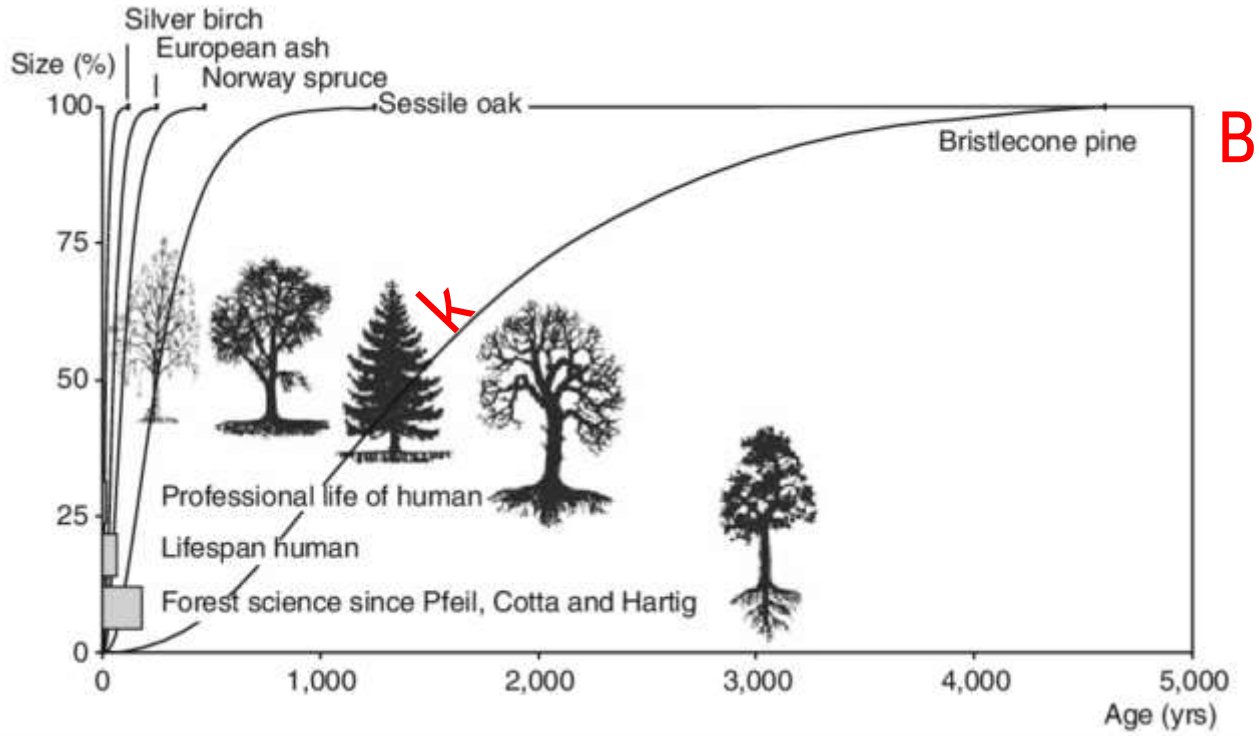
RST= +25years



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2. Plant Life-history strategies for fire

3. Growth



Bmax

Logistic growth equation:

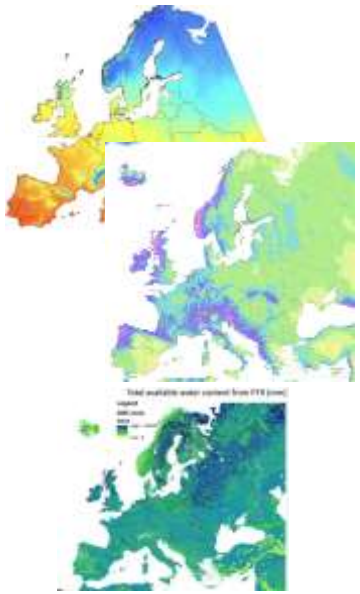
$dB/dt = k \cdot B \cdot (1 - B/Bmax)$

FORCLIM (Bugmann 1996, Ecology)

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3. Environmental Constraints

1. Climate
    - Mean Annual Temperature (MAT)
    - Mean Annual Precipiation (MAP)
2.. Topography
    - Slope, Aspect
    - Soil Available Water Capacity
    - Wind/Water Erosion
3. Human
    - Forest Management strategy





IMPACTS

Drought → Recovery Growth Time (RGT)

Drought → Recovery Starting Time (RST)

Recovery Starting Time (RST)

Recovery Starting Time (RST)

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4. Processing Chain for EU Resilience Map

COPING CAPACITY

Tree species distribution



Corine Land Cover



Resistance traits:

69 tree species

Bark Thichkness

Tree height

Basal Crown Height

Fire Line Intensity Map

Rescaling 0-1 → Mean (species)

Species presence maps



Species Resistance (0-1)



Mean

Coping Capacity Map (0-1000)



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4. Processing Chain for EU Resilience Map

RECOVERY TIME

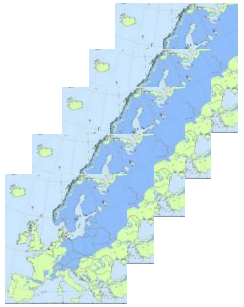
Tree species distribution



Corine Land Cover



Species presence maps



Regeneration traits (69 trees):

Sprouting

Dispersal

Recovery Starting Time (RST)

Environmental constraints

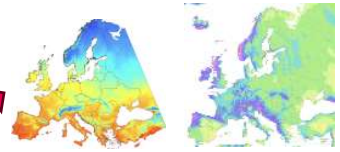


Growth traits (69 trees):

Tree height

Growth rate

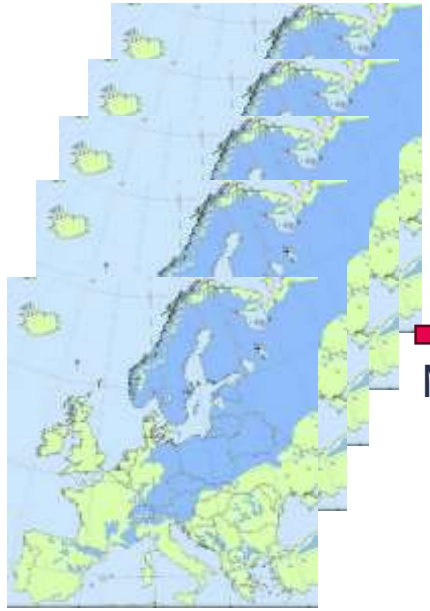
Recovery Growth time (RGT)





Recovery Time (RT)

Species RT (years)



Mean

Recovery Time (years)



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Ecosistem services (Natural Capital)

Simone Martino (The James Hutton Institute, UK)

Clara Ochoa (University of Alcalá, Spain)

Juan Ramon Molina (University of Cordoba, Spain)

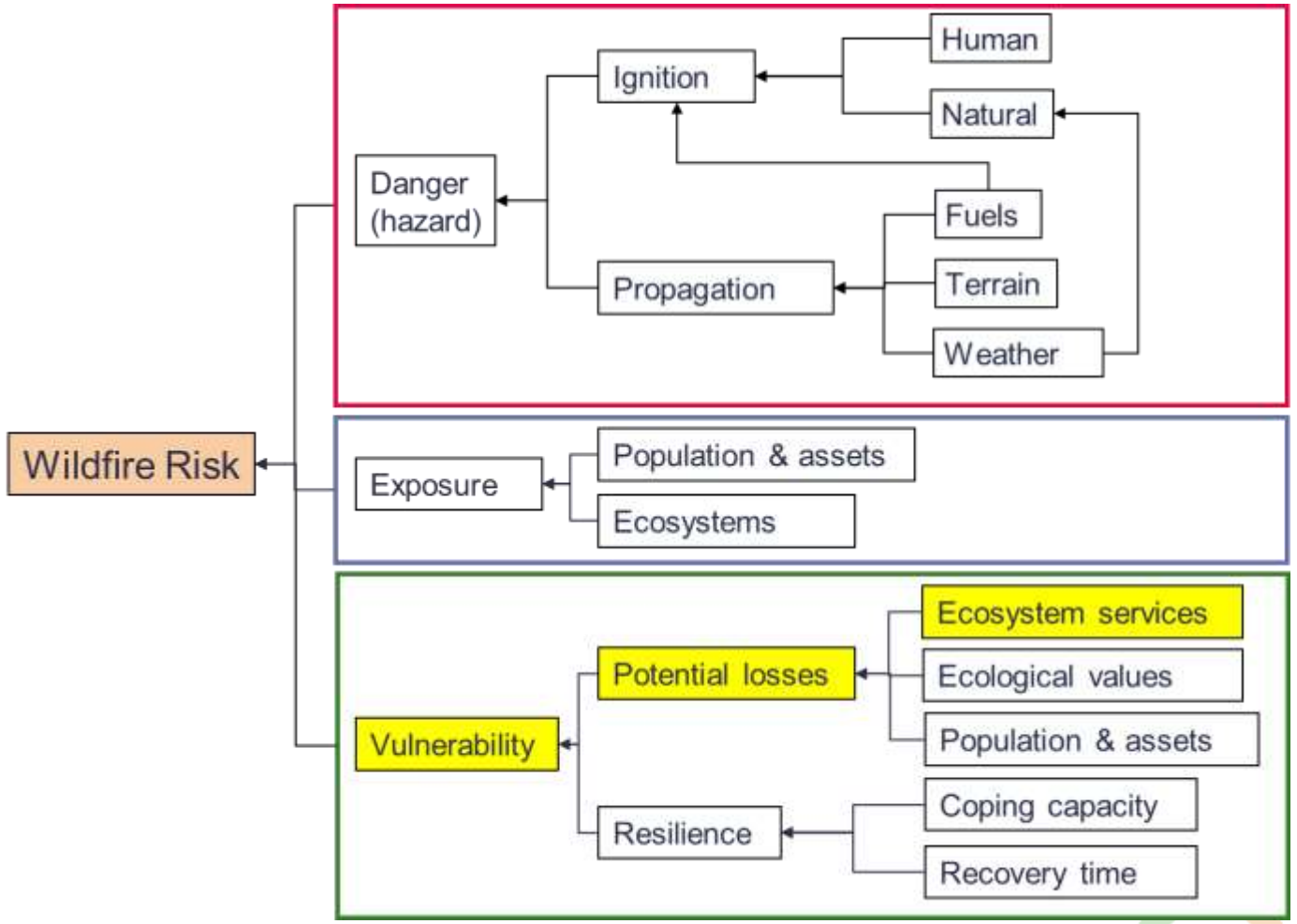


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Outline

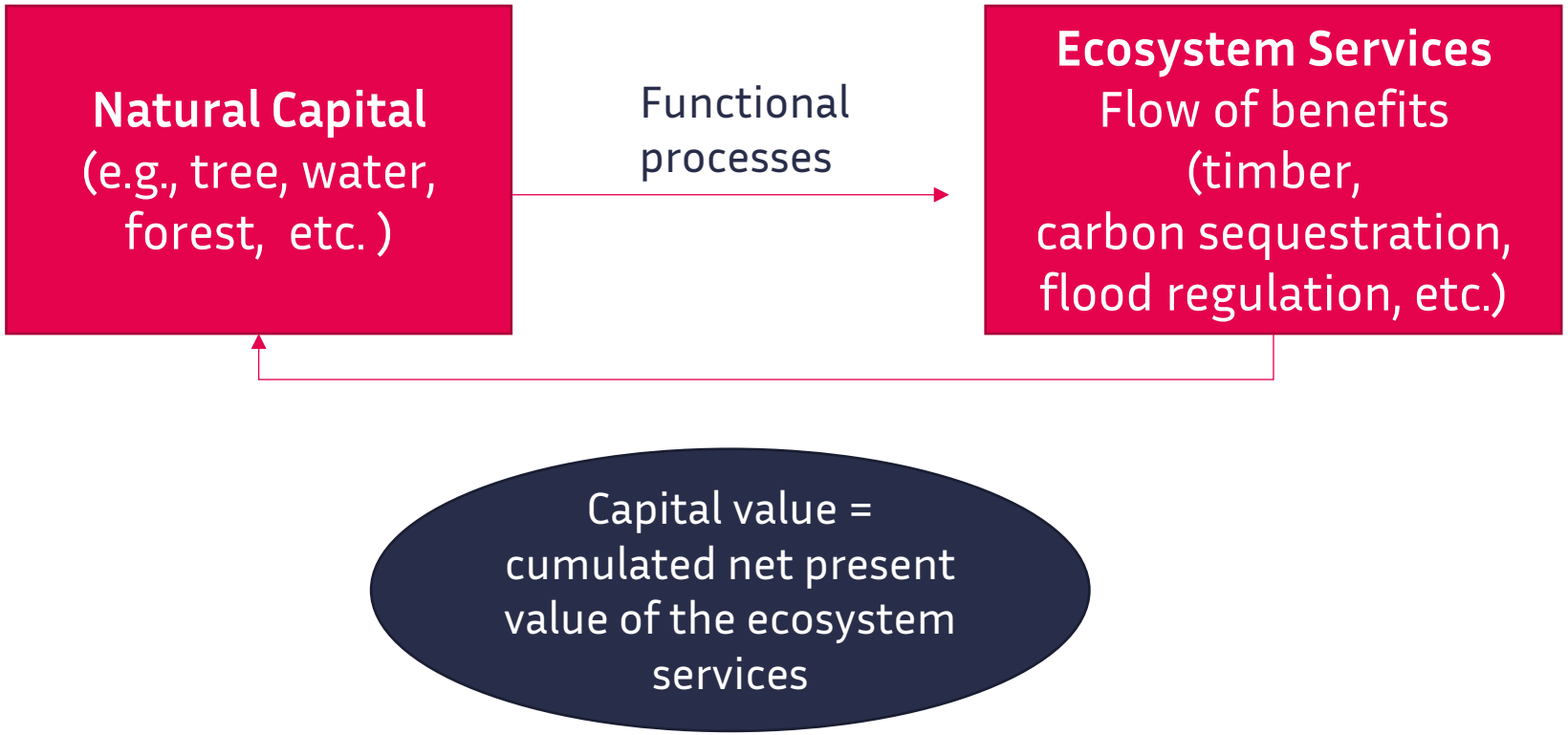
Ecosystem Services Valuation at ET scale

Valuation of Damage



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Natural Capital and Ecosystem Services



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Valuation of Ecosystem Services

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Economic values

Market approach		Market for carbon sequestration and pollination Cost based approach for the other ES	
Provisioning ES – physical Capitals (€/ha/year) – 2021		**Regulating and cultural ES (€/ha year) – 2021**	
Fruit trees	**Cattle**	**Crop pollination**	**Soil retention**
Olive groves	**Sheep**	**Water purification**	**Carbon sequestration**
Timber	**Vineyard**	**Flood control**	**Recreation**
Properties (houses)		**Crop provision**	**Wood provision**

European Territory – resolution 1 km2

Provided by JRC – INCA project Resolution 1km2 Output Data | INCA Platform (europa.eu)

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Valuation Process

timber, fruit trees, olive groves, vineyard, livestock

Information on physical resources - EUROSTAT at NUTS1 or NUTS2

Prices from literature

Gross value (€/ha year)

Cost of service provision or profit margin- from literature

Net annual benefit (€/ha year)

Capitalization rate 3%-10%

Capital value (€/ha)

Mapping at ET- 1 km2 (Corine Land Cover, 2018) Fuel map (Aragoneses, 2022)

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Valuation of properties

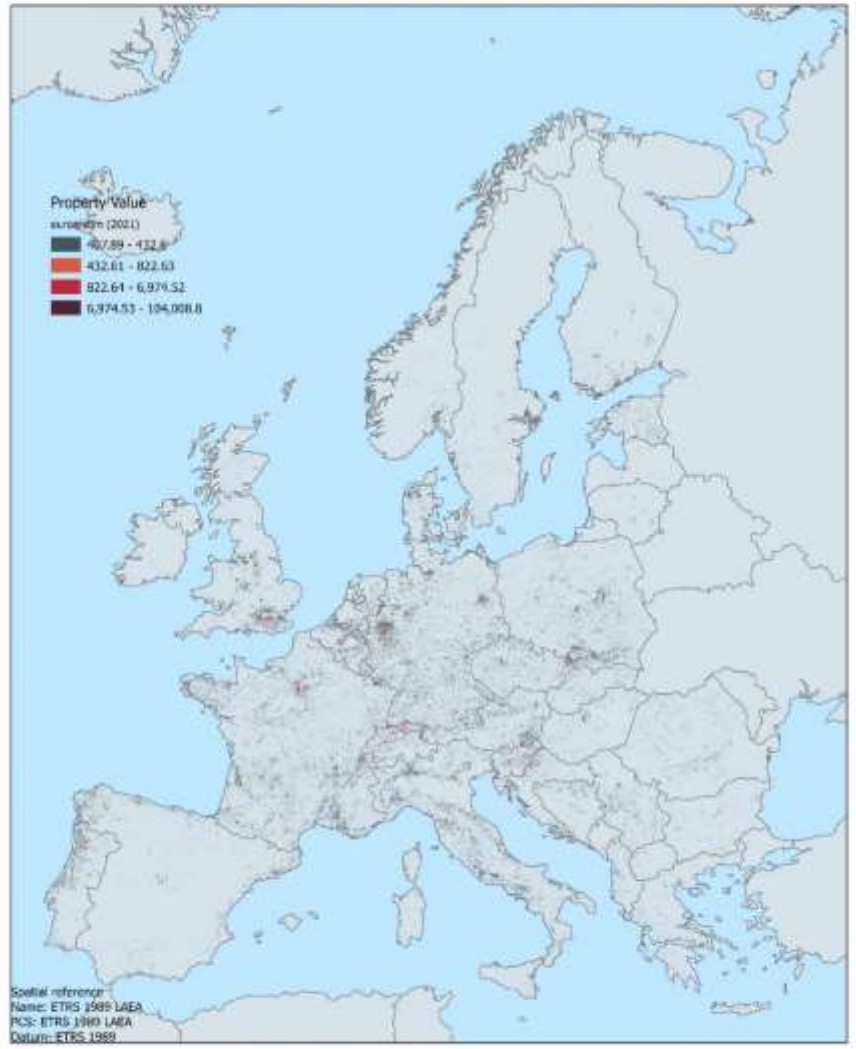
NUMBEO prices
$/m2

Map of local GDP
Kummu et al., 2018
GDP per capita and population density

Average national price corrected in €/m2 (2021)

Mapped property value in €/m2

Map of properties in WUI €/m2



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.

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Valuation of damages

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Valuation of economic damage

$$Damage = BENEFIT \; x \; LOSS \; x \; \frac{1-(1+r)^{-RT}}{r}$$

- ***BENEFIT*** is the net value of the ecosystem service (€/ha/year),
- ***LOSS*** is the expected loss in %, as a result of the fire impact
- **RT**=recovery time; **r**=discount rate

Average flame length (m)	Foreseen Fire Impacts (FIP)
< 2	I
2 – 3	II
3 – 6	III
6 – 9	IV
9 – 12	V
> 12	VI

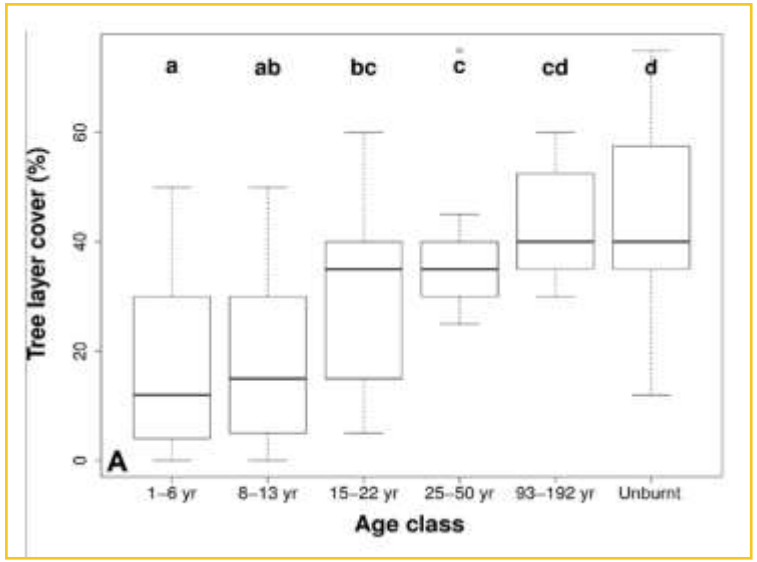
	FIP					
Ecosystem services	**I**	**II**	**III**	**IV**	**V**	**VI**
Timber[1]	**0.08**	**0.17**	**0.39**	**0.58**	**0.83**	**0.90**
Olive groves	0.08	0.17	0.39	0.58	0.83	0.90
Fruit groves	0.08	0.17	0.39	0.58	0.83	0.90
Vineyards	0.08	0.17	0.39	0.58	0.83	0.90
Cattle and sheep[2]	0.45	0.65	0.85	1.00	1.00	1.00
Pollination	0.08	0.17	0.39	0.58	0.83	0.90
Carbon sequestration[3]	0.16	0.40	0.60	0.85	0.98	1.00
Soil retention[4]	0.15	0.25	0.45	0.65	0.95	1.00

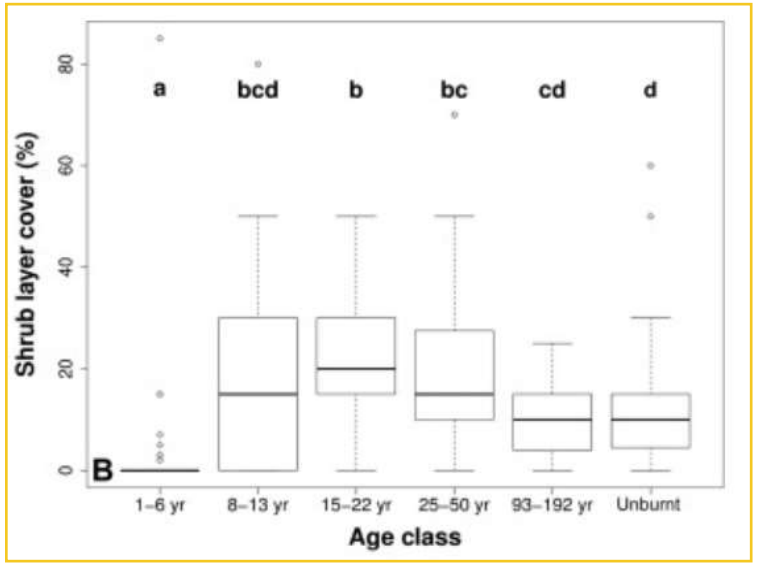
1 Based on damage on timber provided by y Silva, F.R., Molina, J.R., González-Cabán, A. and Machuca, M.Á.H., 2012. Economic vulnerability of timber resources to forest fires. Journal of Environmental management, 100, pp.16-21.
2 Martínez, J.R.M., Machuca, M.H., Díaz, R.Z., y Silva, F.R. and González-Cabán, A., 2011. Economic losses to Iberian swine production from forest fires. Forest Policy and Economics, 13(8), pp.614-621.
3 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.
4 Gomez, E. and Alvarez, K., 2009. Forest fires: detection, suppression and prevention. Nova Science Publishers.

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Recovery time

Fruit trees	**RT = 5 years**	16% of damage	No scientific evidence
Livestock	**RT = 1-2 years**	3% of damage	
Timber	**RT = 50 years**	82% of damage	Scientific evidence
Pollination	**RT = 6 years**	19% of damage	





Post-fire stands differed from the unburnt plots at least for 25–50 years. After about 140 years (median age of the last stage), however, the differences were almost undetectable

Martin Adámek, Veˇroslava Hadincová, Jan Wild. 2016. Long term effect of wildfires on temperate Pinus sylvestris forests: Vegetation dynamics and ecosystem resilience. Forest Ecology and Management 380 (2016) 285–295.

This project has been granted funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no. 101003890

Soil erosion damage calculation

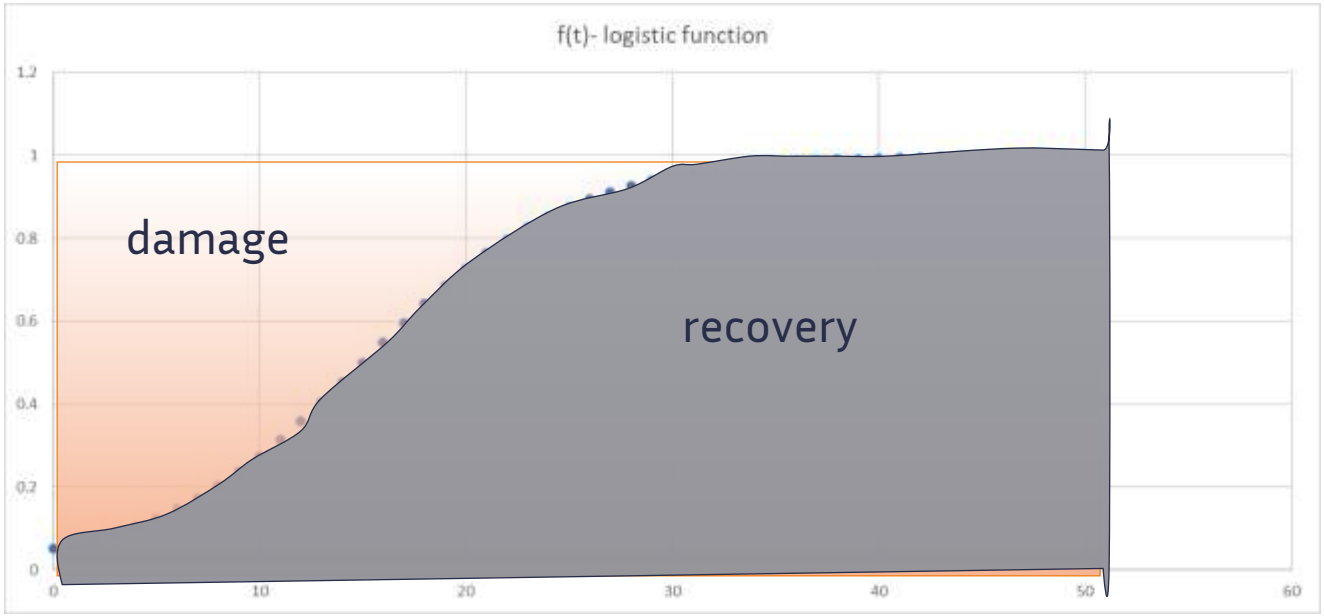
1. Reduced erosion (FIP I and II) – RT 6 years — 19% of damage
2. Medium erosion (FIP III and IV) – RT 13 years — 36% of damage
3. High erosion (FIP V and VI) – RT 20 years — 50% of damage

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 (2022): 153672.

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Assessing carbon sequestration from vegetation dynamic

Sigmoid growth curve for the biomass recovery



$$F(t) = \frac{L}{1 + e^{[-K*(t-xo)]}}$$

L	t- time (year)	K (growth rate) (1/year)	xo (time at 50% biomass recovery)- year
1	50	0.25	15

From the literature we found that after 20 years 70% of the vegetation is recovered

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Carbon sequestration from vegetation – sensitivity analysis

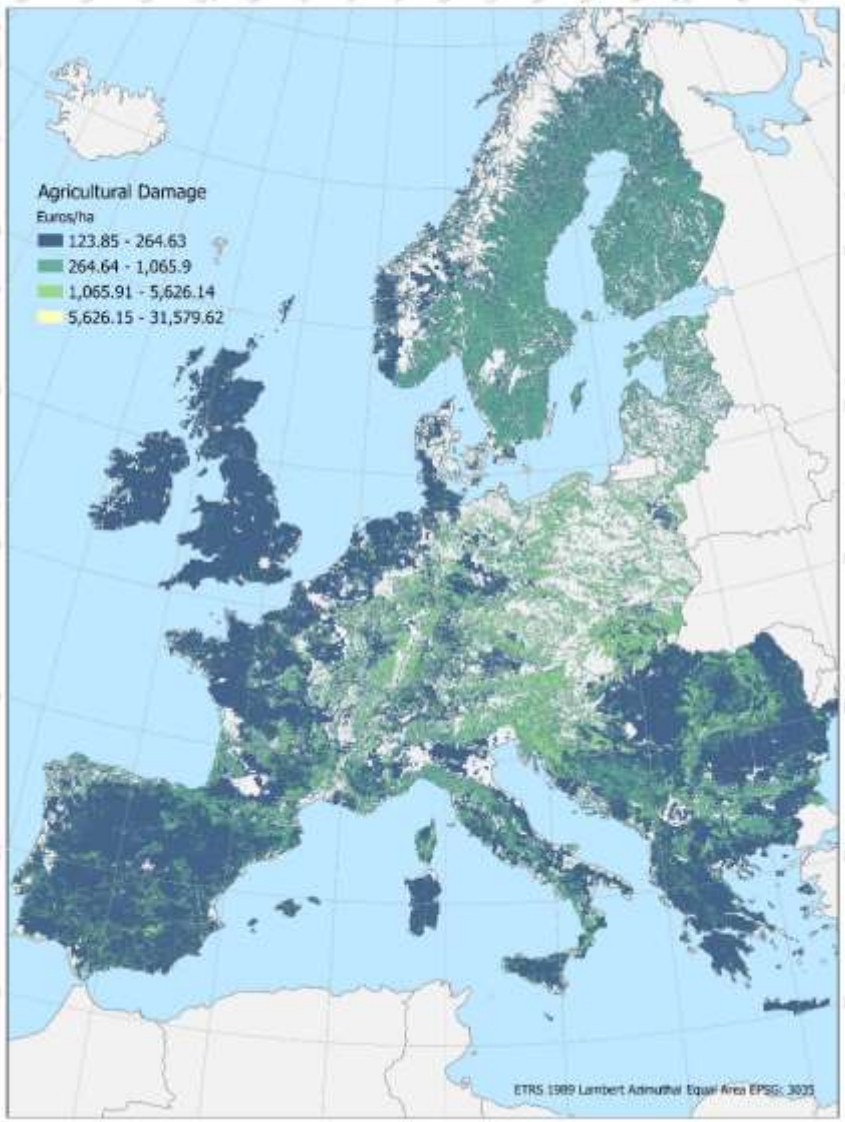
$$F(t) = \frac{L}{1 + e^{[-K*(t-xo)]}}$$

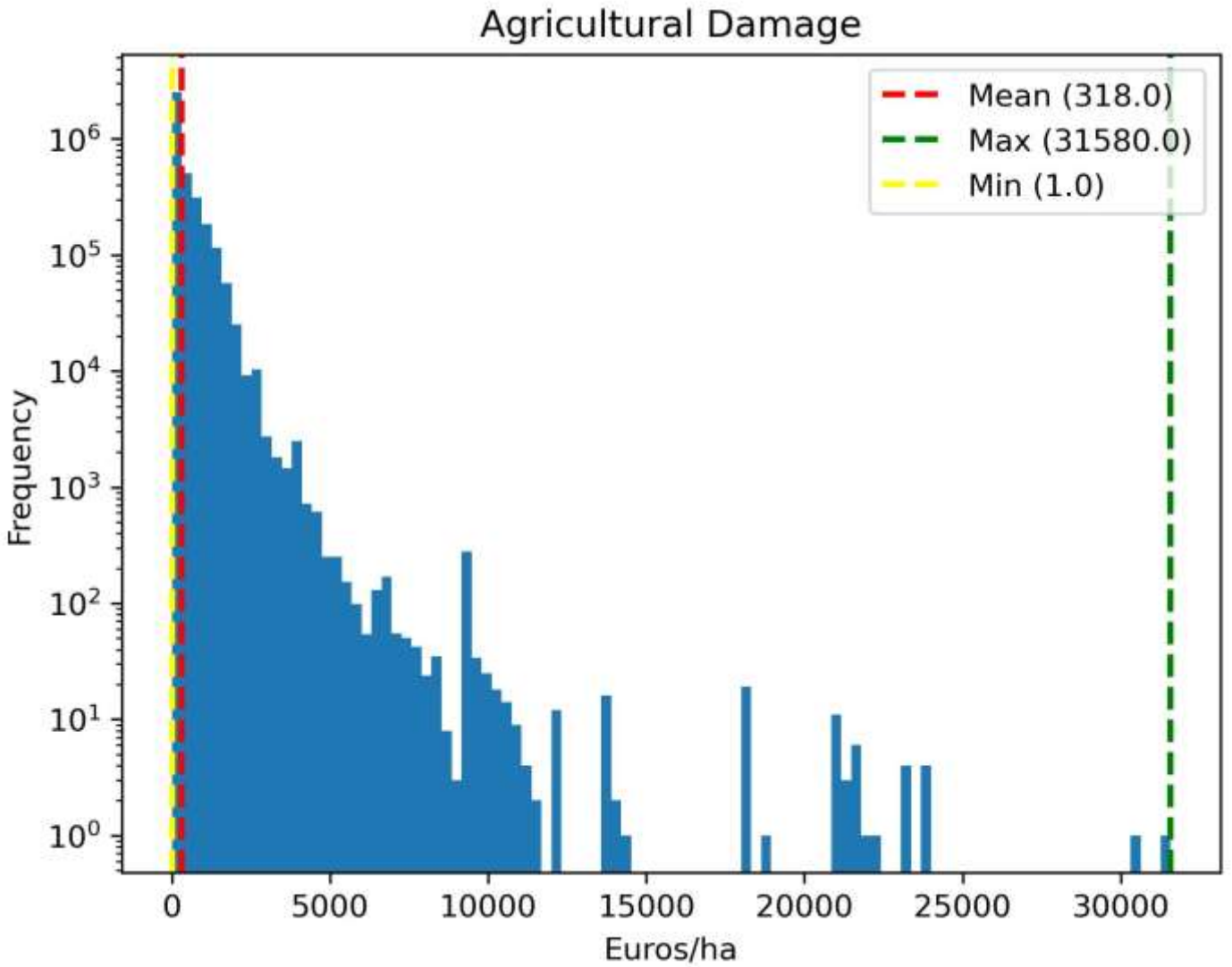
Discount factor - recovery time=50 years; r=0.035.

K	xo= 10	xo=25	xo=35
0.10	8.45	14.07	17.3
0.25	7.64	15.65	19.36
0.50	7.74	16.11	19.73
average	**7.94**	**15.27**	**18.80**
damage	**FIP I and II**	**FIP III and IV**	**FIP V and VI**

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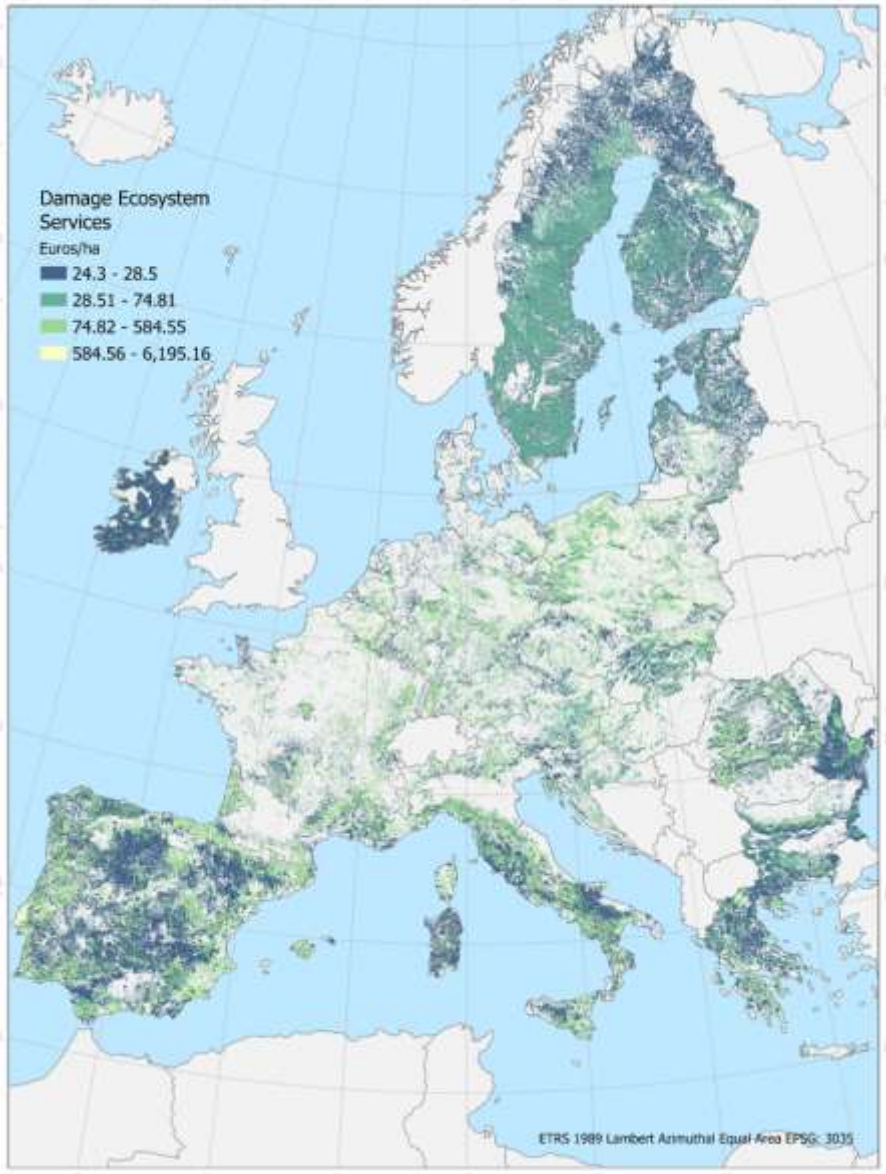
Total damage of provisioning services - agro-forestry values

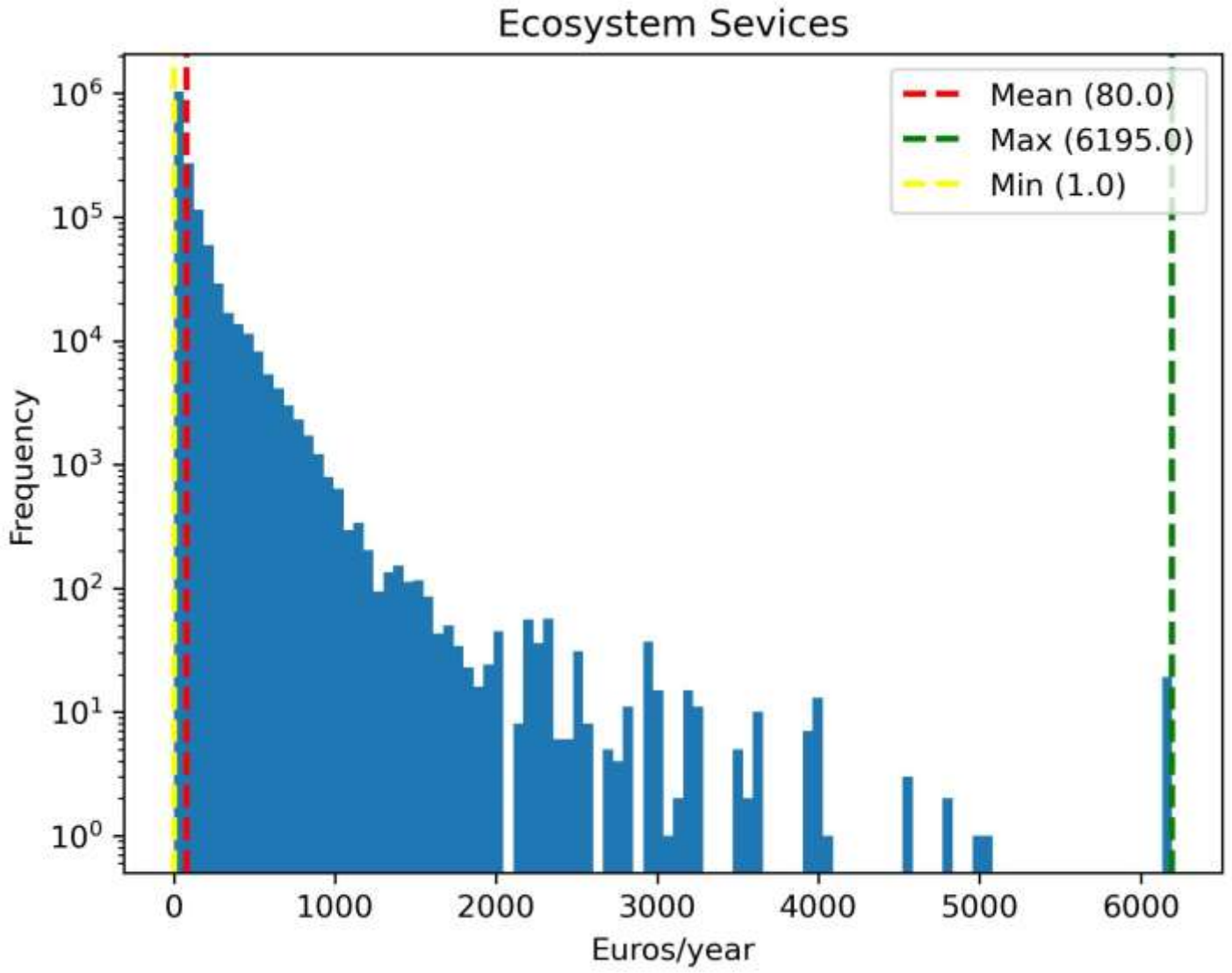




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Total damage of regulating ecosystem services





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Conclusions

- We have provided an approach to estimate damage from wildfires
  - Agroforestry assets, regulating ecosystem services, properties
  - More ES can be introduced (e.g., water purification) as well as other manufactured assets such as linear infrastructures
- LIMITS
  - Damage to certain agricultural values and ecosystem services are not well studied
  - Assumptions are made for the choice of the recovery time and for the coefficient measuring the loss of the asset
  - We assume that coefficients of loss estimated in Spain can be transferred to central and northern Europe
- We expect the most relevant damage to occur in southern Europe.
- The maps of damage can be used to define financial resources, investments to prevent and to compensate damage in those areas characterised by the highest impact.

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Thanks for your attention

If you need further information, do not hesitate to contact our team :

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Juan Ramon Molina jrmolina@uco.es

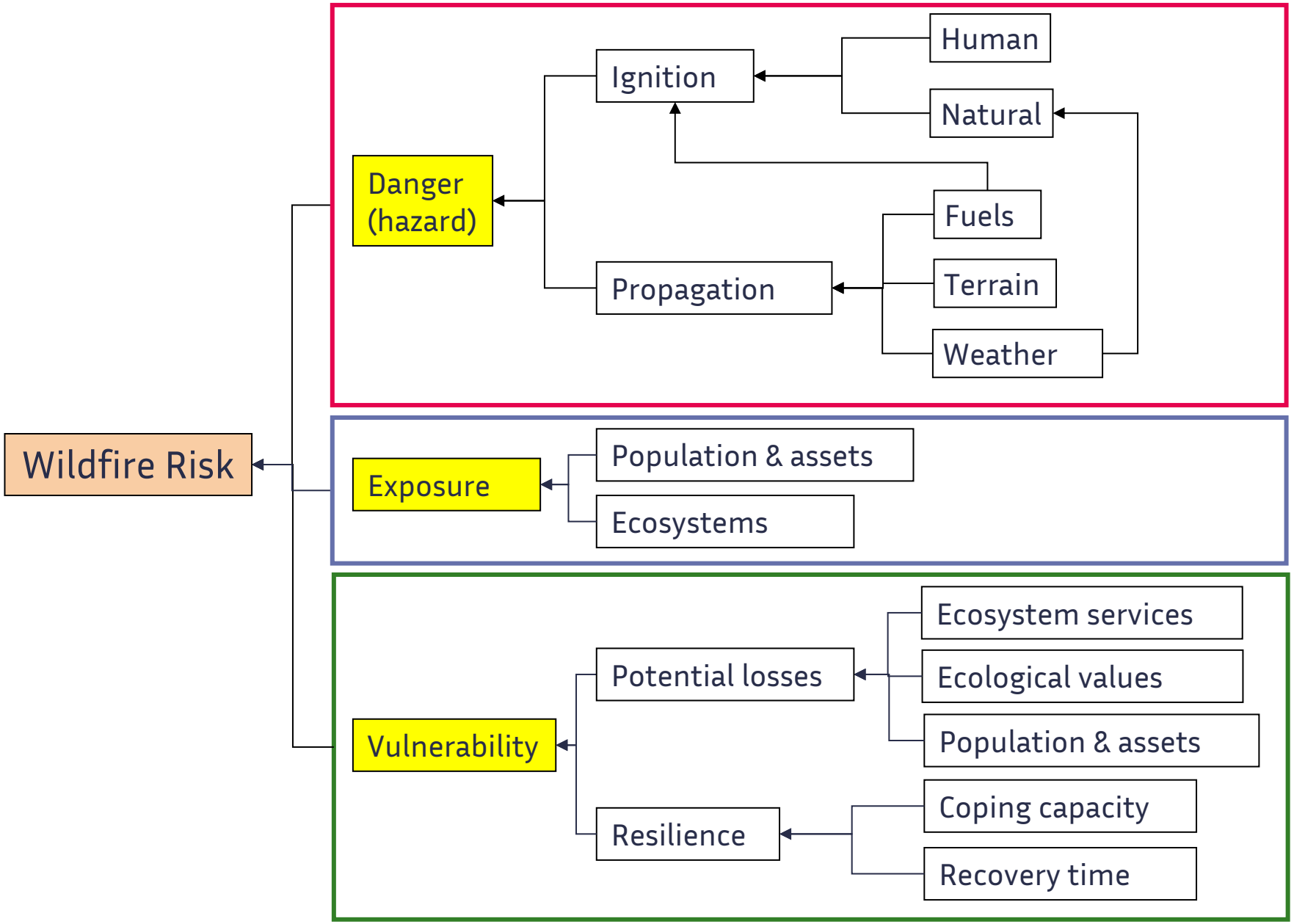
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Integrated fire risk index

Emilio Chuvieco, Universidad de Alcalá (Spain)



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Wildfire risk assessment integration

- Target area: ET
  - Lambert Azimutal Equal Area EPSG 3035 using the ETRS 1989 datum, with the following coordinates of the UL and LR limits:
    - UL 2635914.000, 5414917.000
    - LR 5955914.000, 1384917.000
  - Spatial resolution: 1000 x 1000 m.



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Wildfire risk assessment integration

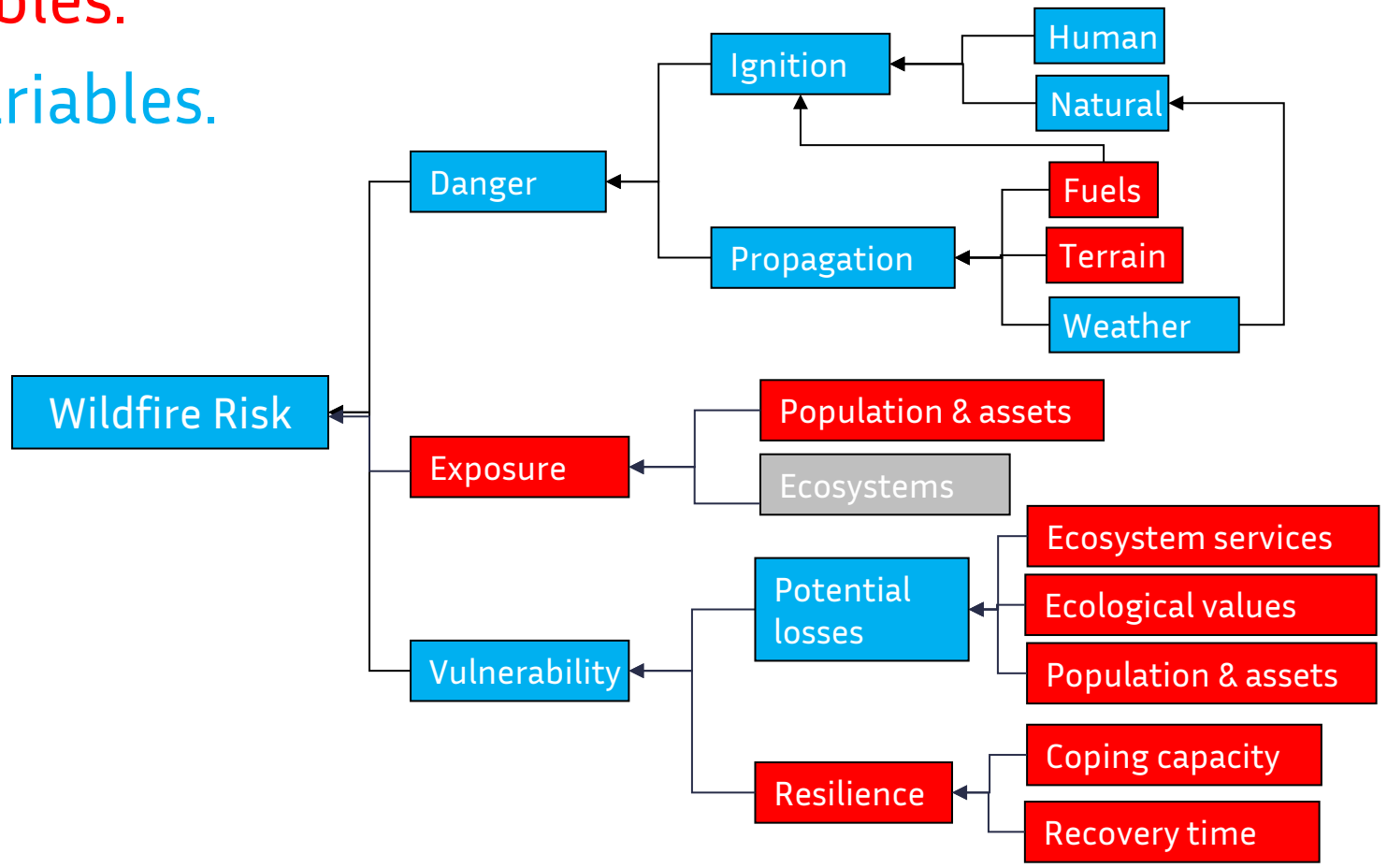
- Target period:
  - July-August, 2023.
  - June-September, 2024.
- Weather scenarios:
  - Historical occurrence: High-risk days: dates any fire > 2000 hectares in the ET area.
    - Extreme fire conditions (95%)
    - Average-High (50%)
  - Daily calculation:
    - Predictions from 6 to 12 h.



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Wildfire risk assessment integration

- Static variables.
- Dynamic variables.



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Input data

Variable	Units	Sources	Responsible
TP, Temperature	° C	DWD-ICON7 data	Meteogrid (downscaling)
Pp, Precipitation	mm	DWD-ICON7 data	Meteogrid (downscaling)
WS, Wind speed	m/s	DWD-ICON7 data	Meteogrid (downscaling)
RH, Relative Humidity	%	DWD-ICON7 data	Meteogrid (downscaling)
FT, Fuel types	Fuel classes	FirEUrisk fuel map	Elena
PNI, Probability of natural ignition	0/1000	Weather data and lightning	Evgeny
PHI, Probability of human ignition	0/1000	Human and biophysical factors	Simone – Clara
LFMC, Live fuel moisture content	% DW	Satellite data	Valerio
E, Exposure	0, 0.8, 1	WUI, land cover	Avi – Clara, static
H, Value of Houses and Infrastructures	€/ha	Statistics	Clara / Simone, static
CL, Climatic regions	1-2 / No-Yes Mediterranean	Proxy of building materials	Clara
ES, Ecosystem service values.	€/ha/year	Statistics	Clara / Simone
EVa, Ecological values	0/1000	Cartographic & vegetation databases	Fatima
CC, Coping capacity	0/1000	Cartographic & vegetation databases	Florent
RT, Regeneration time	years	Several species	Florent

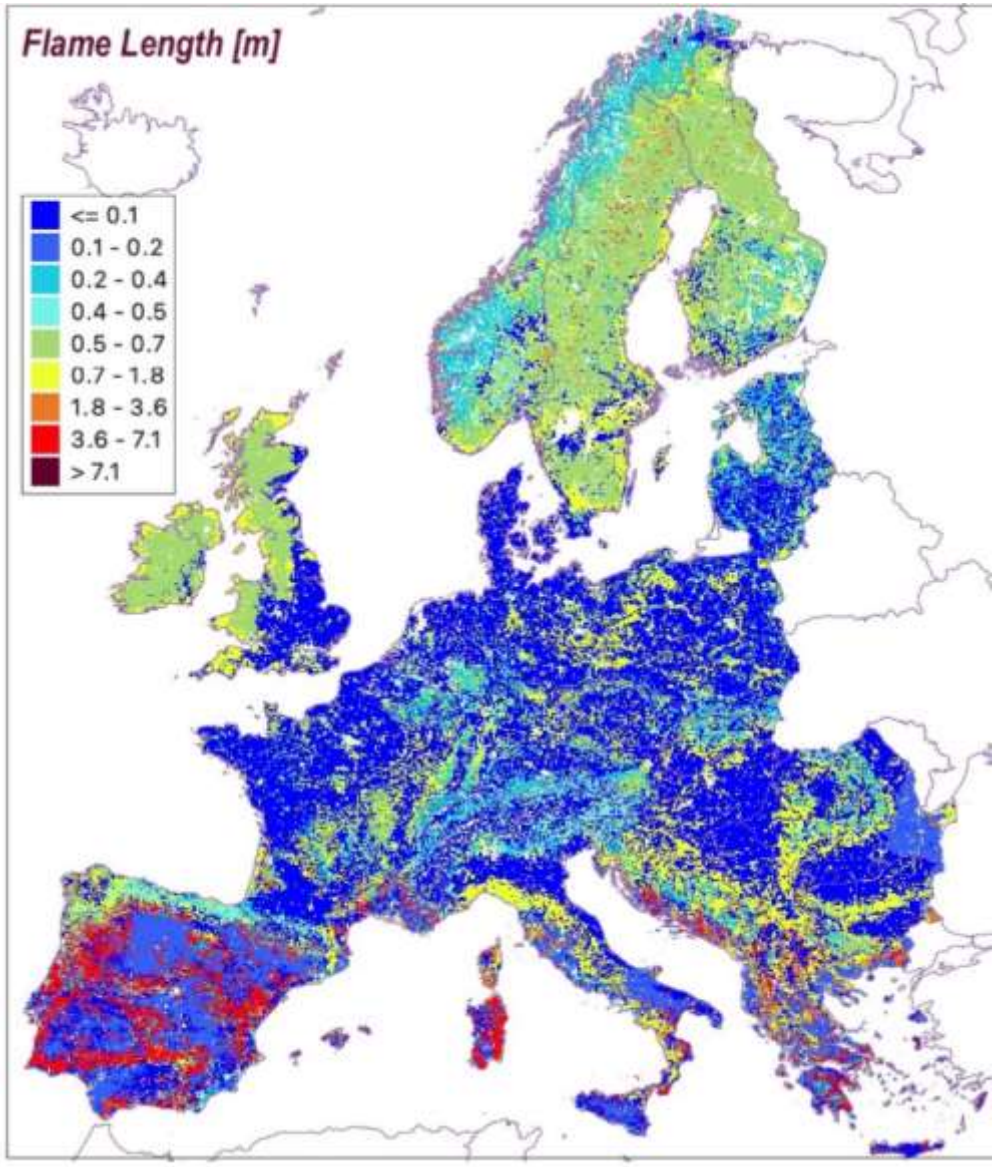
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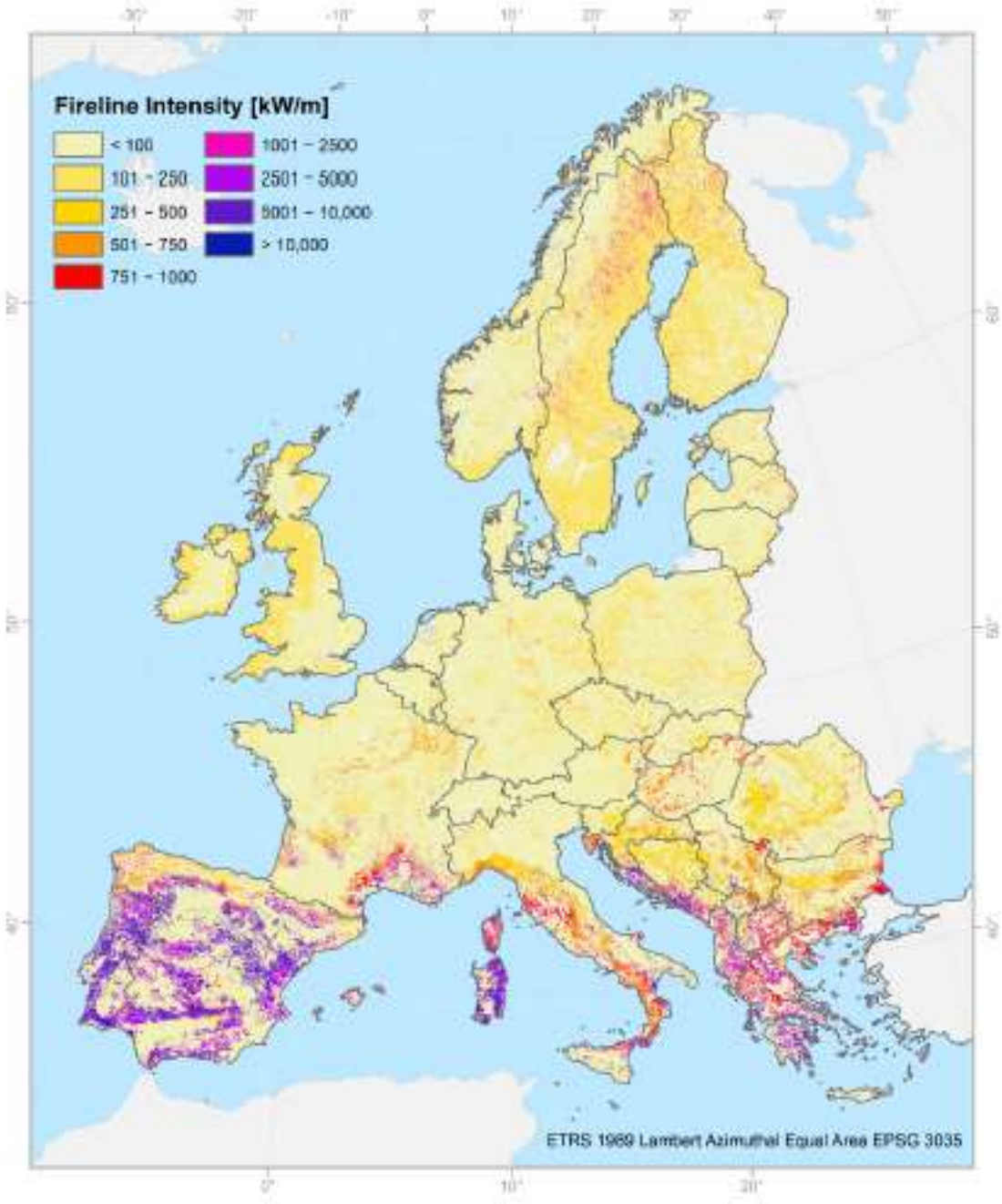
Outputs

Variable	Units	Inputs	Source
FI , Fireline intensity	kW/m	Weather data, LFMC	Darko (code) Meteogrid (acquisition and processing)
FL, Flame Length	m	Weather data, LFMC	Darko (code) Meteogrid (acquisition and processing)
PI, Probability of Ignition	0/1000	PNI, NHI	Emilio's code
PP, probability of propagation	0/1000	FI	Emilio's code
D, Danger	0/1000	PHI, PNI	Emilio's code
RHV, Reduction of House values	€/ha	Estimated from FL and H	Tables from Juan Ramon
RES, Reduction of Ecosystem services	€/ha/year	Estimated from FL and ES	Tables from Juan Ramón
HL, human vulnerability	0/1000	RHV, RES	Emilio's code
REV, Reduction of Ecological values	0/1000	EVa, CC	Emilio's code
EL, Ecological vulnerability	0/1000	REV, RT	Emilio's code
V, Vulnerability	0/1000	EV, HV	Emilio's code
IRI, Integrated Risk Index	0/1000	D, V, E	Emilio's code

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Propagation outputs





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Danger (D: 0/1000):

- Ignition probability (PI):
  - Integration of natural (PNI) and human (PHI) ignition, following a Kolmogorov probabilistic rule:
  - PI = (PHI/1000 + PNI/1000 – PHI/1000*PNI/1000) * 1000
- Propagation potential (PP)
  - Based on FLI.
  - 0 – 500: 0 - 346 kW/m (corresponding to 100 BTU/s/ft).
  - 501- 750: 346 - 1731 kW/m (=500 BTU/s(ft).
  - 751-1000: 1731 - 17.000 kW/m
- Danger:
  - D = 0.33*PI + 0.66* PP.

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Vulnerability (0/1000)

- 1. Human vulnerability (€/km2): potential damages to:
  - Houses-infrastructures:
    - Estimate pre-fire housing values (H).
    - RHV = f (Flame Length, H).
  - Ecosystem services:
    - Estimate ES values (ES).
    - RES = f(Flame Length, ES).
  - Integration through recovery time.
  - Integrated human values:
    - HV = LOG (RHV)+ RES
    - Normalization:
      - HL = ((HV – HVmin)/ (HVmax – HVmin))*1000

Average flame length (m)	Foreseen Fire Impacts (FIP)
< 2	I
2 – 3	II
3 – 6	III
6 – 9	IV
9 – 12	V
> 12	VI

risk

Resource	I	II	III	IV	V	VI
No Mediterranean Regions (Wood made)	0.05	0.20	0.52	0.77	0.90	0.95
Mediterranean Regions (Concrete – bricks made)	0.01	0.05	0.12	0.20	0.40	0.60

	FIP					
EST	I	II	III	IV	V	VI
Timber	0.08	0.17	0.39	0.58	0.83	0.90
Olive_groves	0.08	0.17	0.39	0.58	0.83	0.90
Fruit_groves	0.08	0.17	0.39	0.58	0.83	0.90
Vineyard	0.08	0.17	0.39	0.58	0.83	0.90
Crop_pollination	0.08	0.17	0.39	0.58	0.83	0.90
Cattle	0.45	0.65	0.85	1.00	1.00	1.00
Sheep	0.45	0.65	0.85	1.00	1.00	1.00
Carbon_sequestration	0.16	0.40	0.60	0.85	0.98	1.00
Soil_retention	0.15	0.25	0.45	0.65	0.95	1.00

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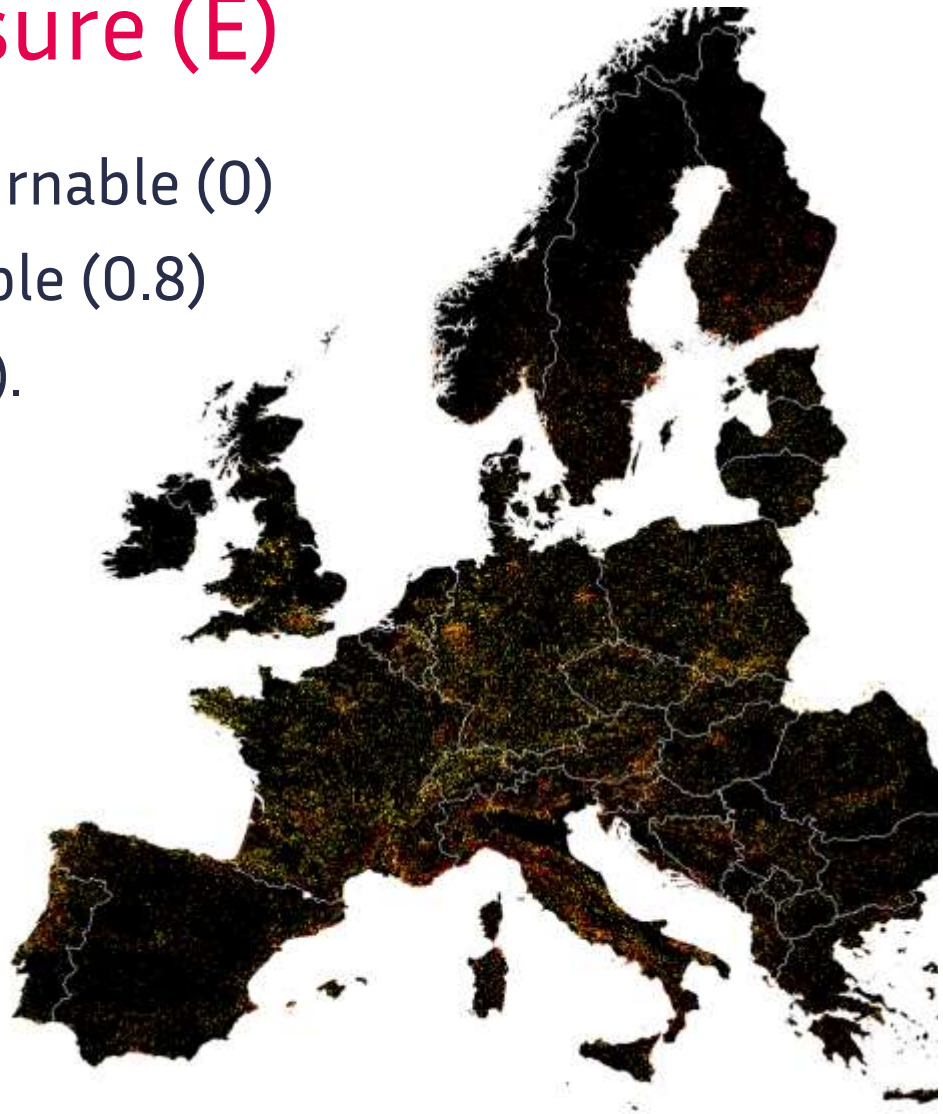
Vulnerability (0/1000)

- 2. Ecological vulnerability
  - Estimation of ecological values (EVa), coping capacity (CC), and Recovery time (RT).
  - Reduction of ecological values (REV) = (EVa x (1-CC)).
  - Integration of ecological losses (TEV) throughout the time:
    - $TEV = REV \times \frac{1-(1+r)^{-\log RT}}{r}$, r = discount rate.
  - Normalization of Ecological Vulnerability:
    - EL = ((TEV – TEVmin)/ (TEVmax – TEVmin))*1000
- 3. Integrated vulnerability:
  - V = 0.6*HL+0.4*EL

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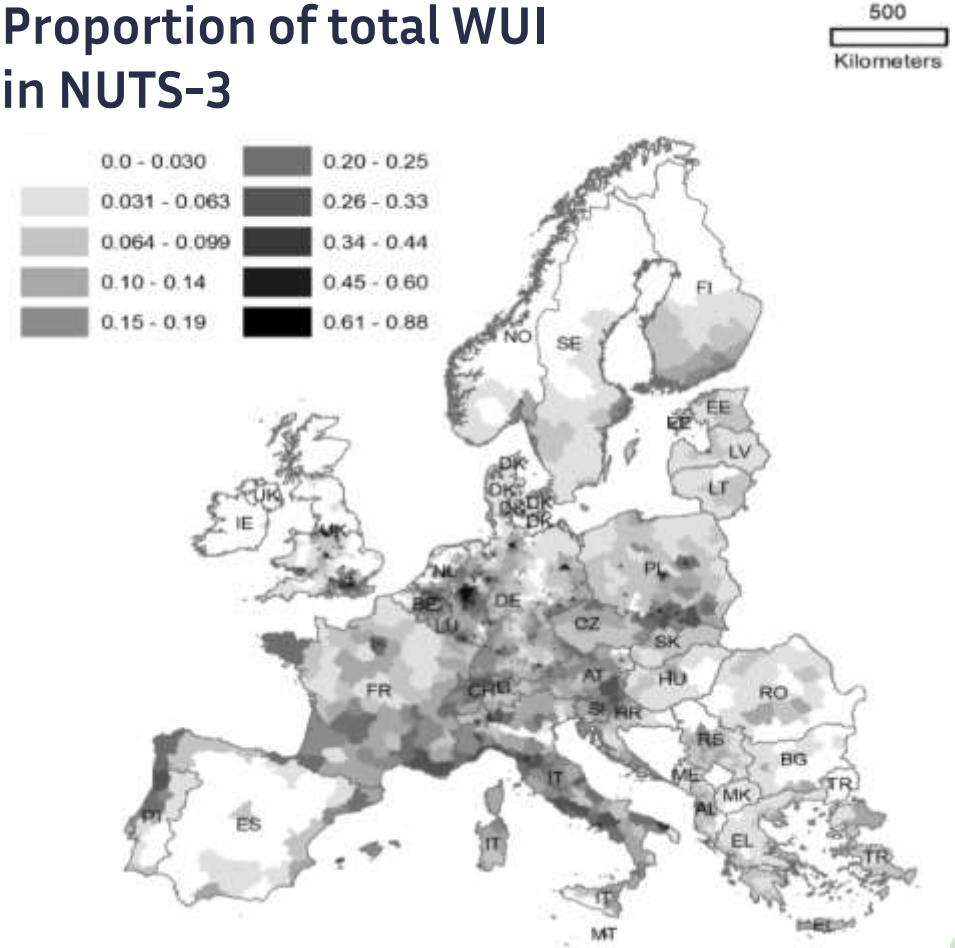
Exposure (E)

- Not burnable (0)
- Burnable (0.8)
- WUI (1).



WUI (2020) Bar Massada et al. 2022

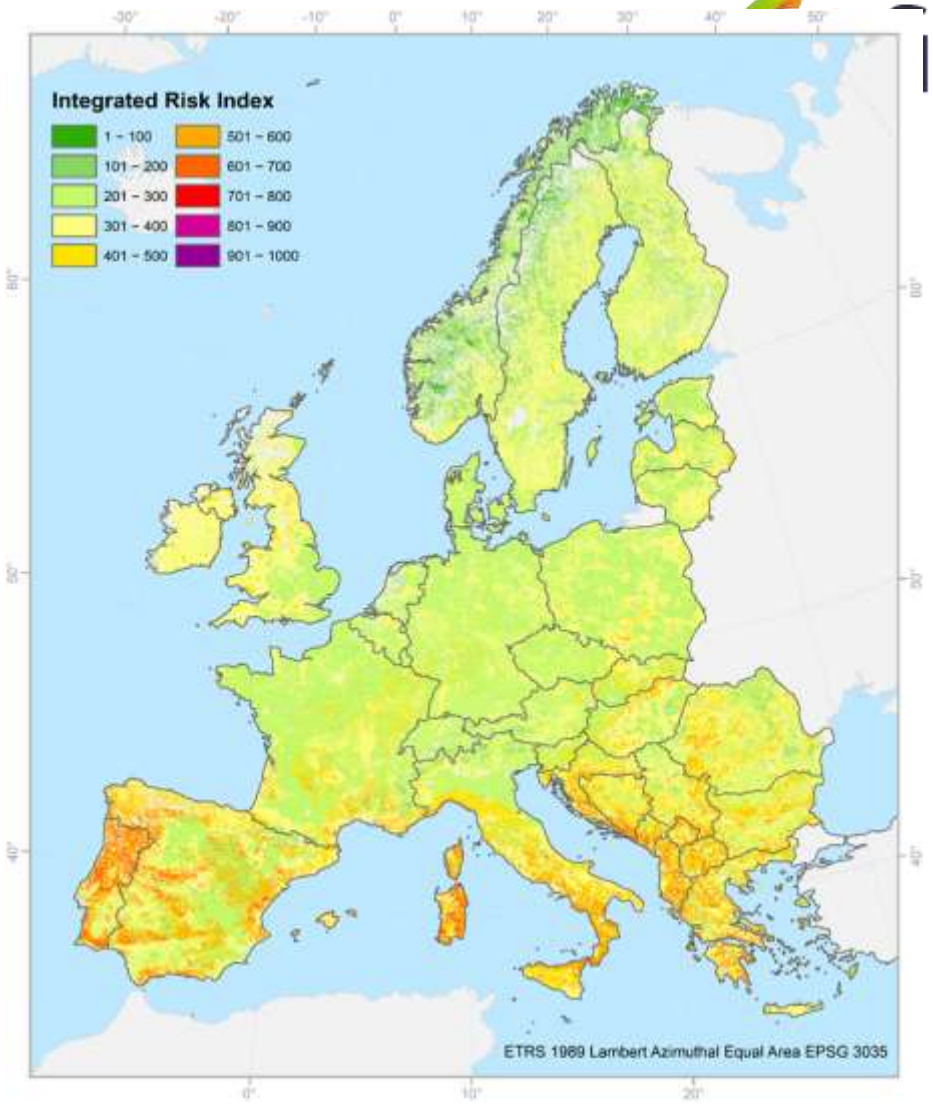
Proportion of total WUI in NUTS-3



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Final Merging

- Integrated risk index (IRI):
  - IRI = (0.6*D + 0.4*V)*E
  - Danger (D).
  - Exposure (E):
  - Vulnerability (V).



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In progress

- Validate indices for 2023 and 2024:
  - Compute historical June-September (AUT).
  - Relate to active fires and FRP (Kings College)
- Implement the system at the project platform.
- Link with data viewer.

Thanks:

Emilio Chuvieco, emilio.chuvieco@uah.es

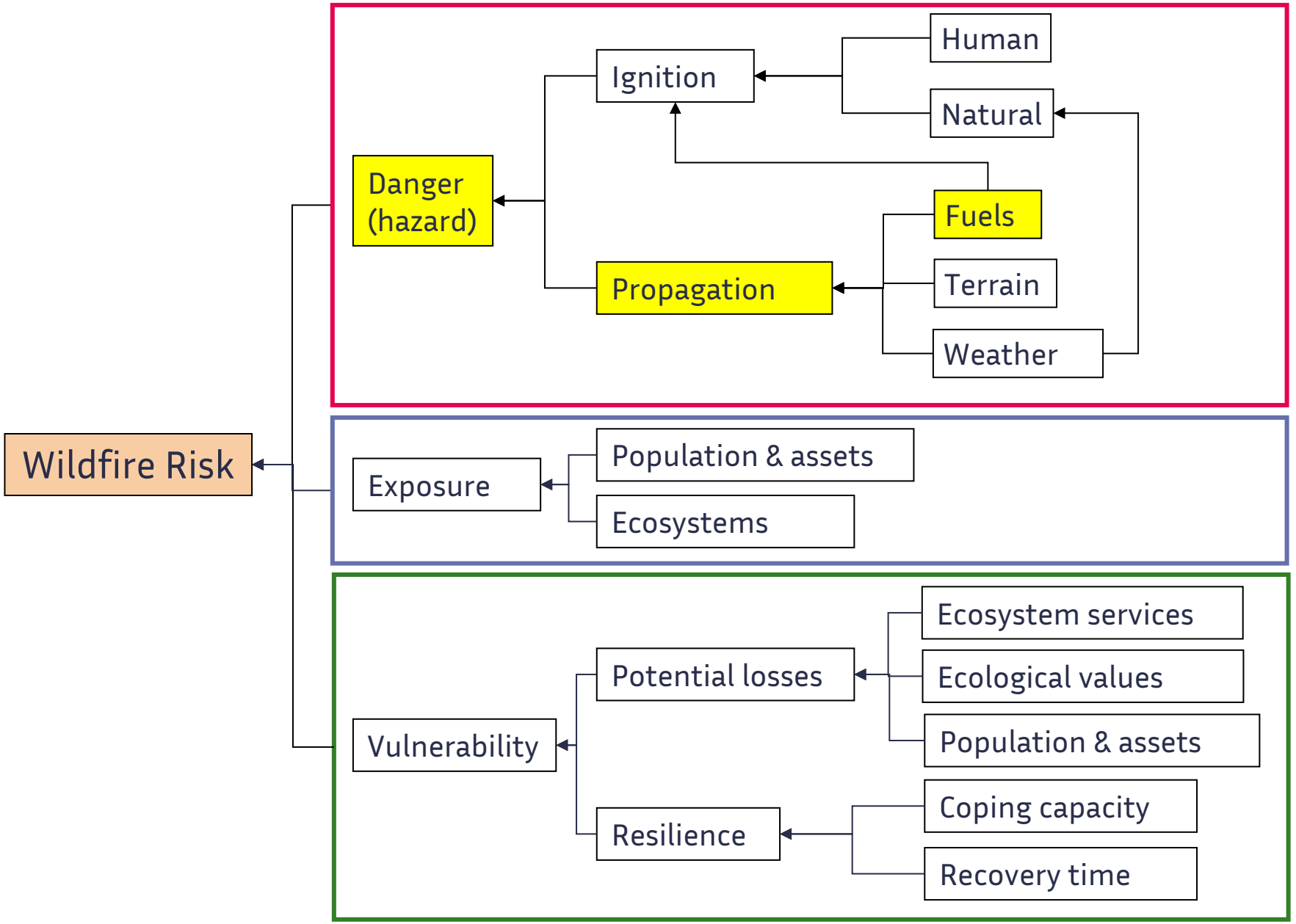
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Fuel Relevant Land Management Strategies (FRLMS) to reduce wildfire risk

Alex Neidermeier and D. X. Viegas



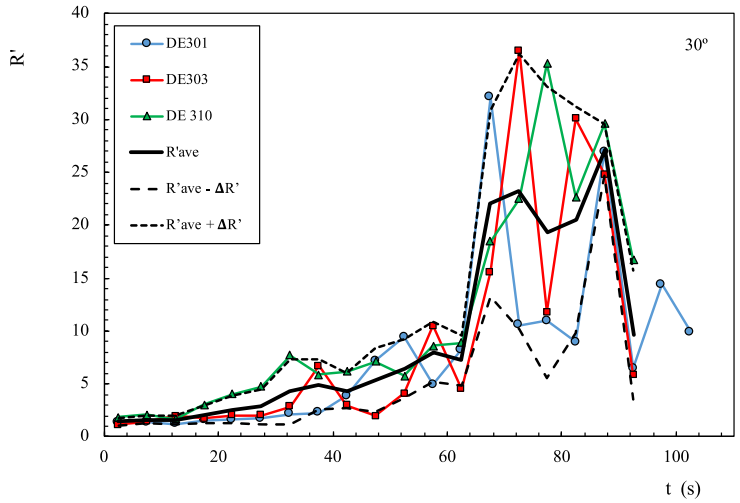
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Fire propagation

In the general conditions a fire will start and grow, due to its dynamics, and may reach very high values of the rate of spread, releasing large amounts of energy, as heat, with great destructive potential.

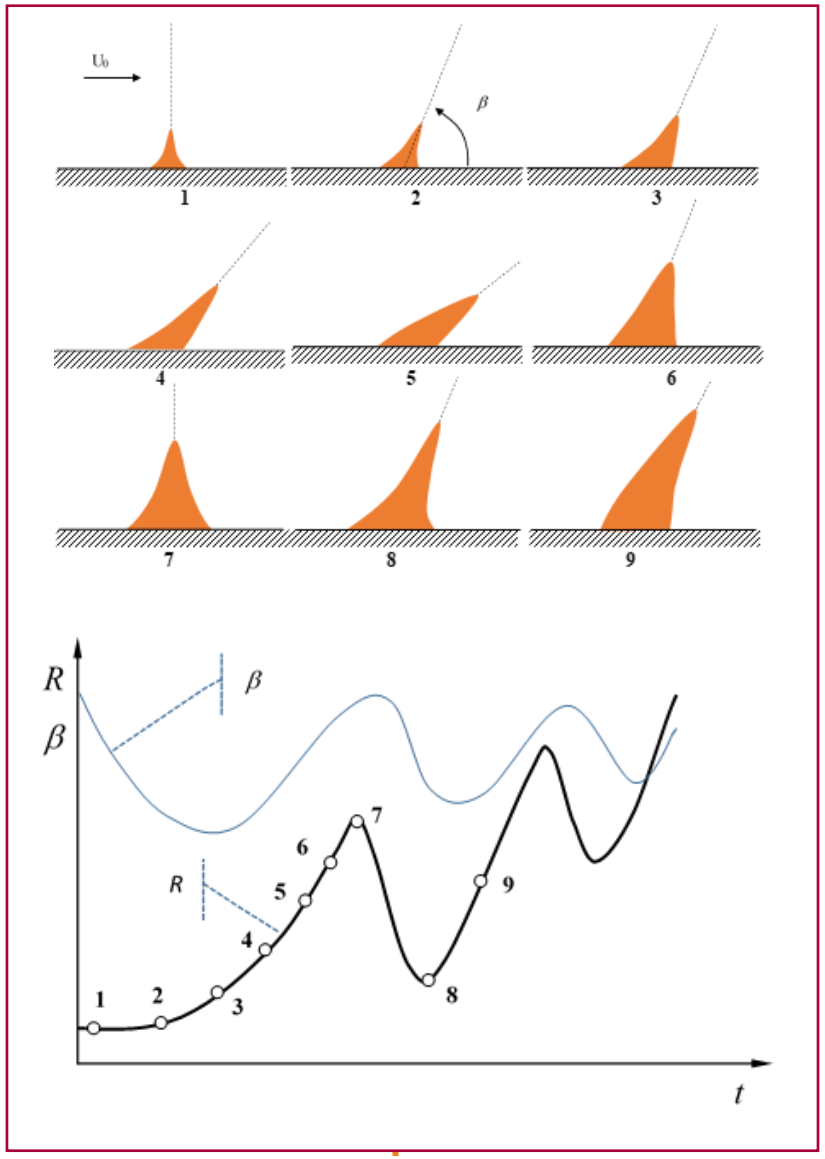




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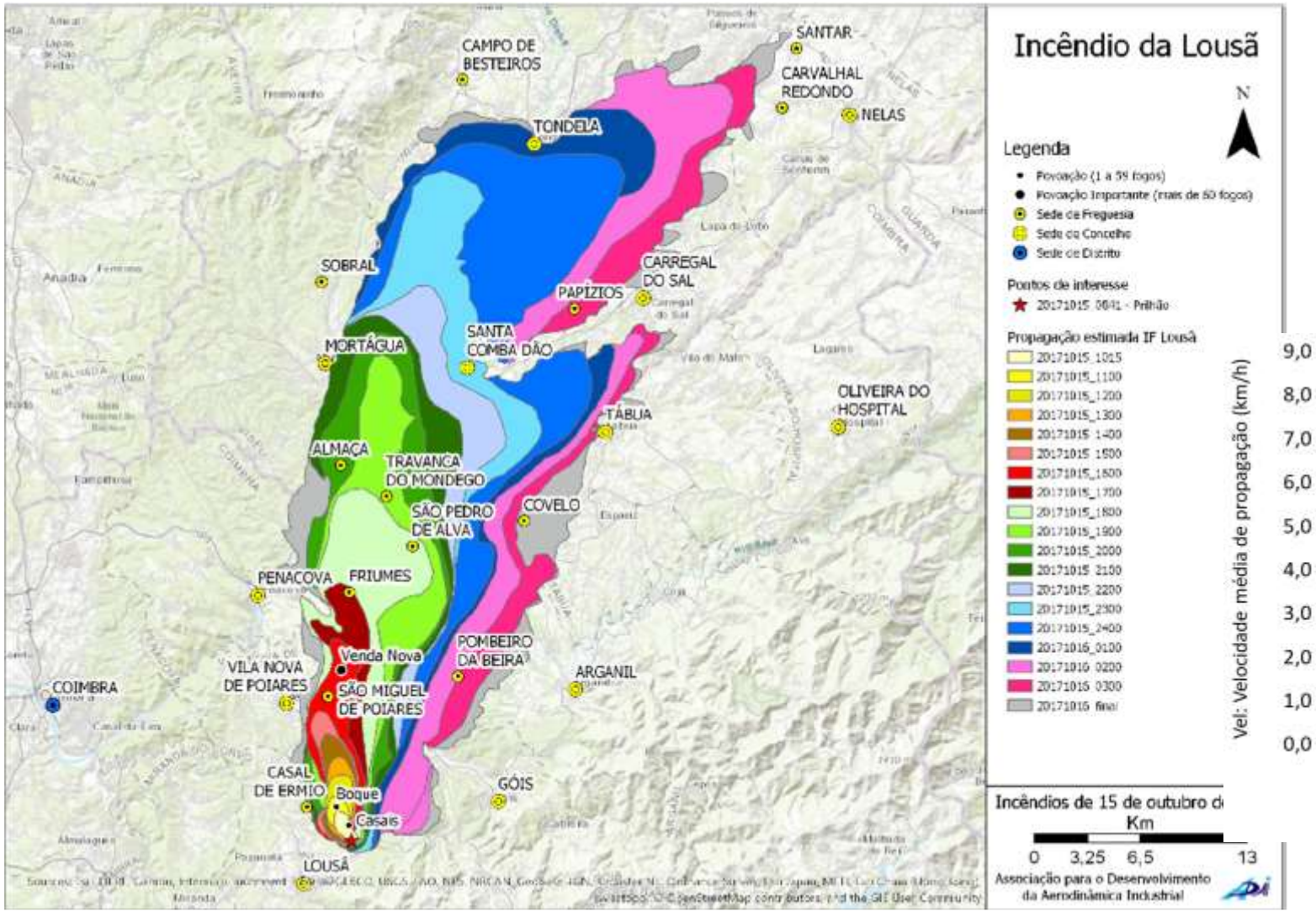
3. Intermittent or oscillatory fire behaviour

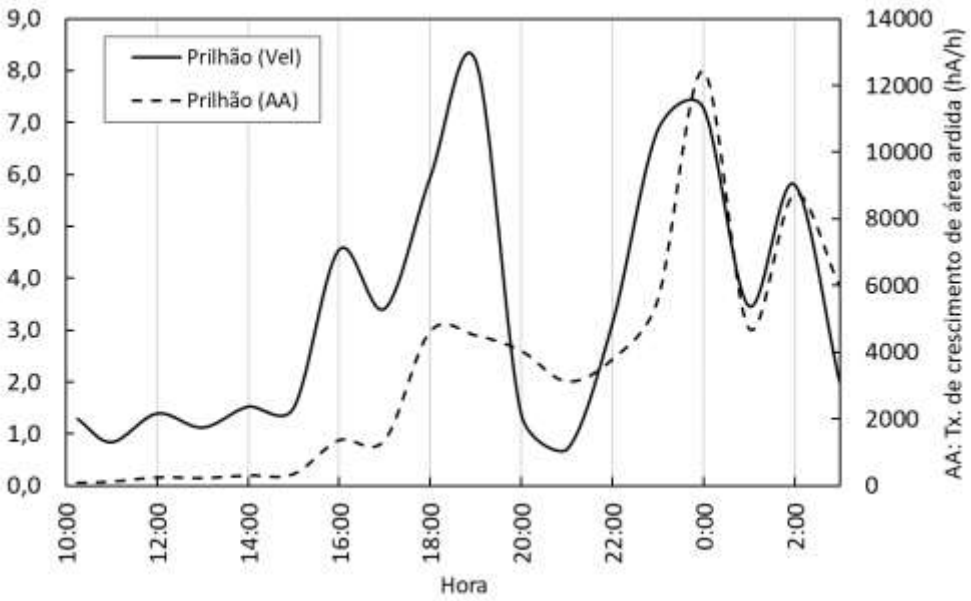
- The behaviour of a fire is oscillatory and intermittent, in the sense that its ROS may increase but then the convective flow induced by the fire counteracts the acceleration tendency and decreases the ROS value; the fire will undergo another cycle of ROS increase and decrease as it is observed in various carefully documented laboratory and field experiments and in real fires as well.



Viegas DX, et al., 2021. On the non-monotonic Behavior of Fire Spread, Int. J. Wildland Fire. https://doi.org/10.1071/WF21016.

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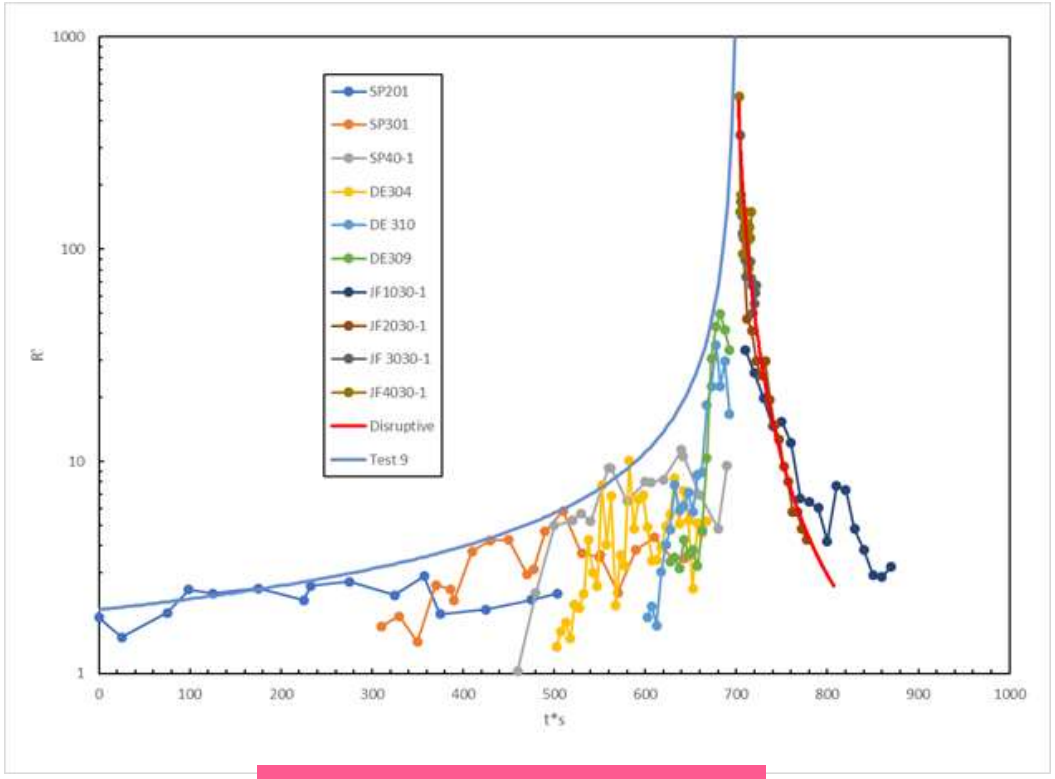
Fire of Lousã, 15 October 2017
53kHa, 23 victims

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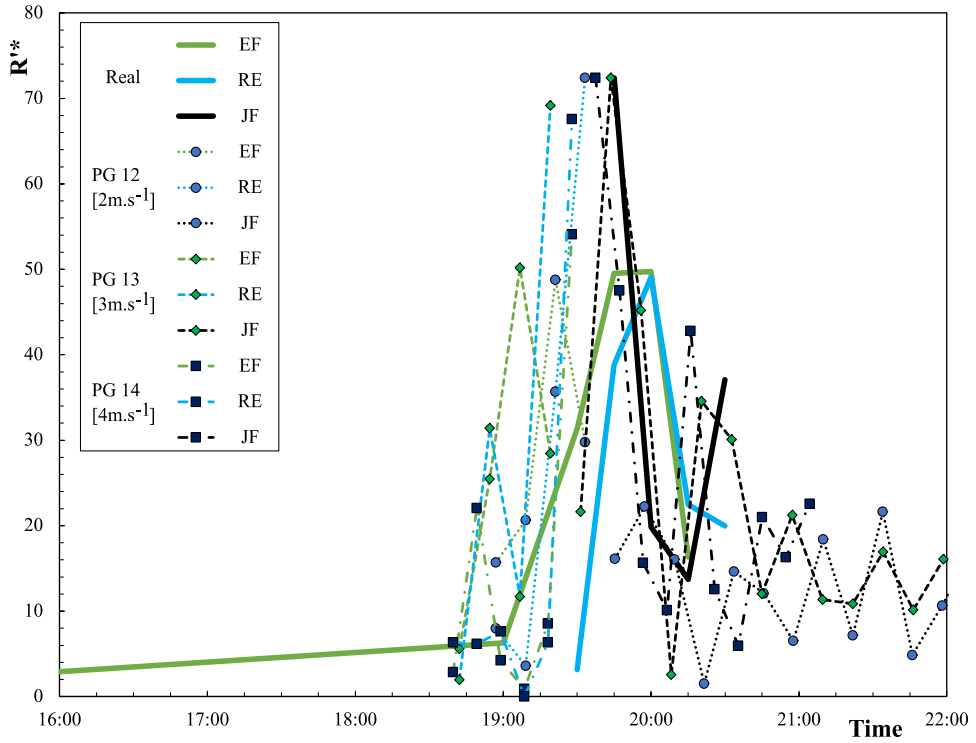
Acceleration and deceleration of the head fire

Joint analysis of the acceleration and the deceleration of the fire

$$\frac{dR'}{dt'} = a'_1{}^{\frac{1}{b_1}} b_1 a'_2 (R' - 1)^{1-\frac{1}{b_1}} R'^{b_2}$$



Laboratory experiments



Fire of Pedrógão Grande

Analysis of Extreme Fire Behaviour

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In **FirEUrisk** we are studying the spread of very large fires that affect vast areas of the territory and endanger the citizens at the Wildland Urban Interface.

When these fires develop they create their own dynamics and are very difficult to stop and suppress.

To avoid this and to mitigate the risk of wildfire, we must change the conditions that support and promote very intense fire spread.

The only factor that can be modified by human action is the vegetation or fuel cover.

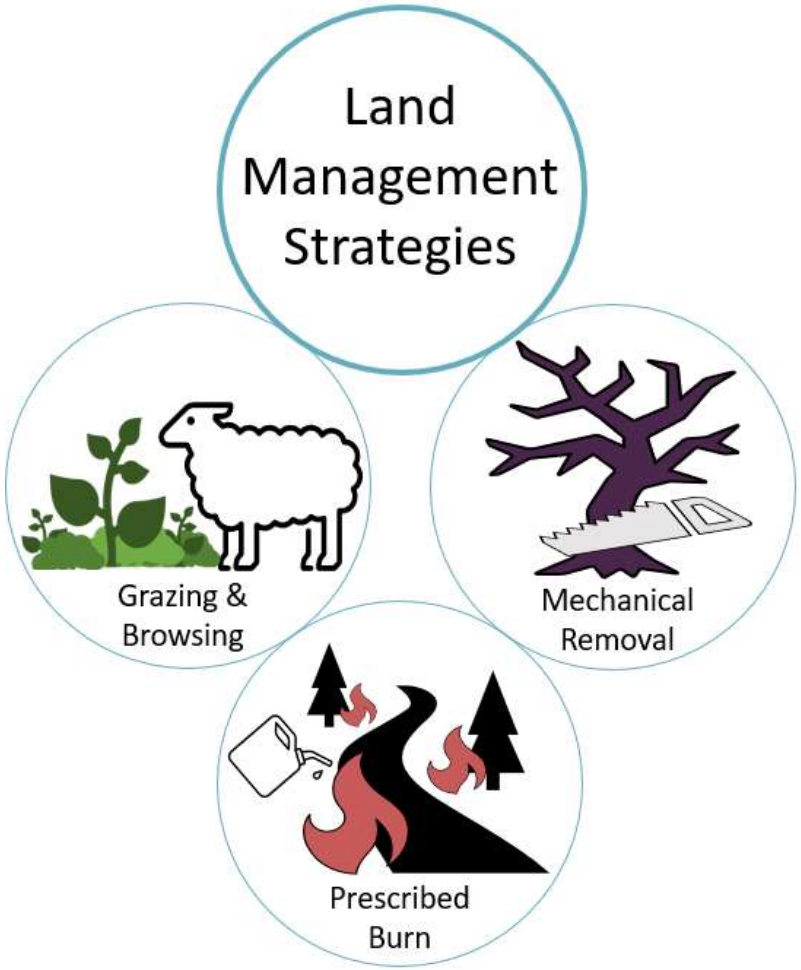
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Methods to manage the vegetation cover:

- Landscape management
  - Species replacement
  - Vegetation mosaics
  - Fire breaks
- Biomass reduction
  - Grazing
  - Mechanical tools
  - Prescribed fire.

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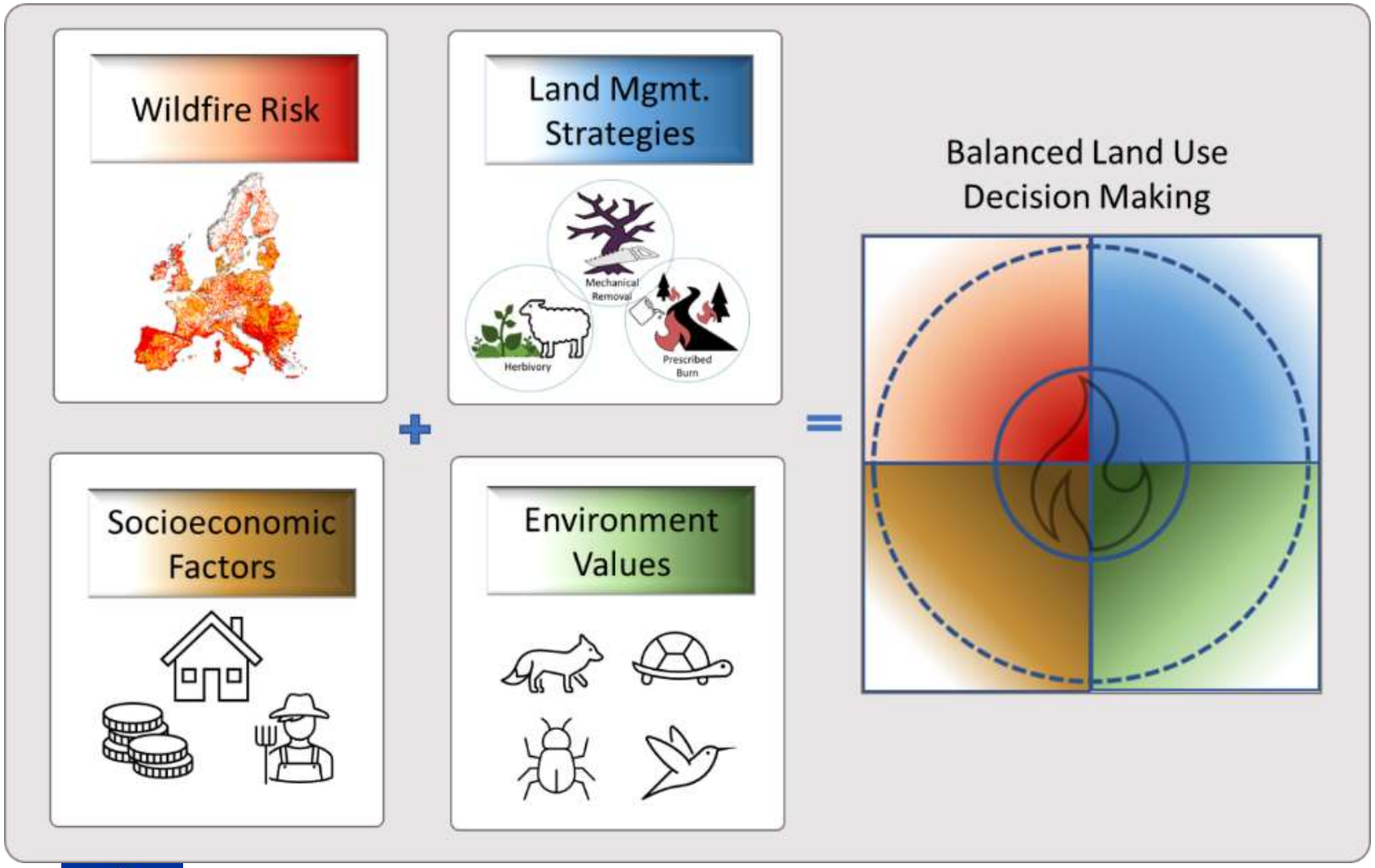
Which areas of Europe are suitable for Fuel Relevant Land Management Strategies (FRLMS?)





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D2.3: Guidelines for FRLMS: Applicability, socio-economics and environmental concerns

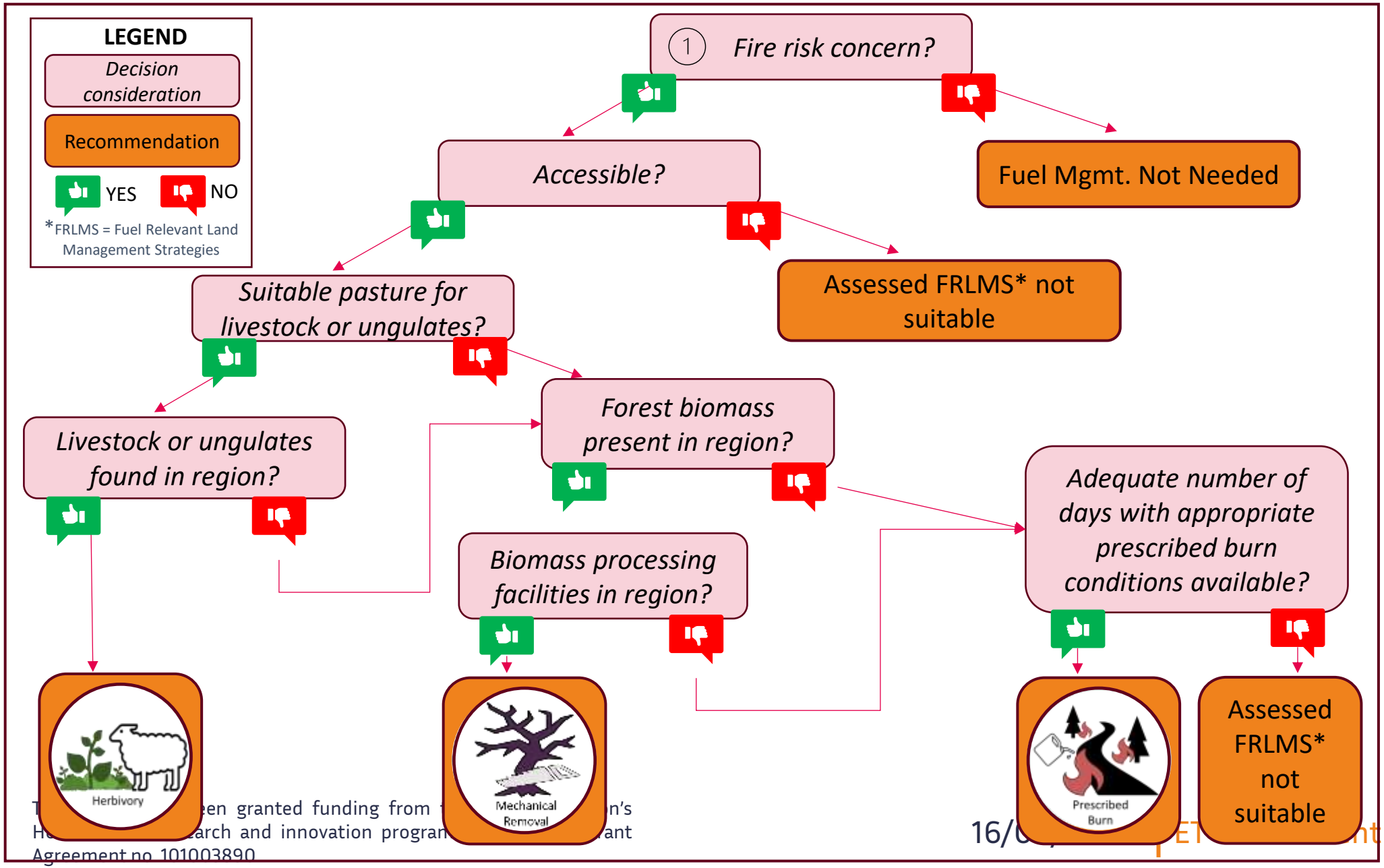


Policy-relevant guidelines to support landscape-level decision aiming to reduce fuel accumulation in Europe via application of FRLMS.

- Literature review & Expert consultation
- Socio-economic assessment with 3 pilot sites
- Potential environmental trade-offs
- Synthesis of considerations for the use of FRLMS to manage fuels

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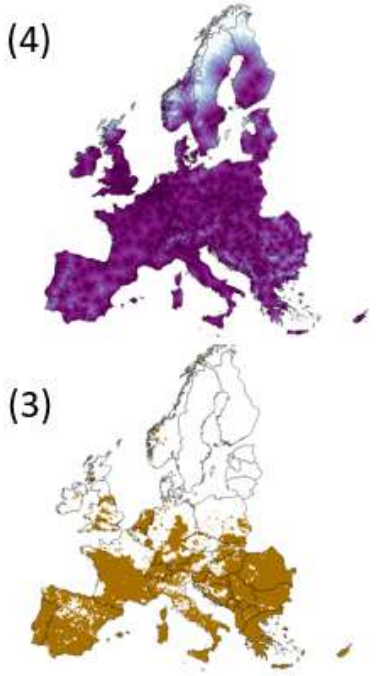
D2.3 Decision tree for FRLMS biophysical limitations

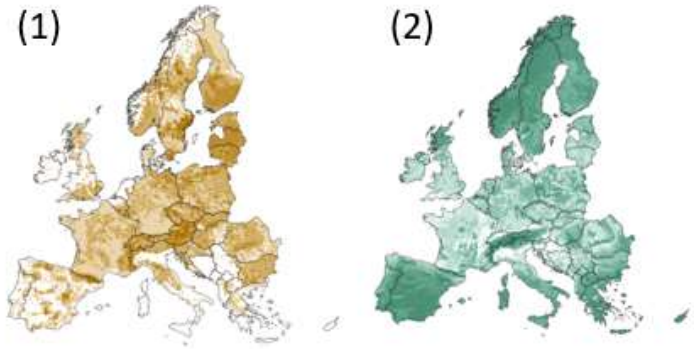


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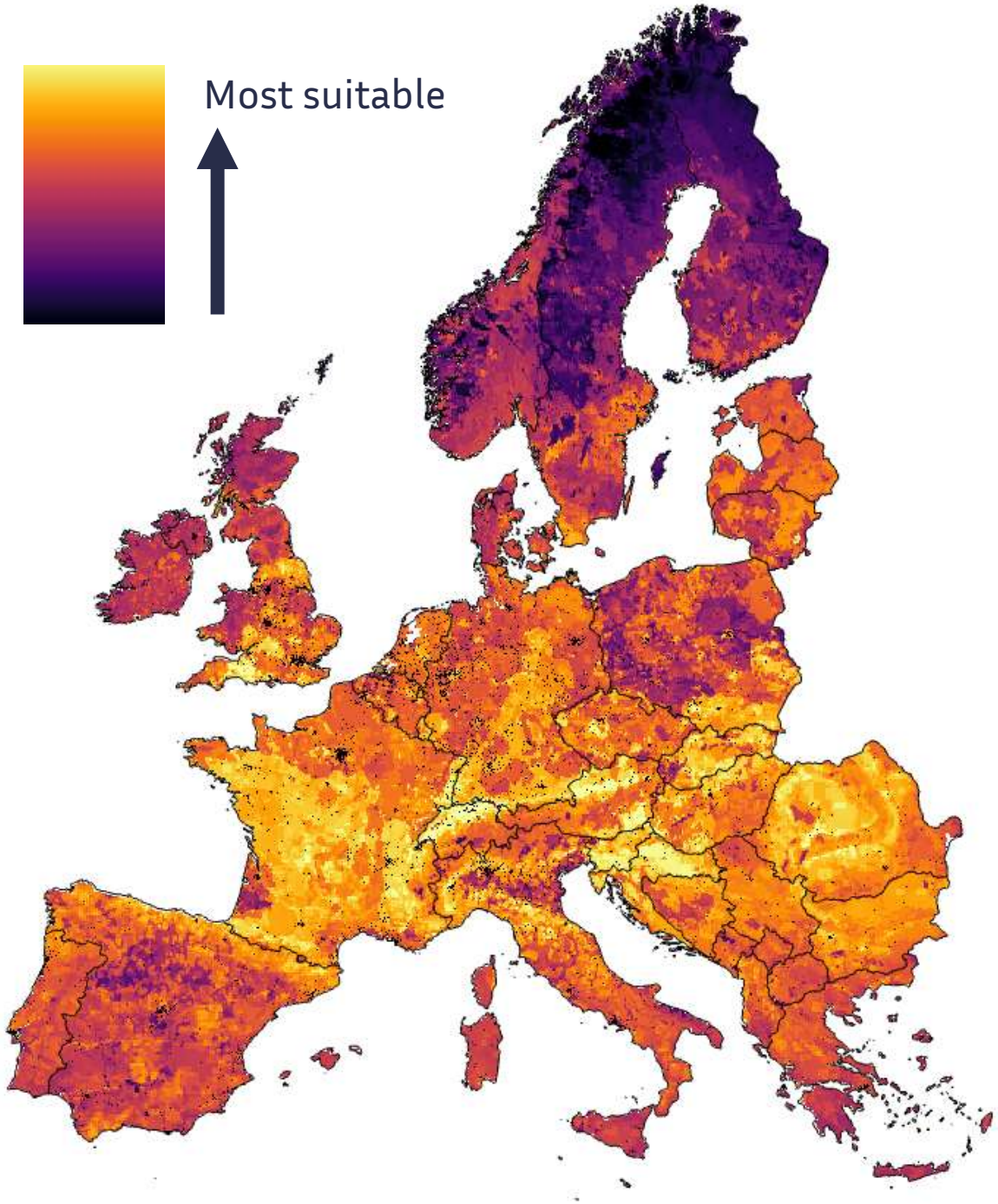
D2.4







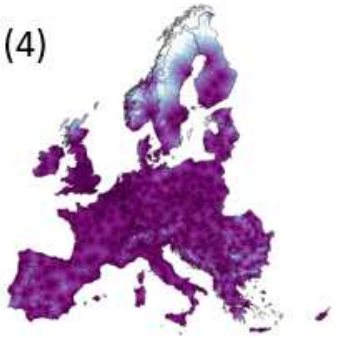
(1) Ungulate diversity
(2) Pasture suitability
(3) Livestock diversity
(4) Accessibility

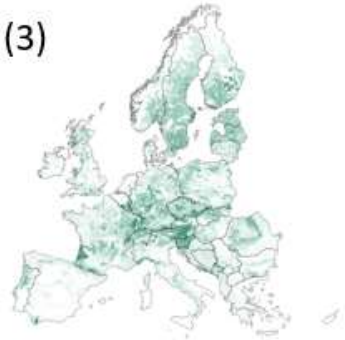


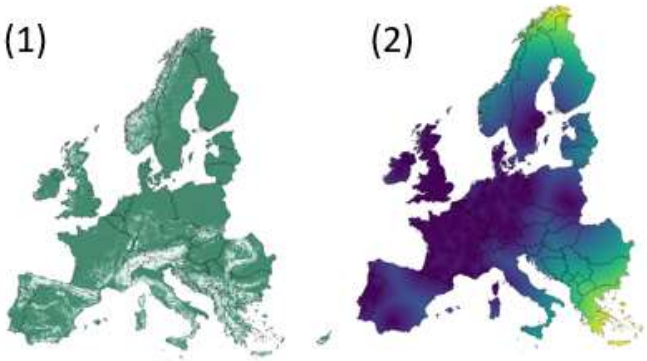
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D2.4

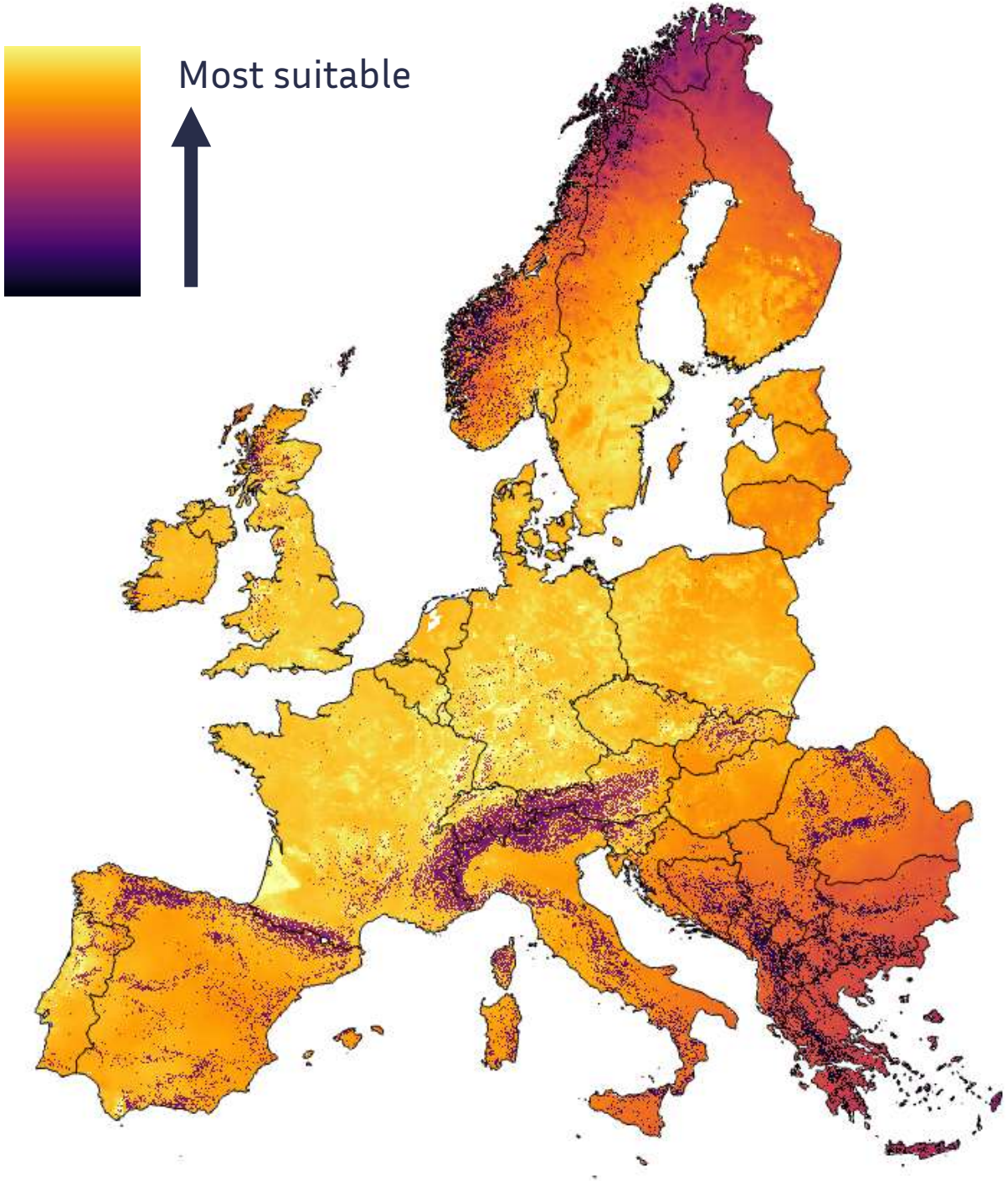








(1) Slope
(2) Biomass facilities
(3) Forest Biomass availability
(4) Accessibility

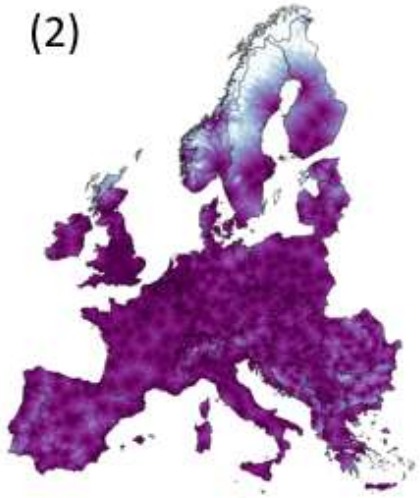


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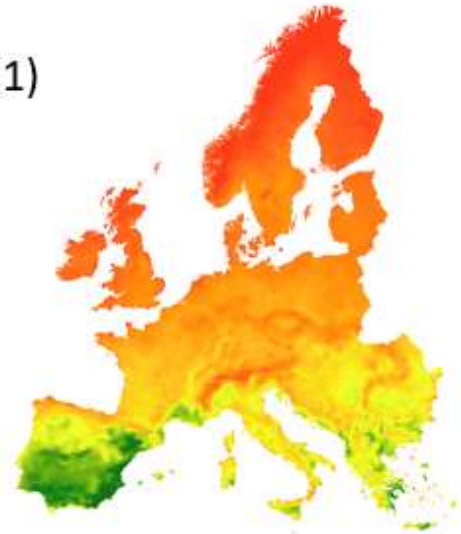
D2.4



(2)



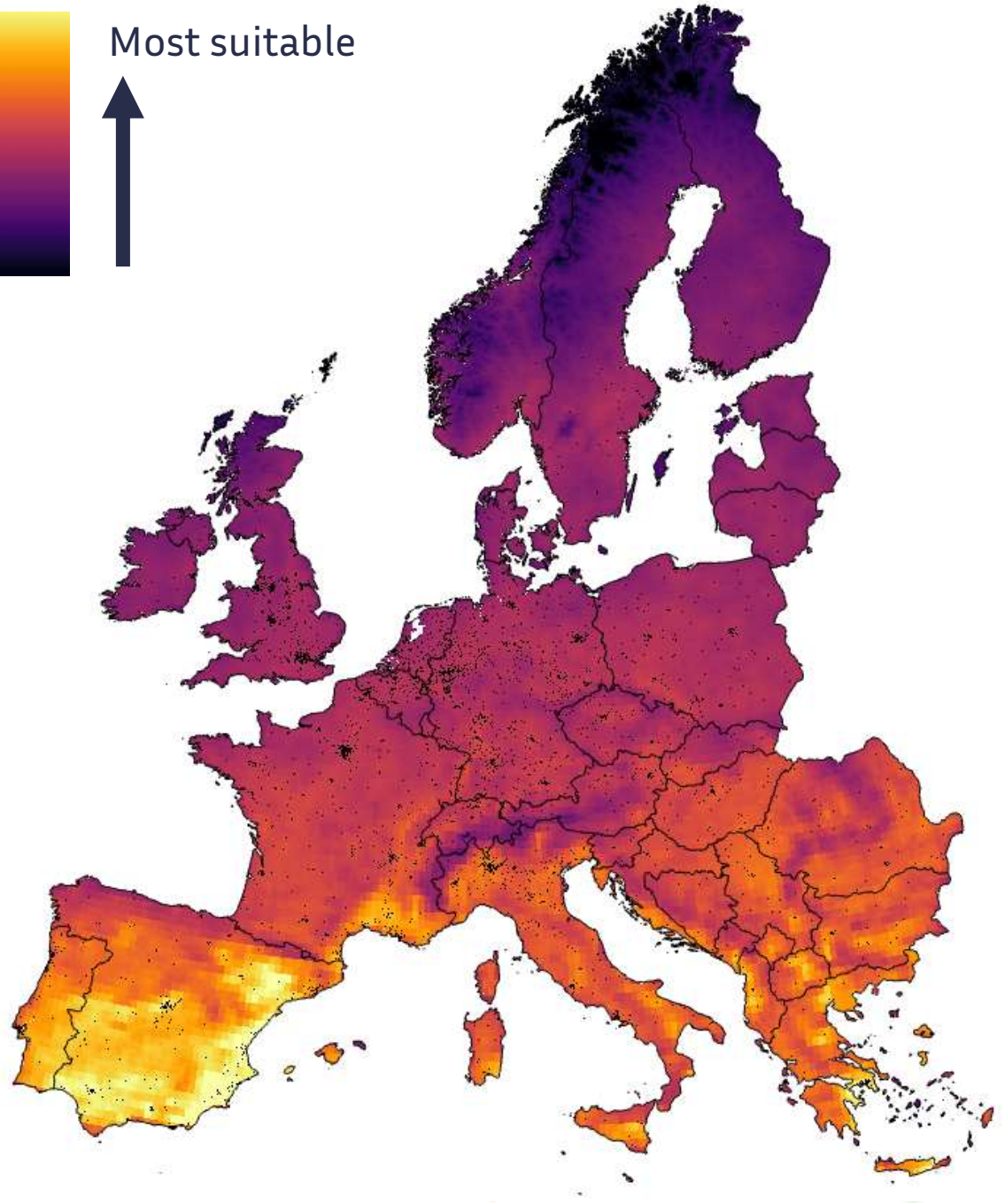
(1)



(1) Prescribed burn days
(2) Accessibility

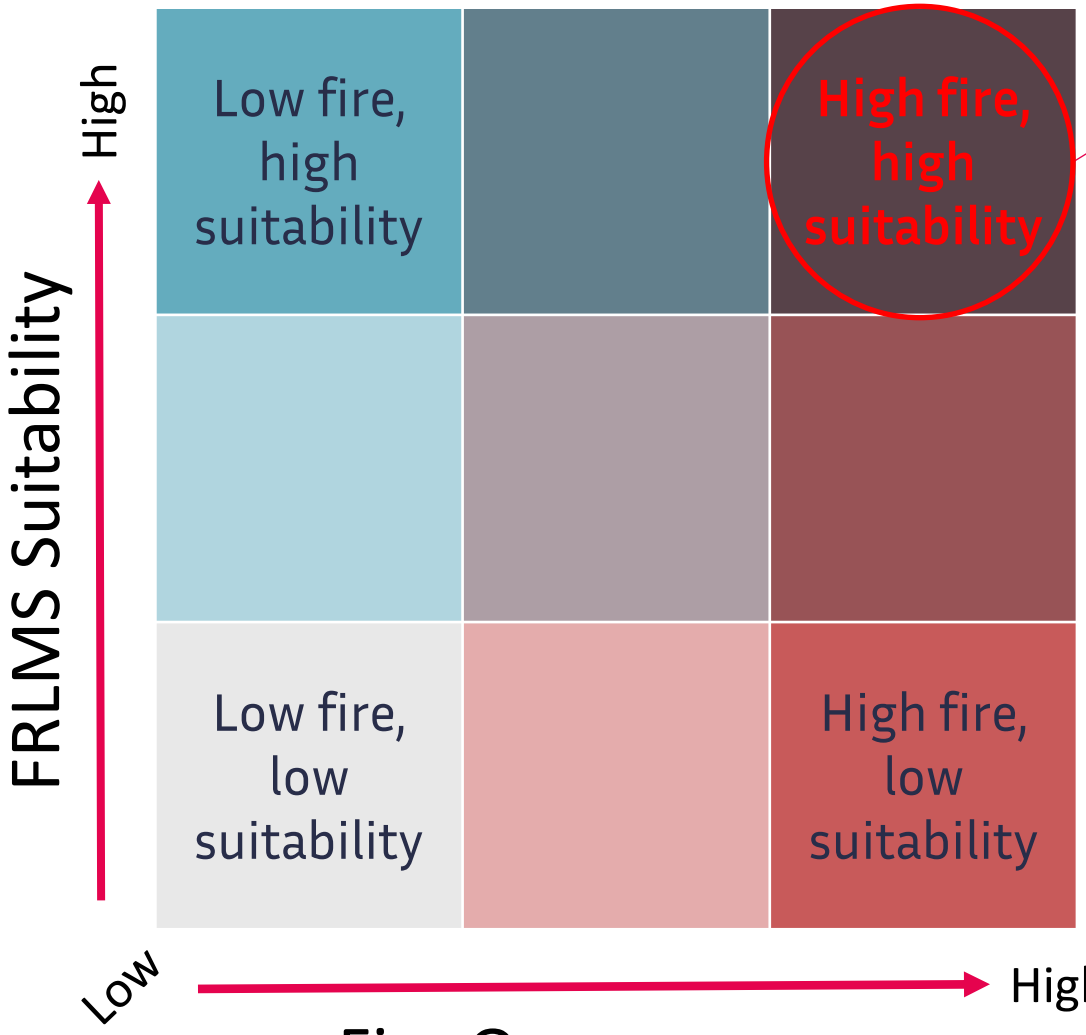


Most suitable

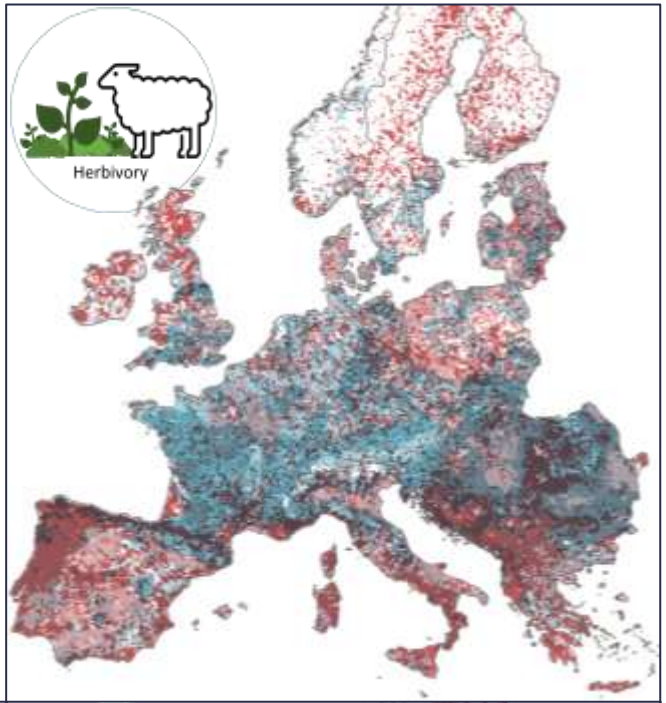


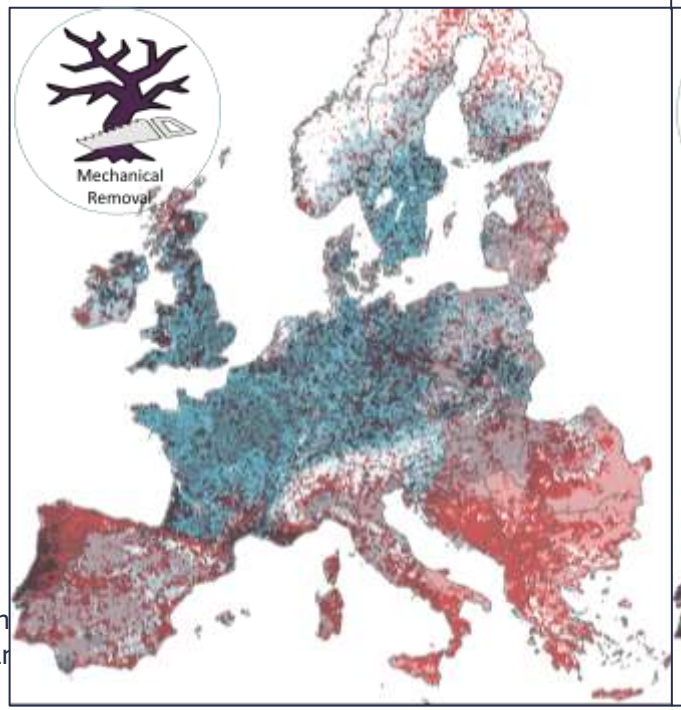
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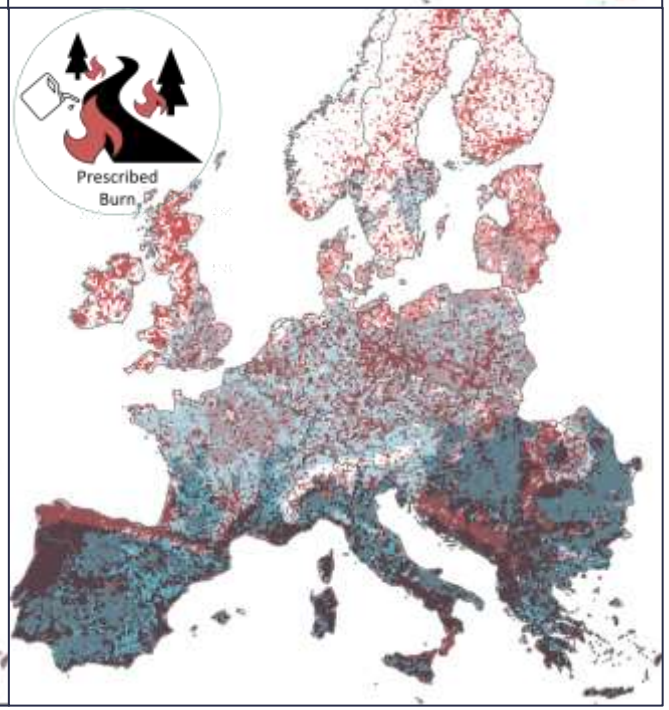
D2.4: Prioritizing areas with fire occurrence



Areas to prioritize for targeted interventions



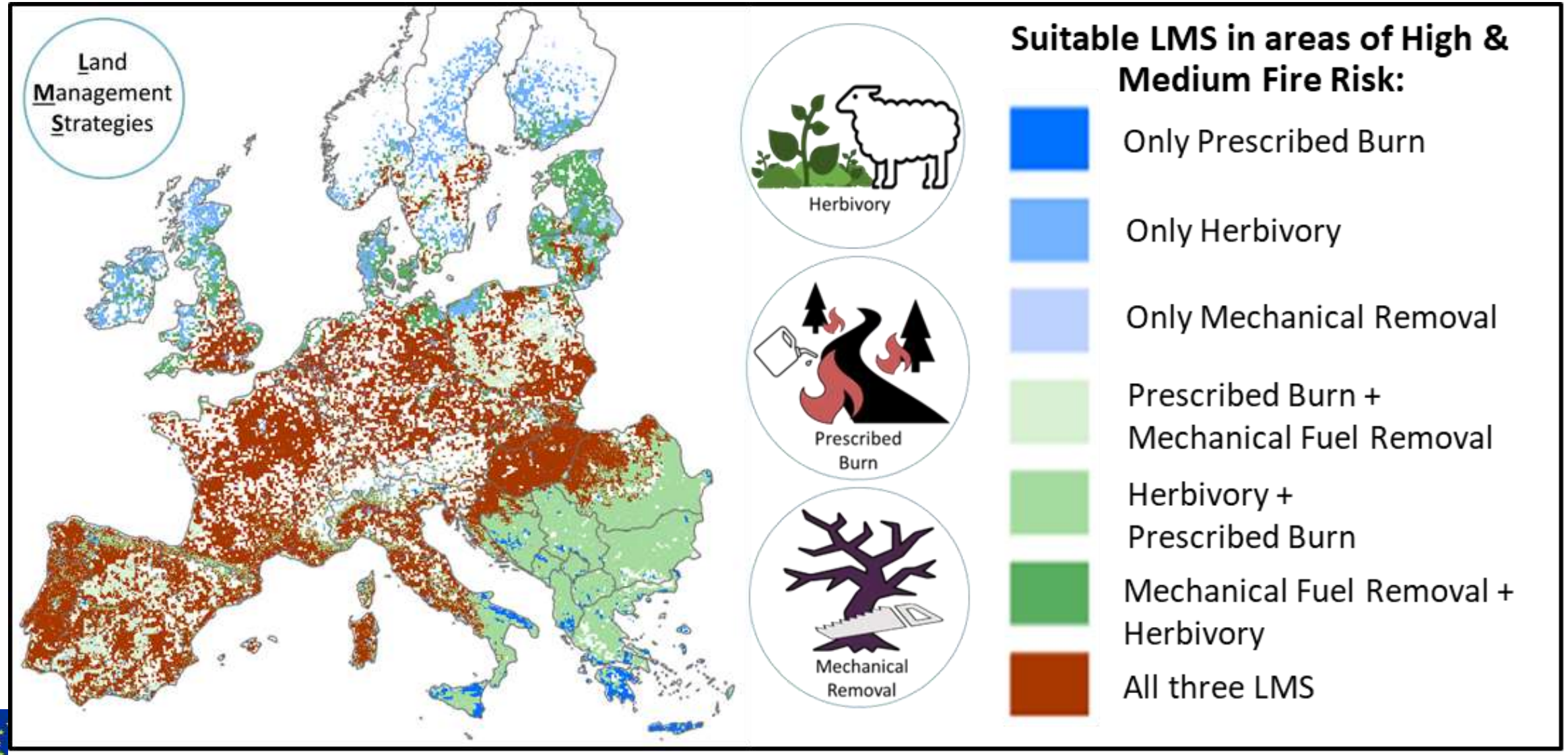




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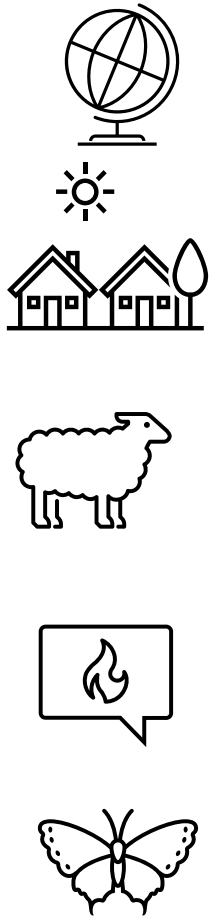
D2.4: Using concurrent and singular FRLMS in areas of higher fire occurrence

QR Code to publication:



Neidermeier et al. 2023

D2.4: Discussion of FRLMS Maps



- Data that covers all the EU, especially socioeconomics, is limited.
- Must consider local factors (funding, ecology, etc.). We are combining data at 1km scale—useful for policy, less for local decision making.
  "Non-suitable" areas of course may be able to (or already) use FRLMS. "Rules" created here had to be true for all of Europe.
- Fire risk has many aspects—our study only targets fuels.
- We also considered potential ecological effects of the FRLMS—You can find out more in Deliverable 2.4 and Neidermeier et al. 2024, in prep!

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Alex Neidermeier
Vrije Universiteit, Amsterdam
a.Neidermeier@vu.nl

Future fire regimes

Maik Billing

Potsdam Institute for Climate Impact Research (PIK), Germany

on behalf of WP3



This project has received funding from the European Union 's Horizon 2020 research and innovation programme under grant agreement No 101003890

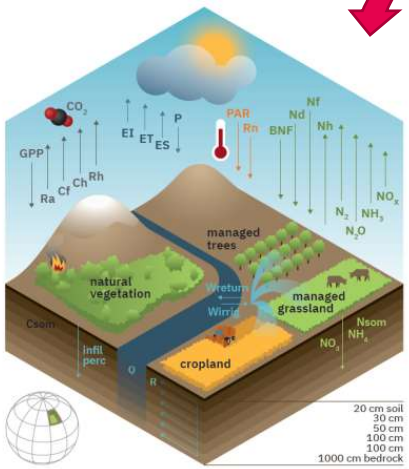
Towards future fire regimes

Data input

Climate scenarios (GCMs)

LU scenarios

Vegetation model



LPJmL5.6

Fire model

SPITFIRE

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Changes in burnt area

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Climate scenarios (GCMs)

From IPCC climate model archive (CMIP6) to high-resolution scenario data

meteogrid

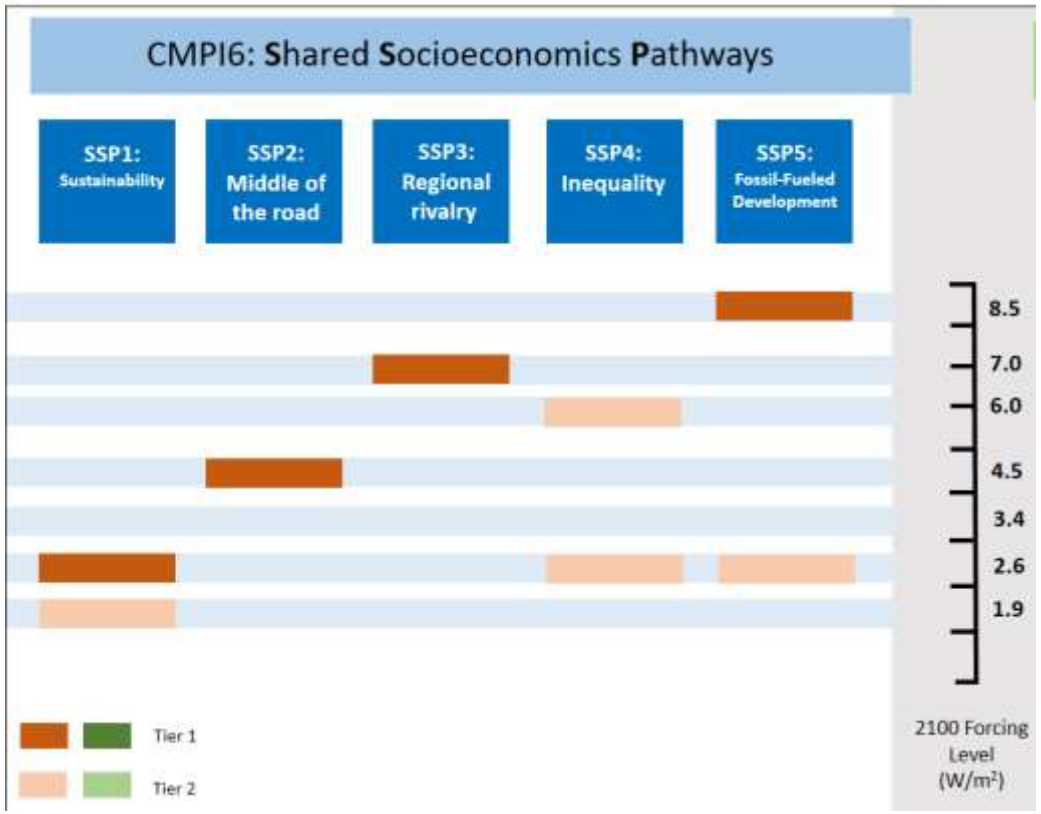


1. Climate scenarios are
   - Bias corrected using ERA5-Land reanalysis climate data
   - Statistical downscaling method applied daily values & 9x9 km spatial resolution
   - Produced for FirEUrisk European region (map) and Pilot sites

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Climate scenarios (GCMs)

From IPCC climate model archive (CMIP6) to high-resolution scenario data

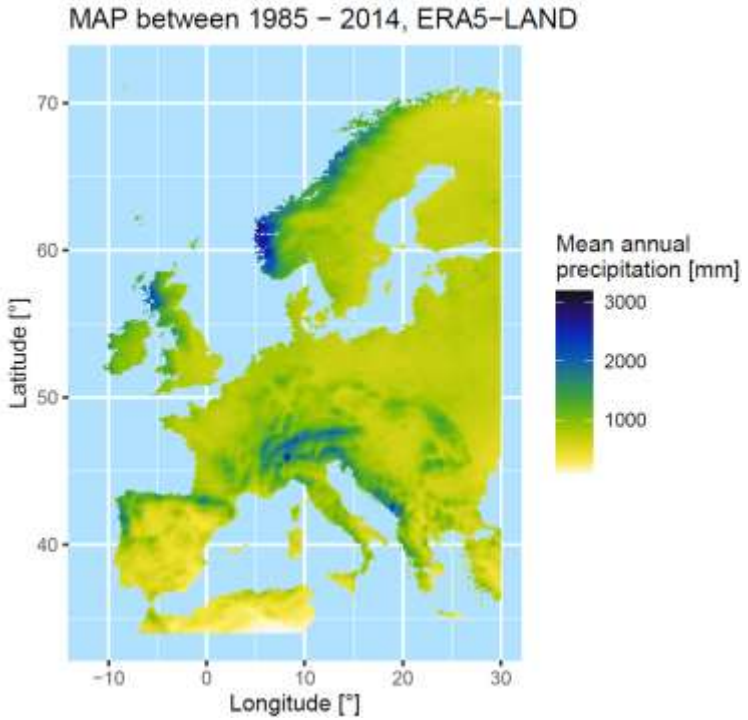


2. Selection of climate scenarios

- **Sustainable pathway (Paris Accord achieved): RCP2.6 (climate) and SSP1 (land-use, economic and policy trajectory)**
- **Regional rivalry (In a 3 to 4°C warmer world): RCP7.0 and SSP3**
- **Each climate model has different model outcome, we selected the scenarios according to their ranking using the FWI**

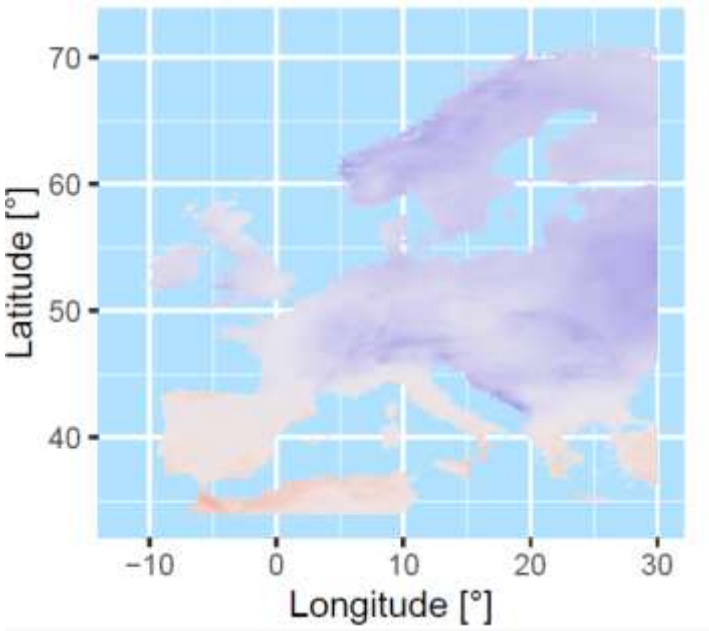
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Future climate conditions - Precipitation

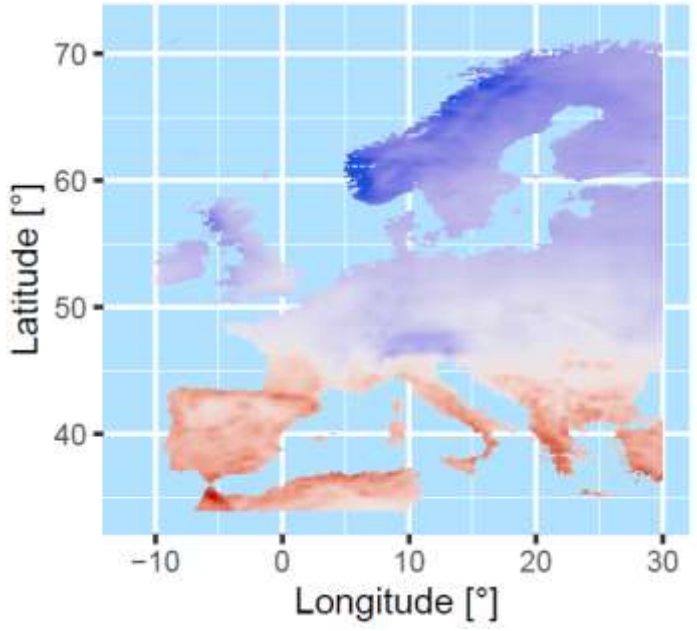


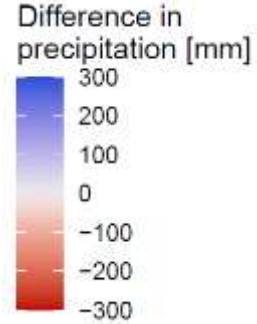
Historical (1985 – 2014) reconstructed precipitation (ERA-5 Land)

- Paris goal met



- In a 3 to 4°C warmer World

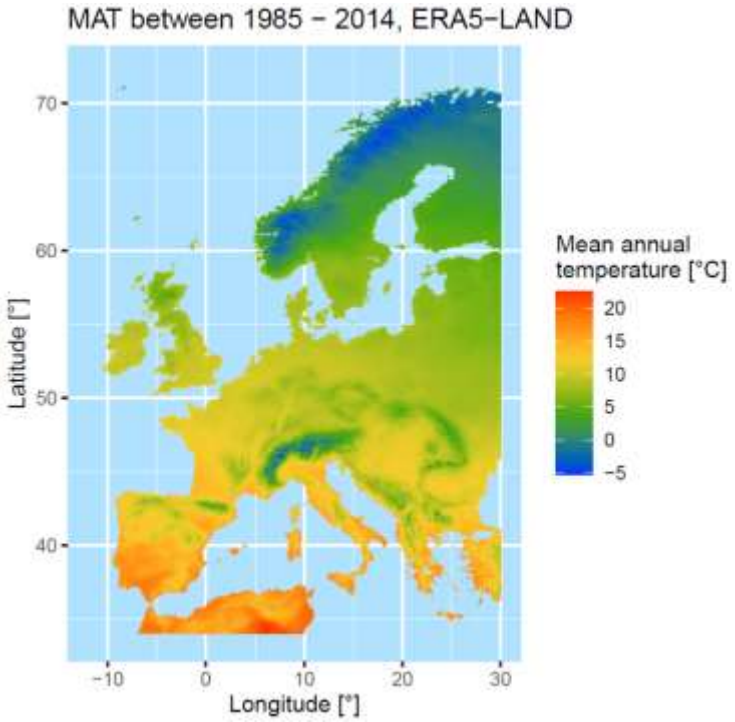




- Future scenarios: averaged over 5 climate models, differences to present shown
- Change in precipitation under climate change (2070-2099)

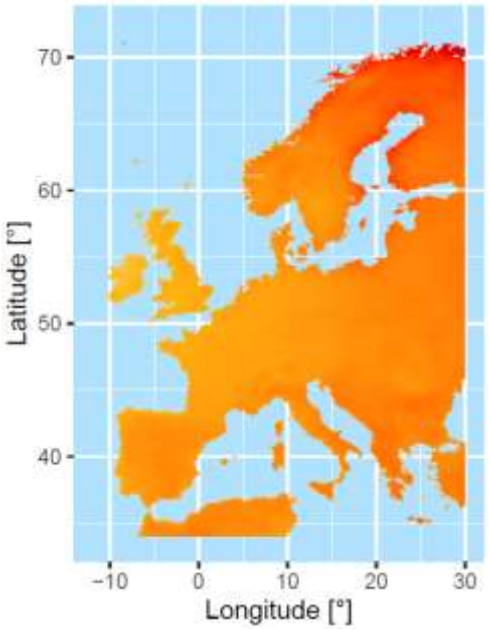
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Future climate conditions – Air temperature

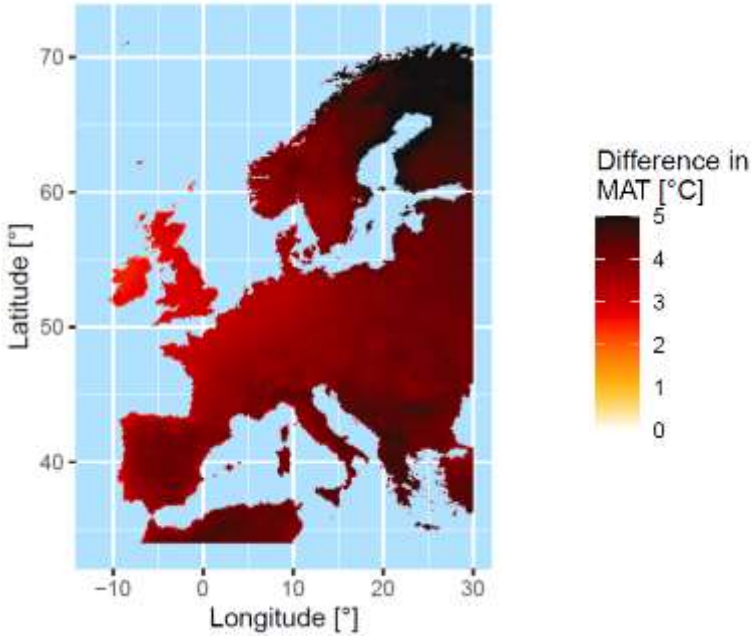


Historical (1985 – 2014) reconstructed air temperature(ERA-5 Land)

- Paris goal met



- In a 3 to 4°C warmer World



- Future scenarios: averaged over 5 climate models, differences to present shown
- Change in air temperature under climate change (2070-2099)

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Future changes in fire weather

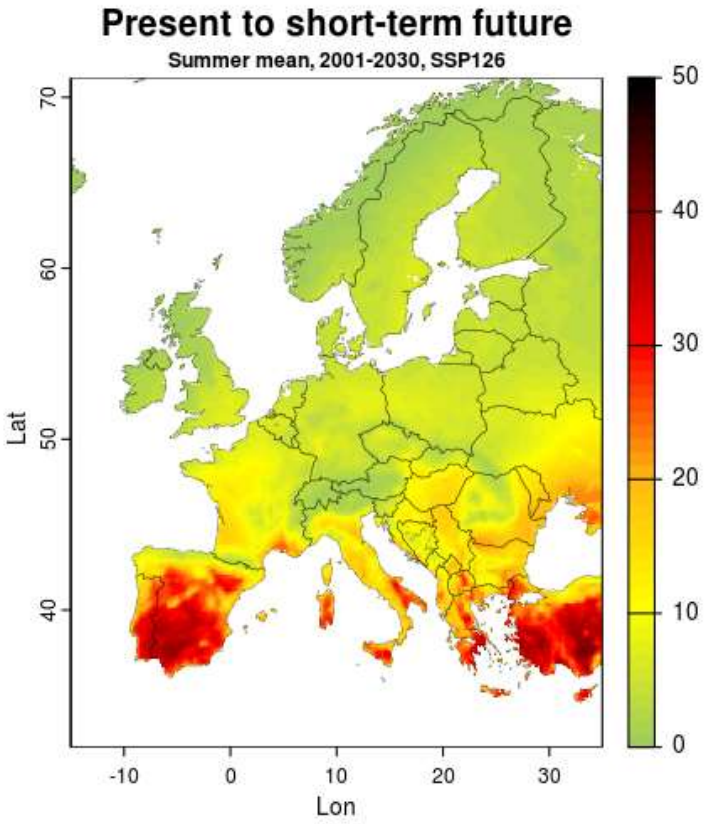
Applying the Canadian Fire Weather Index (FWI)

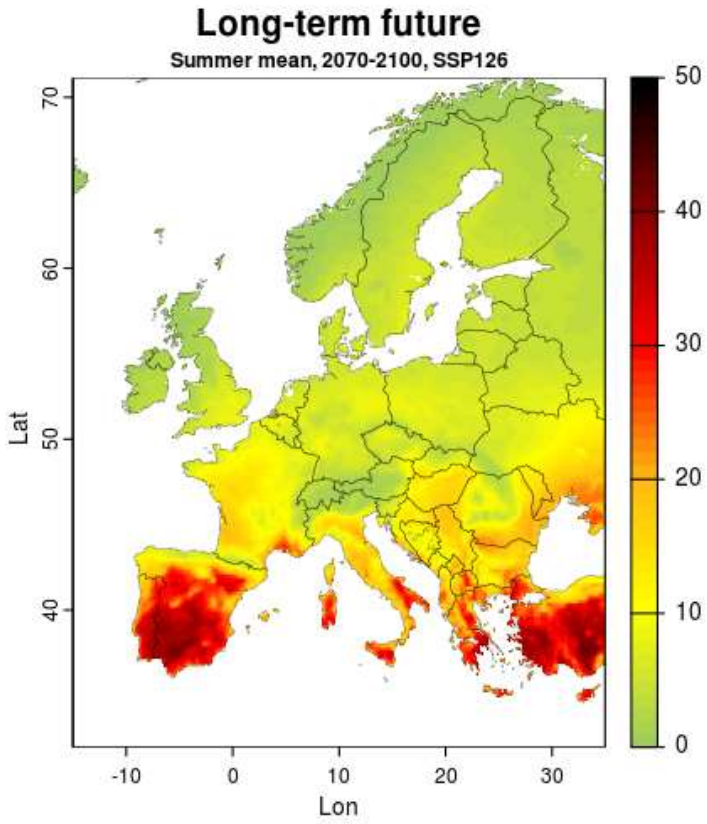
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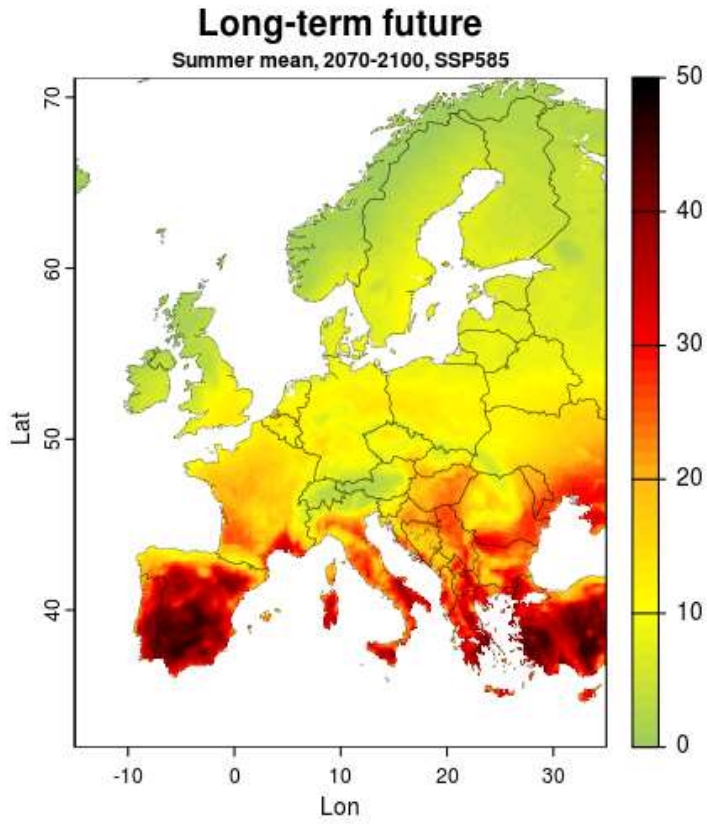
1. Future fire weather

We calculated the Canadian Fire Weather Index (FWI) using future climate scenarios

Danger classes	
FWI < 5.2	very low
5.2 ≤ FWI < 11.2	low
11.2 ≤ FWI < 21.3	moderate
21.3 ≤ FWI < 38	high
38.0 ≤ FWI < 50	very high
50 ≤ FWI	extreme

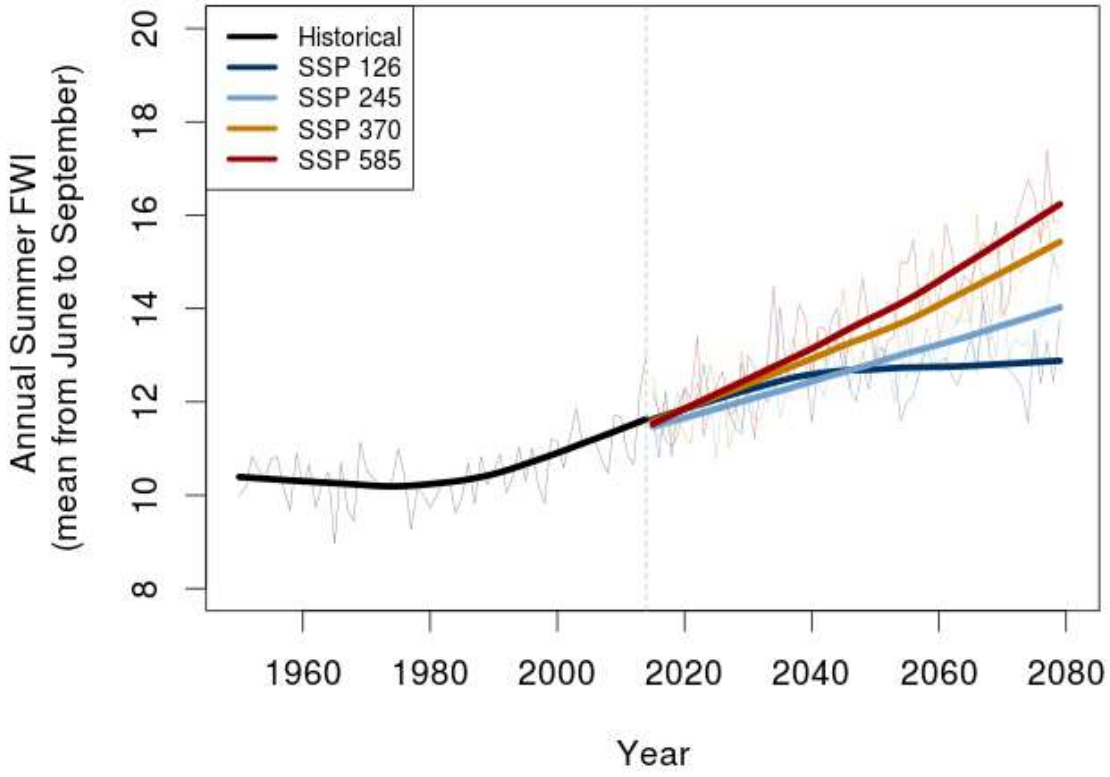


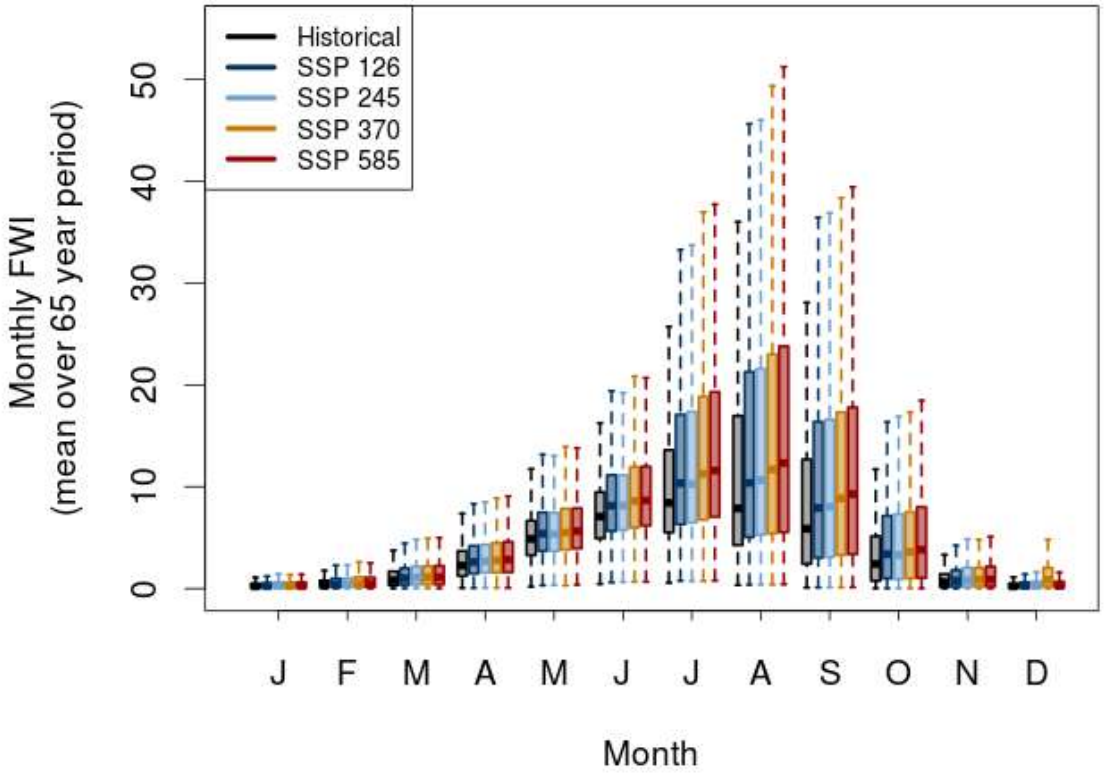




1. Future fire weather

1. Long-term trends in Europe and changes in seasonality





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1. Future fire weather

Jessica Hetzer *et al.* *The fire weather in Europe: large-scale trends towards higher danger (2024)*
Environ. Res. Lett. **19** 084017

	$FWI_{q0.95}$ Historical	$FWI_{q0.95}$ SSP1-2.6	$FWI_{q0.95}$ SSP2-4.5	$FWI_{q0.95}$ SSP3-7.0	$FWI_{q0.95}$ SSP5-8.5
Iceland	2.02	3.05 (51%)	3.44 (71%)	3.64 (80%)	3.7 (84%)
Norway	5.08	5.72 (12%)	6.14 (21%)	6.31 (24%)	6.83 (34%)
Liechtenstein	5.1	6.67 (31%)	7.19 (41%)	7.91(55%)	8.81 (73%)
Faroe Islands	5.29	5.8 (10%)	5.97 (13%)	6.08 (15%)	6.09 (15%)
Switzerland	6.51	8.7 (34%)	9.28 (43%)	10.37 (59%)	11.5 (77%)
Ireland	8.55	9.53 (12%)	10.12 (18%)	10.72 (25%)	11.84 (38%)
Austria	10.18	12.2 (20%)	13.1 (29%)	14.04 (38%)	15.19 (49%)
United Kingdom	10.94	12.31 (12%)	13.06 (19%)	13.7 (25%)	15.02 (37%)
Sweden	11.21	12.29 (10%)	12.84 (15%)	13.13 (17%)	14.08 (26%)
Finland	11.23	12.21 (9%)	12.62 (12%)	13.12 (17%)	13.75 (22%)
Isle of Man	11.31	11.96 (6%)	12.5 (11%)	12.68 (12%)	13.48 (19%)
Andorra	14.04	19.17 (37%)	20.72 (48%)	23.46 (67%)	25 (78%)
Slovenia	14.45	17.67 (22%)	18.98 (31%)	20.58 (42%)	22.24 (54%)
Aland	14.56	17.02 (17%)	17.5 (20%)	18.3 (26%)	18.78 (29%)
Estonia	14.75	16.15 (9%)	16.24 (10%)	17.36 (18%)	18.47 (25%)
Latvia	14.78	16.15 (9%)	16.52 (12%)	17.8 (20%)	19.17 (30%)
Czech Republic	15.36	18.25 (19%)	19.43 (26%)	20.7 (35%)	22.34 (45%)
Germany	15.63	18.39 (18%)	19.32 (24%)	20.65 (32%)	22.4 (43%)
Lithuania	15.63	16.98 (9%)	17.67 (13%)	19.12 (22%)	20.42 (31%)
Luxembourg	15.67	19.49 (24%)	20.36 (30%)	22.75 (45%)	24.19 (54%)
Denmark	16	17.85 (12%)	18.65 (17%)	18.83 (18%)	20.49 (28%)
Netherlands	16.06	18.95 (18%)	19.73 (23%)	21.21 (32%)	22.8 (42%)
Belgium	16.64	20.31 (22%)	21.33 (28%)	23.18 (39%)	24.88 (50%)
Slovakia	17.79	20.96 (18%)	22.23 (25%)	23.85 (34%)	25.24 (42%)
Belarus	18.01	20.13 (12%)	21.13 (17%)	23.51 (31%)	24.9 (38%)
Poland	18.1	20.23 (12%)	21.22 (17%)	22.91 (27%)	24.37 (35%)
Monaco	20.65	24.26(17%)	25.36 (23%)	26.55 (29%)	27.43 (33%)
Montenegro	21.21	26.85 (27%)	28.45 (34%)	30.7 (45%)	32.34 (52%)
France	22.18	26.97 (22%)	28.32 (28%)	30.28 (37%)	31.88 (44%)
Bosnia and Herzegovina	22.34	27.45 (23%)	29.1 (30%)	31.44 (41%)	33.4 (49%)
Romania	24.39	28.23 (16%)	29.93 (23%)	31.5 (29%)	33.44 (37%)
Croatia	24.89	29.32 (18%)	30.68 (23%)	32.5 (31%)	34.77 (40%)
Italy	26.54	30.53 (15%)	31.76 (20%)	33.09 (25%)	34.37 (30%)
Ukraine	26.73	29.86 (12%)	31.56 (18%)	33.52 (25%)	34.73 (30%)
Albania	28.66	33.27 (16%)	34.44 (20%)	36.35(27%)	37.52 (31%)
San Marino	29.05	32.97 (13%)	34.19 (18%)	35.63 (23%)	37 (27%)
Kosovo	29.2	34.45 (18%)	35.85 (23%)	38.37 (31%)	39.97 (38%)
Hungary	29.44	32.79 (11%)	33.96 (15%)	35.43 (20%)	37.47 (27%)
Bulgaria	29.65	33.85 (14%)	35.23 (19%)	37.48 (26%)	39.08 (32%)
Republic of Serbia	29.73	34.58 (16%)	36.03 (21%)	38.18 (28%)	40.45 (36%)
Moldova	31.48	35.33 (12%)	36.89 (17%)	38.75 (23%)	40.29 (28%)
Vatican	32.62	36.92 (13%)	38.3 (17%)	39.48 (21%)	40.8 (25%)
Macedonia	33.52	37.85 (13%)	39.18 (17%)	41.45 (24%)	42.63 (27%)
Malta	35.22	36.66 (4%)	37.08 (5%)	37.94 (8%)	38.21 (8%)
Greece	38.2	42.25 (11%)	43.47 (14%)	45.25 (18%)	46.09 (21%)
Cyprus	41.44	41.99 (1%)	42.37 (2%)	42.51 (3%)	42.58 (3%)
Spain	42.39	46.55 (10%)	47.81 (13%)	49.01 (16%)	50.36 (19%)
Portugal	44.58	47.84 (7%)	48.92 (10%)	49.67 (11%)	50.66 (14%)
Turkey	46.57	49.87 (7%)	51.43 (10%)	52.68 (13%)	53.18 (14%)

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SENCKENBERG
world of biodiversity

Danger classes	
FWI < 5.2	very low
5.2 ≤ FWI < 11.2	low
11.2 ≤ FWI < 21.3	moderate
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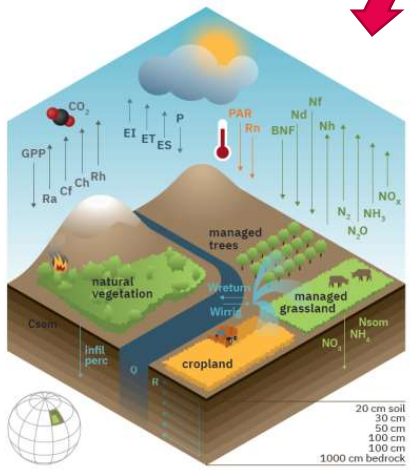
Towards future fire regimes

Data input

Climate scenarios (GCMs)

LU scenarios

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LPJmL5.6

Fire model

SPITFIRE

Future fire regimes

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Changes in burnt area

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Future changes in land use

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a.neidermeier@vu.nl

Modelling with CLUMondo

- we will need different resources: wood, building material, food, ….
- there are defined places of resources
- there are different actors, strategies and goals

- SSPs are run through external macroeconomic models

→ different needs depending on scenario

- CLUMondo allocates the resources to fulfill the demands

→ changes land use



a.neidermeier@vu.nl

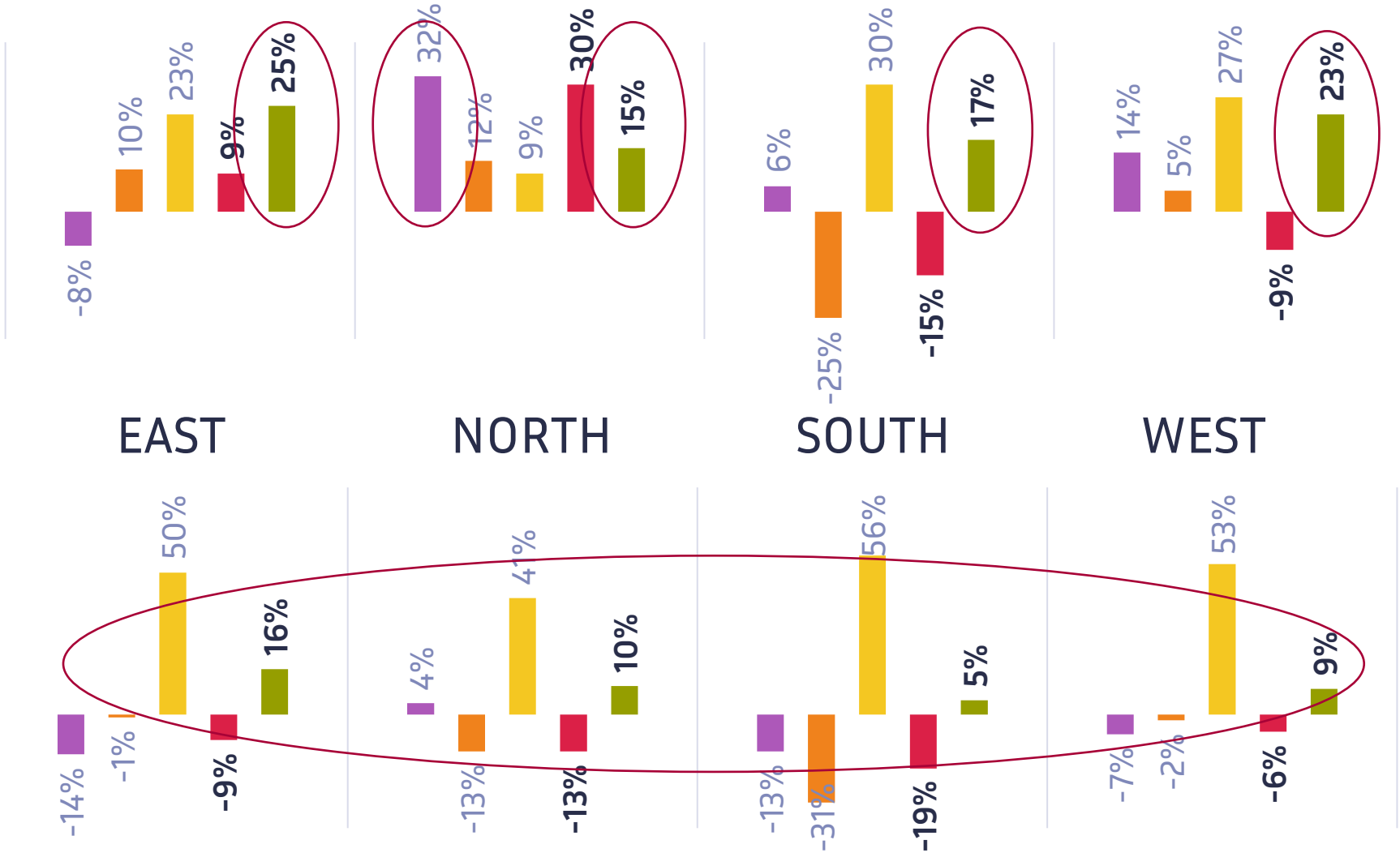
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a.neidermeier@vu.nl

SSP1: Sustainability Taking the Green Road

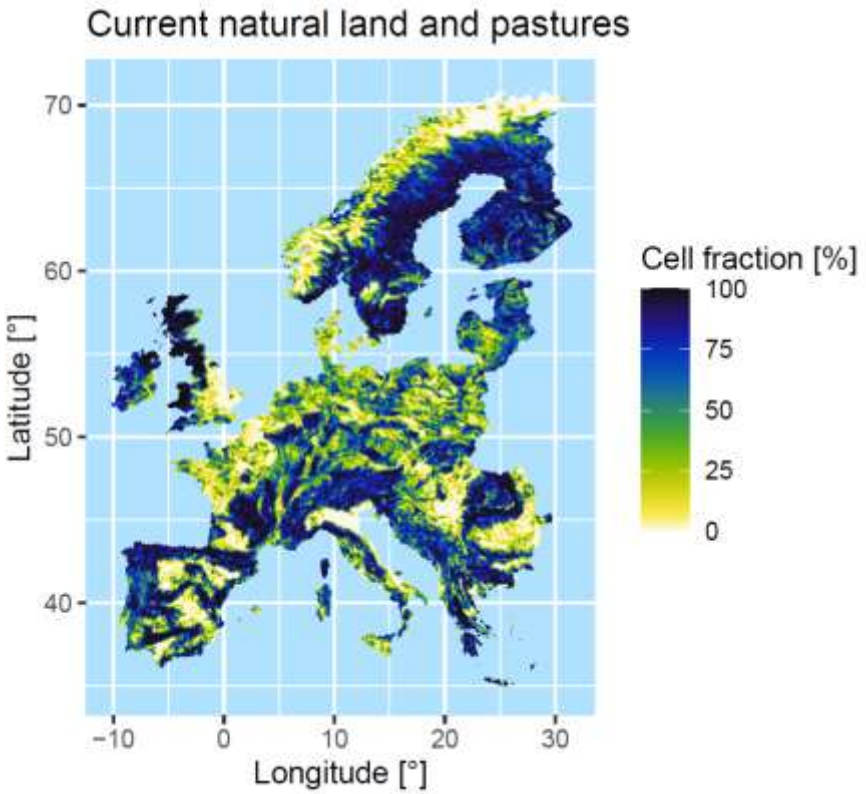
SSP3: Regional Rivalry A Rocky Road

CHANGE BY 2050

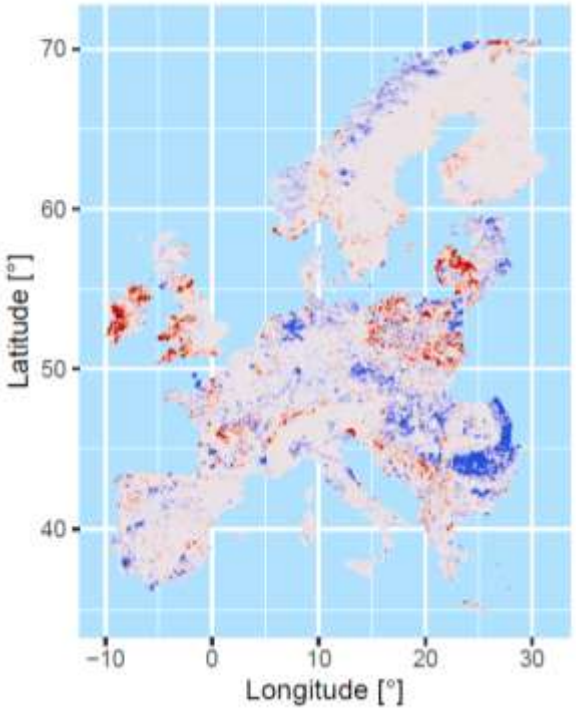


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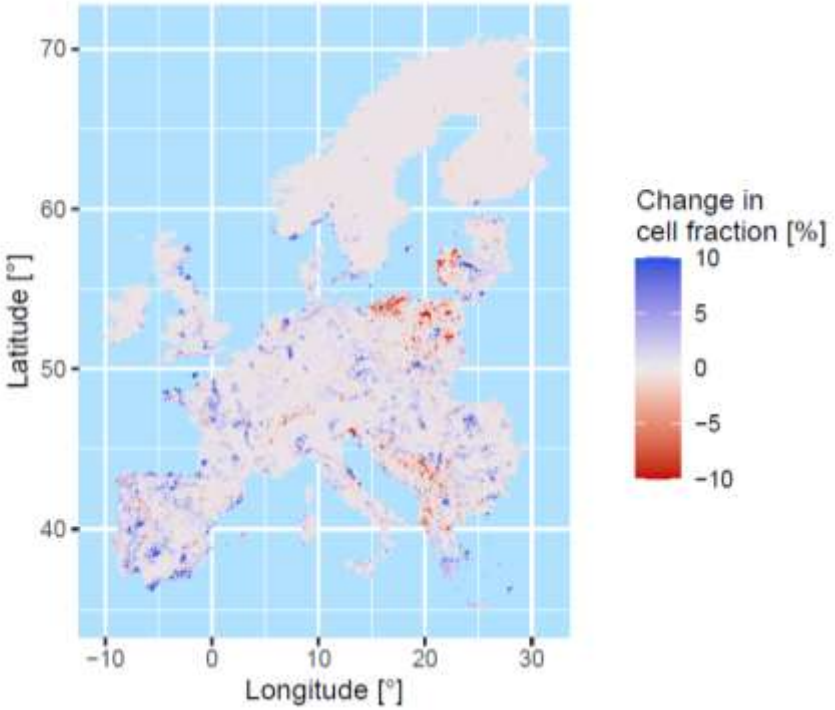
Future Land-use changes



- Paris goal met



- In a 3 to 4°C warmer World



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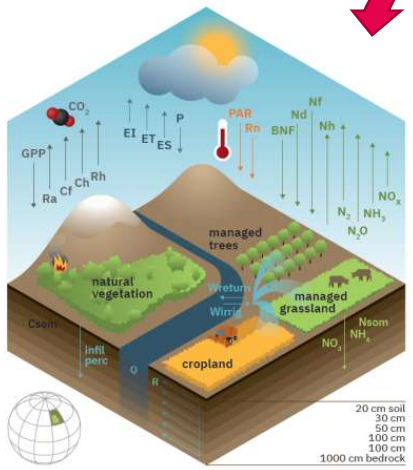
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Future changes in vegetation and burnt area

Applying the whole simulation framework

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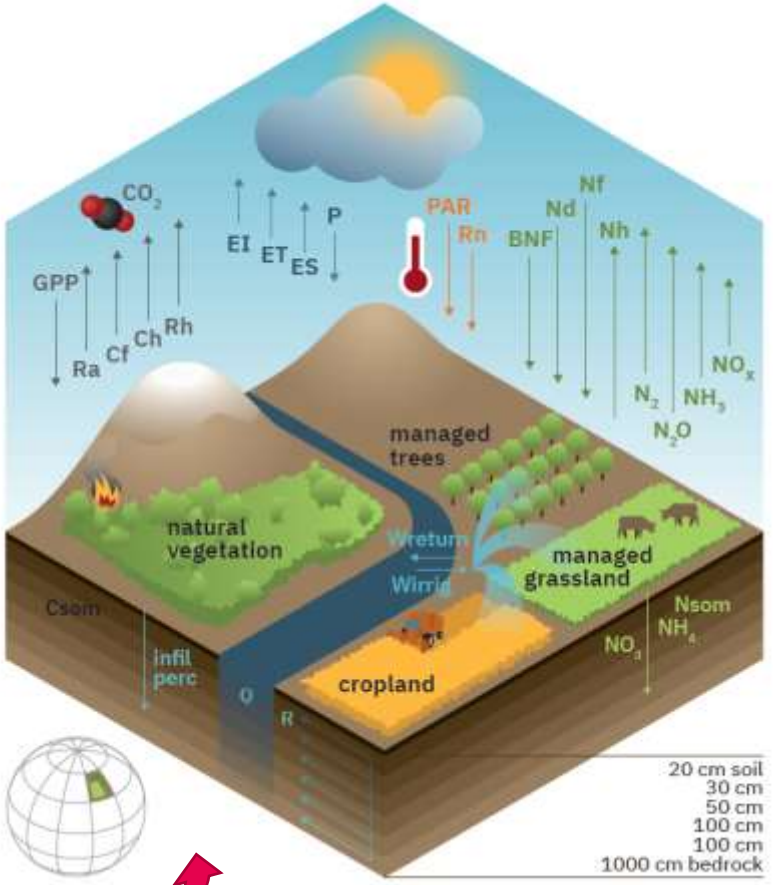
16/09/2024 | ET Demo event

Modelling changes in vegetation

LPJmL (Lund-Potsdam-Jena managed Lands)

- Requires climate & soil, land use input data
- Simulates vegetation changes and carbon fluxes
- Includes hydrological components

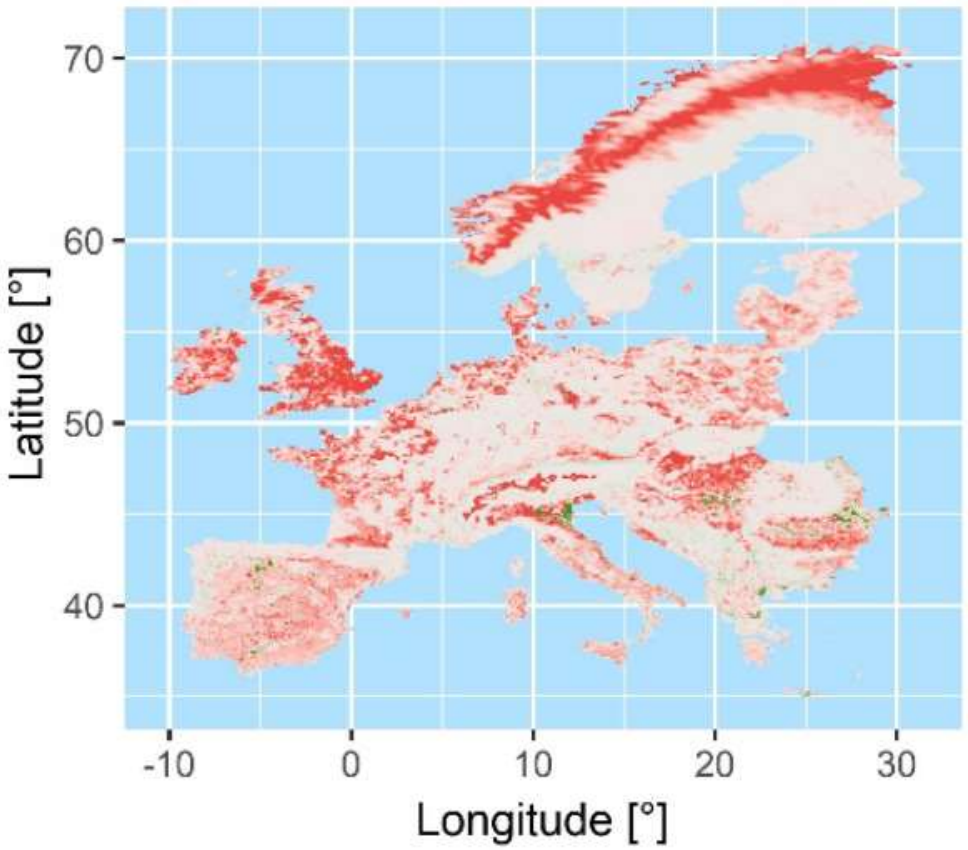
SPITFIRE



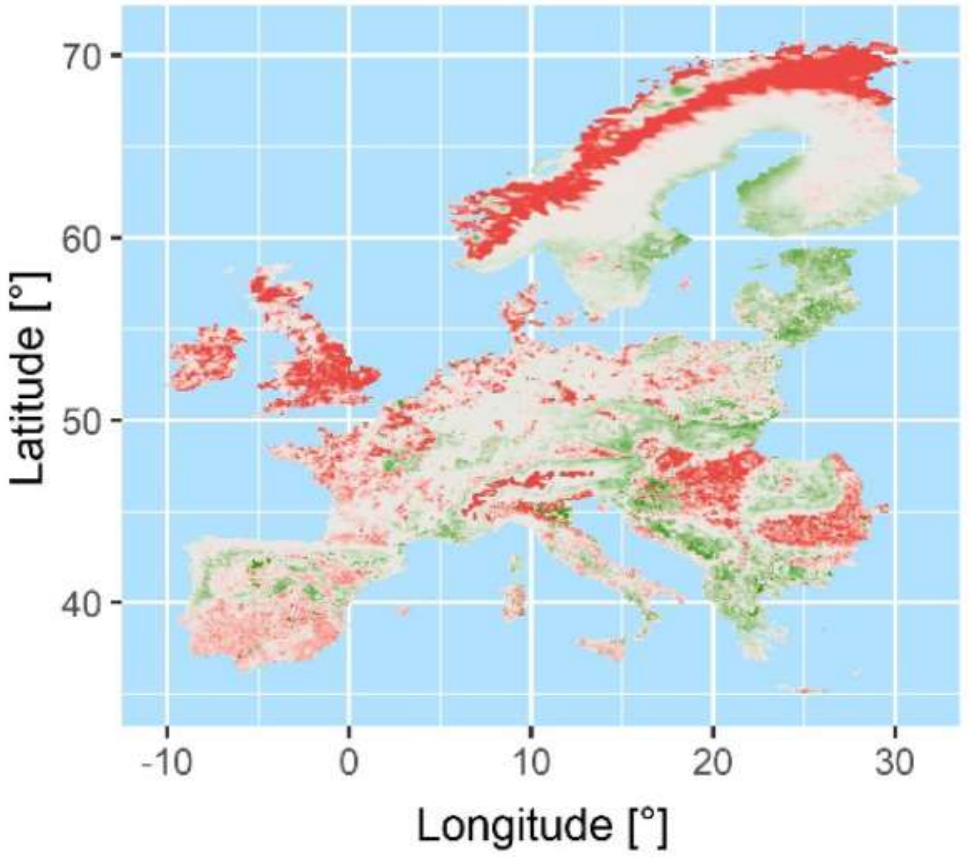
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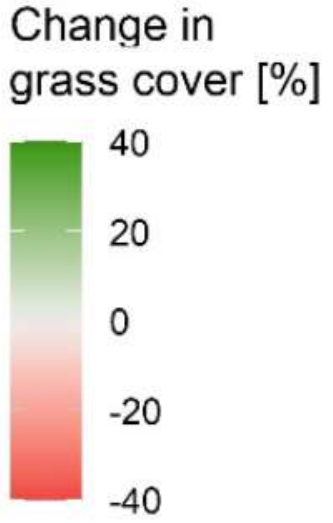
Changes in Grass cover

- Paris goal met



- In a 3 to 4°C warmer World





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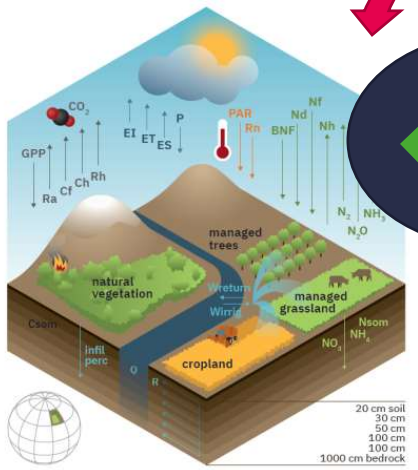
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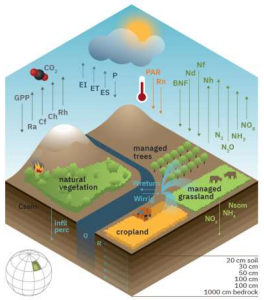
SPITFIRE

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Future projections

Changes in burnt area

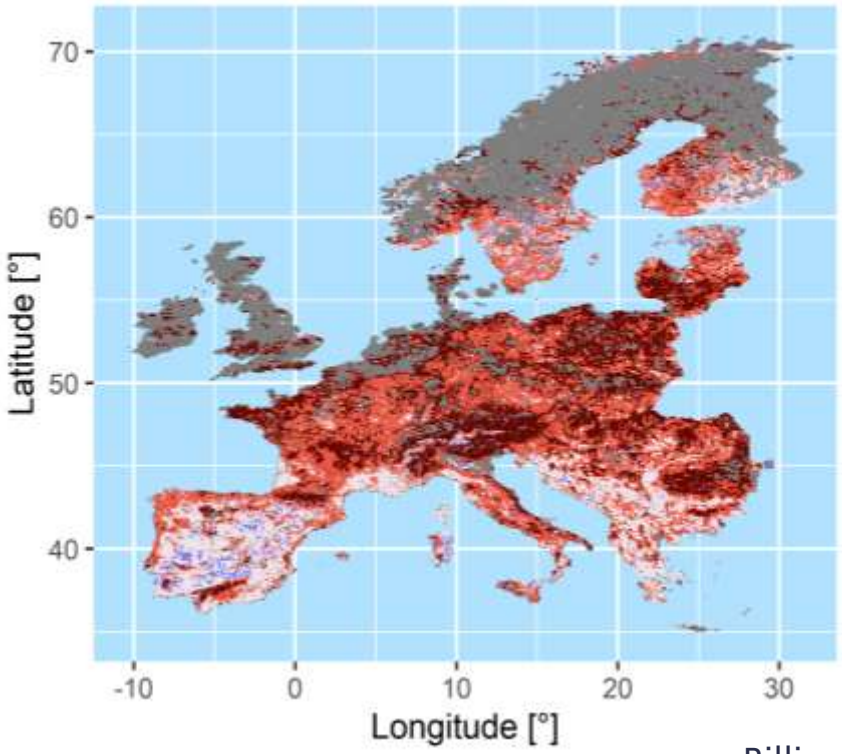
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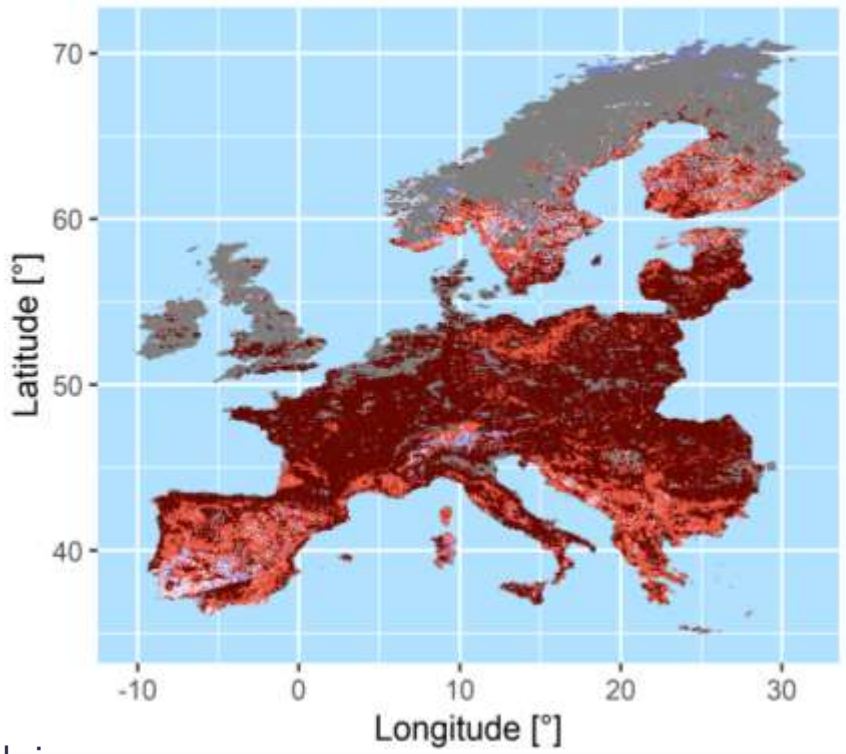
4. Relative change in area burnt (2000 – 2030 to 2070 – 2100)

- Be prepared in central and northern EU!
- More Fires in Southern EU under SSP3

SSP126 – Paris goal met



SSP370 - in a 3 to 4°C warmer world





Billing et al., in prep.

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5. Conclusion

1. Future fire situation in Europe will depend on success of global climate policy
2. Pathways “Paris goal met” OR “in a 3 to 4°C warmer world” decide about intensity of changes in vegetation and fire in the future
3. Europe: Future fire weather will increase, the fire season expand and become more extreme
4. Next step: investigate opportunities & limitations of fire adaptation through land management (fuel removal, fire fighting) in managed forests

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