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Earth Observation Products for Wildfires Monitoring and Forecast 2022

Oct 18-20, 2022

Fire management services for operational, tactical, and strategic decision-making

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Fire management

Recovery → Restoration & Adaptation

The aftermath of a wildfire requires rehabilitation of the burnt area. Immediate dangers include soil erosion and longer-term damage by invasion of exotic and invasive plant species.

Reduction → Prevention

a set of activities developed to mitigate and manage the start and spread of fires as well as navigation of legislation during implementation.

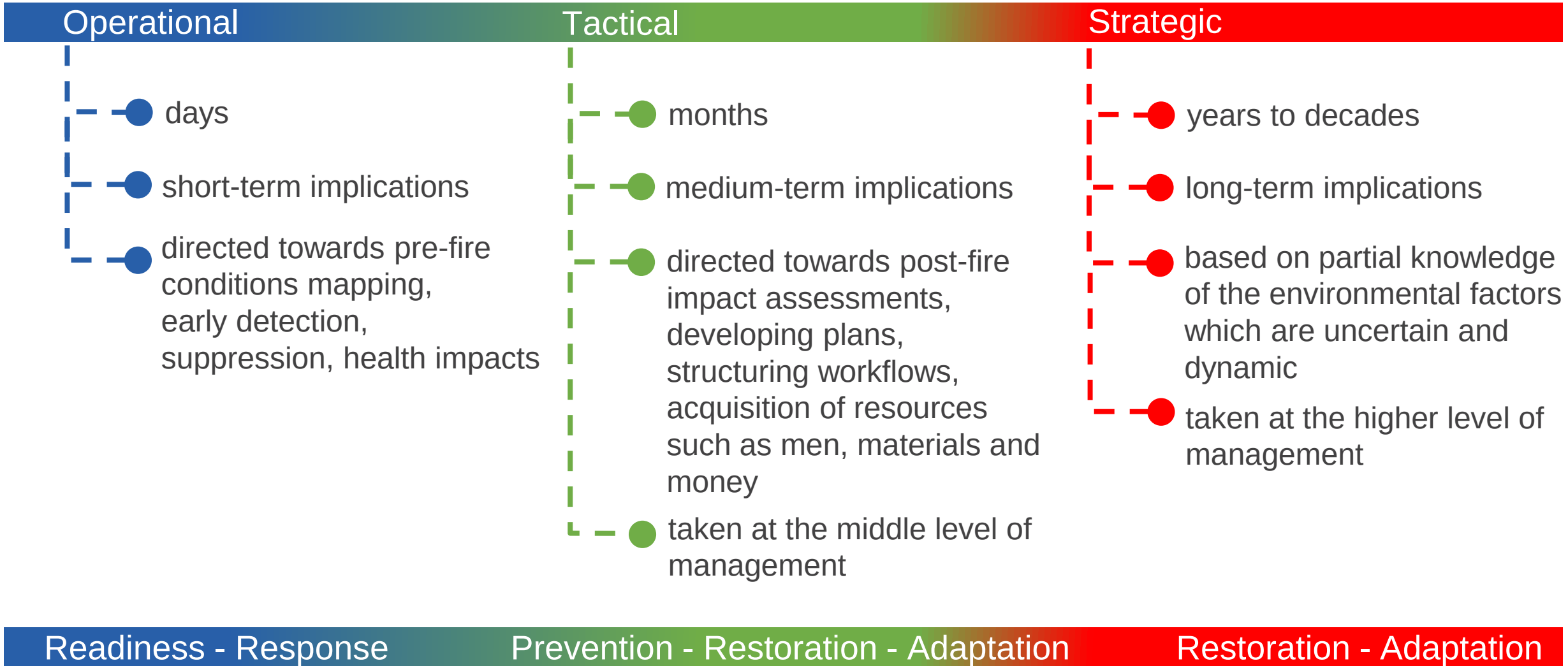
Response

a set of coordinated actions to bring the correct resources with accurate information to an unwanted fire without delay.

Readiness

Mitigate fire risk through planning, training, early detection and resource capacity.

The three categories of decision-making

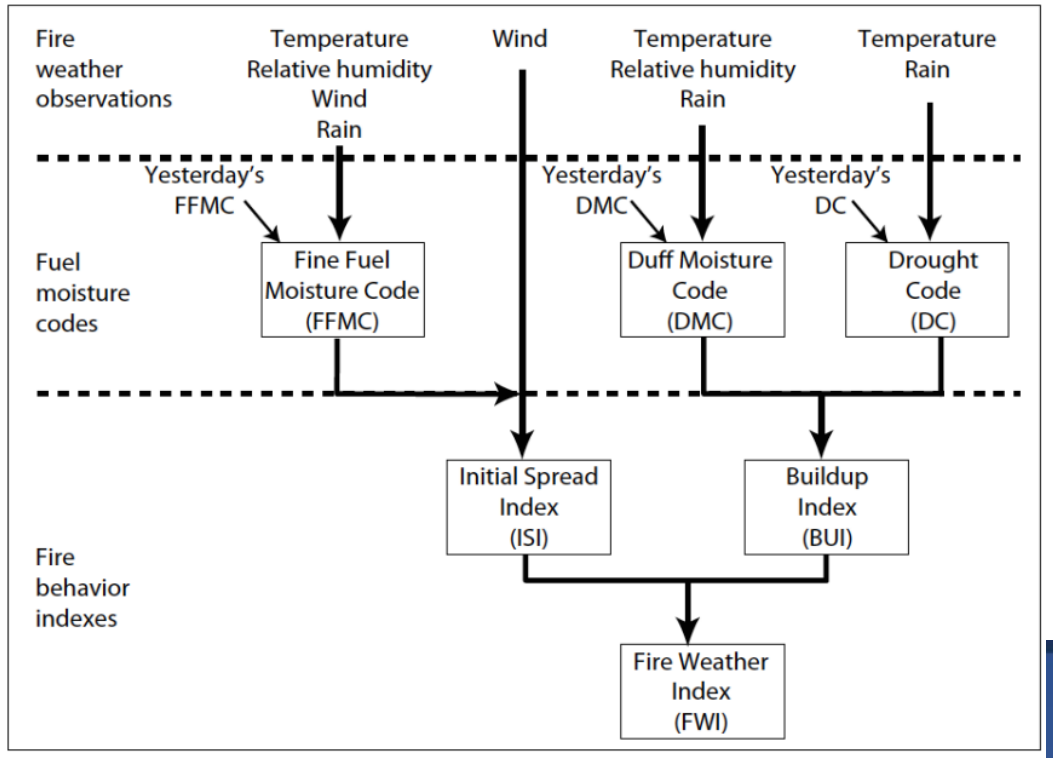


DM: Operational | FM: Readiness

Fire danger

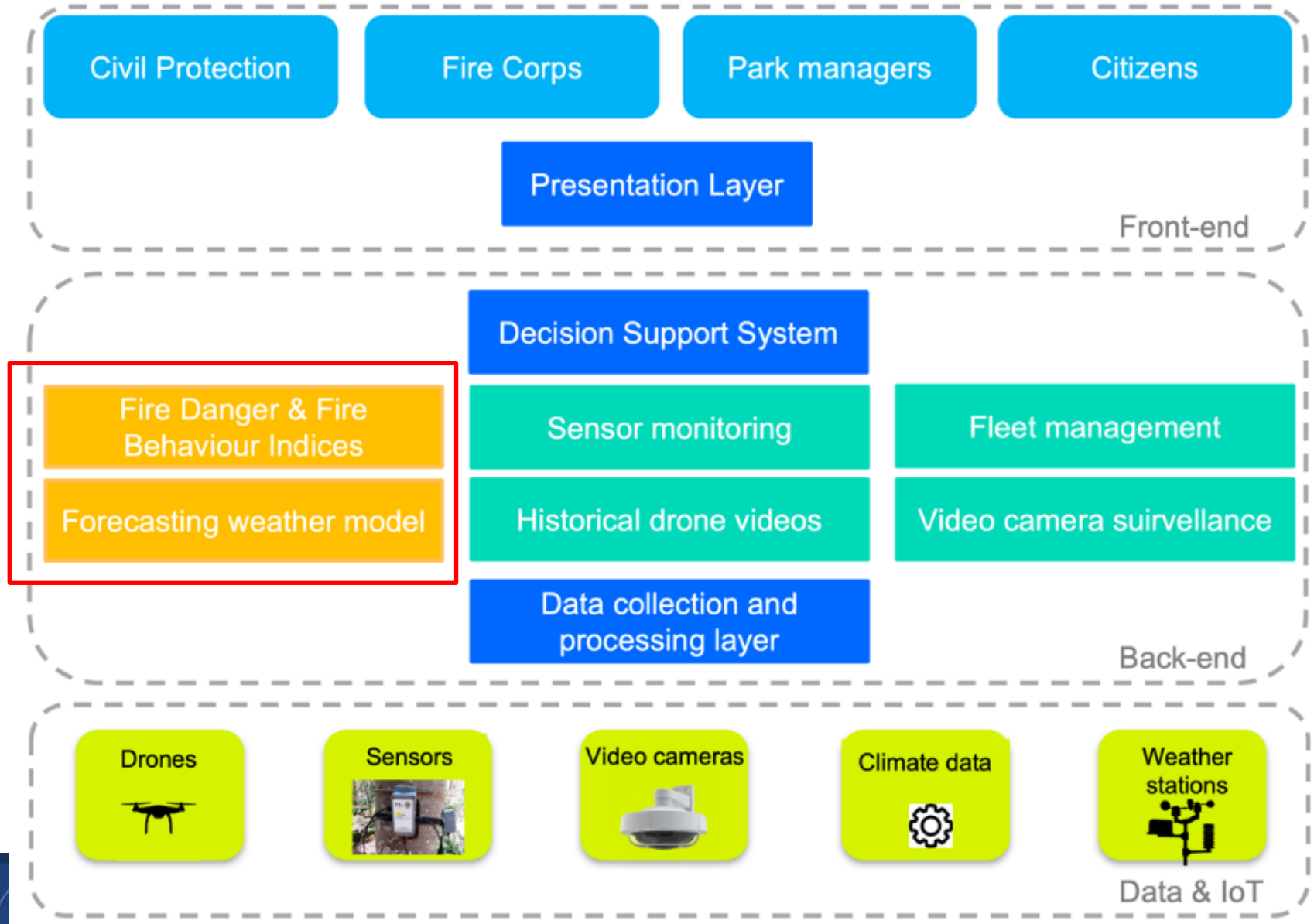
"A general term used to express an assessment of both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control, and fire impact."

- Allow fire managers, emergency responders and the public to identify periods of extreme fire danger, implement fire prevention measures, establish early response mechanisms and possibly reduce fire consequences



- Core of many early warning systems
- FWI used in EFFIS
- Rely solely in weather information

DM: Operational | FM: Readiness



Presentation layer represents the multi-faceted interface used by project stakeholders to access the platform.

Services layer performs complex operations on data coming from the data layer in order to feed services hosted in the Service sublayer

Hybrid data collection and processing layer devoted to data storage, management, filtering, and integration operations performed on the data received from the sources above

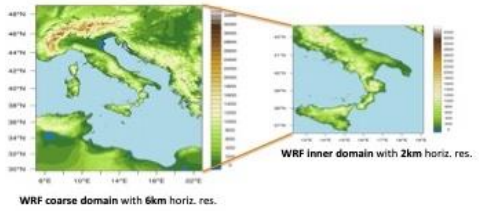
Data & IoT layer includes climate data and heterogeneous devices adopted as data sources.

DM: Operational | FM: Readiness & Response

Fire danger and potential fire spread and behaviour

High resolution weather modelling

Weather parameters



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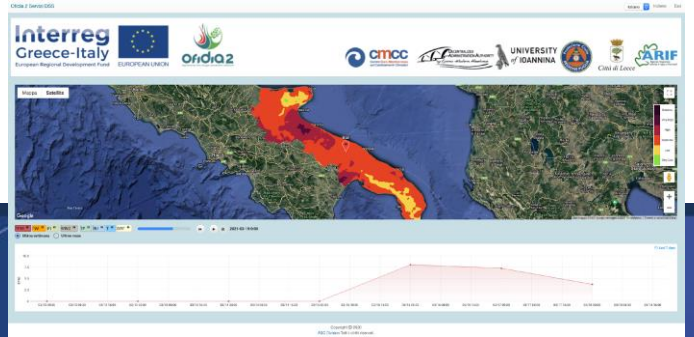
Supercomputing facilities

Fire danger forecasting

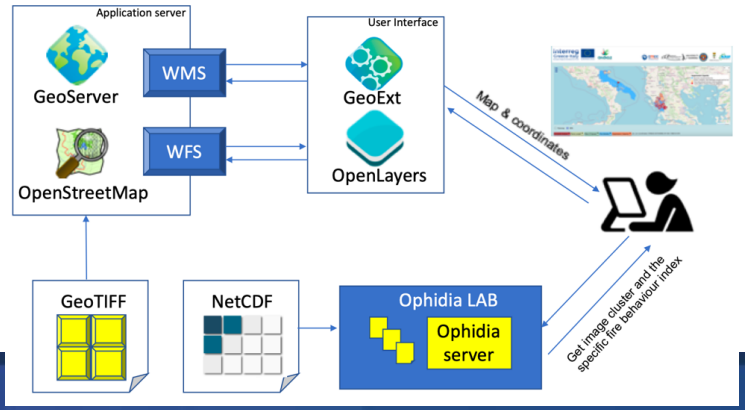
Fire danger indices & risk maps

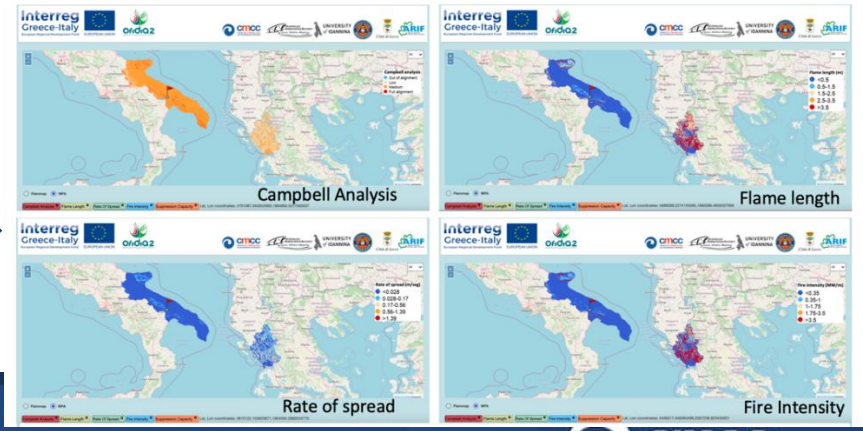


Fire simulation models calibrated over 3 historical fire using Visible Infrared Imager Radiometer Suite (VIIRS) information

Historical weather condition and past fires (>100ha)
-->**fire weather scenario**

Fire simulation models used in a probabilistic mode to assess key wildfire characteristics under different **fire weather scenario**





DM: Operational | FM: Readiness

Fuel moisture estimation

Decisive in the capacity of the vegetation to ignite and to propagate the fire

- Field work → costly and labour intensive, unfeasible for large areas
- Satellite observation

Empirical Models (EMs)

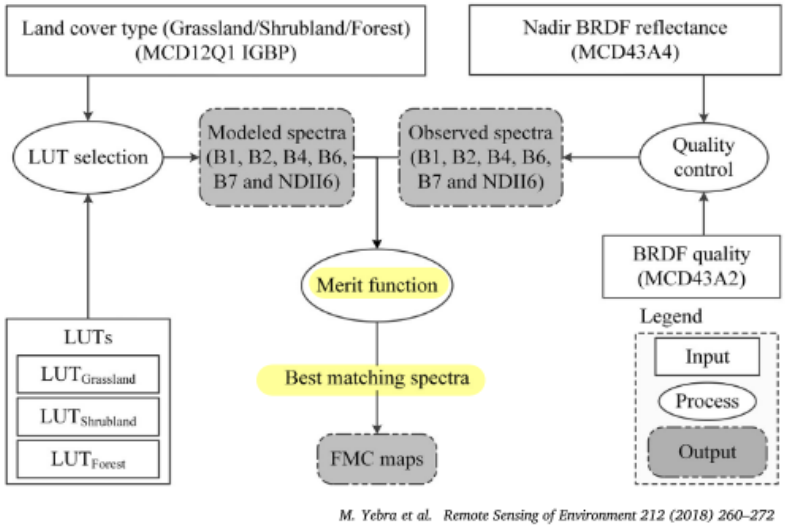
Statistical relations between **spectral indices** and **field measure of LFMC**

$$LFMC_{ij} = \alpha + \beta\, SI_{ij}$$

Case study sensitive
Easy calibration

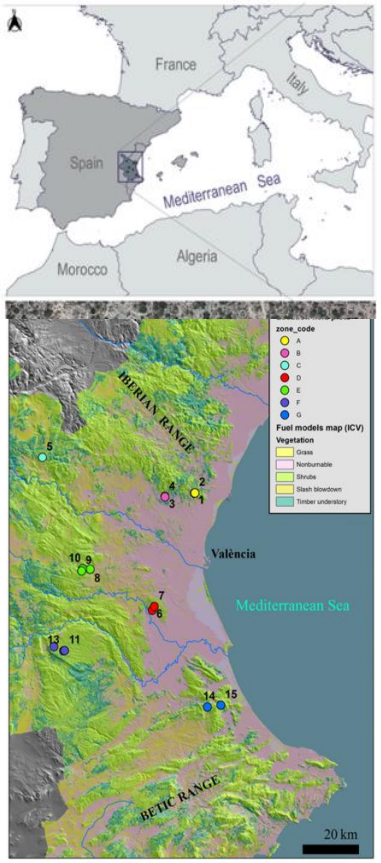
Radiative Transfer Models (RTMs)

Physical models **simulating plant reflectance** based on **water content** (among others)

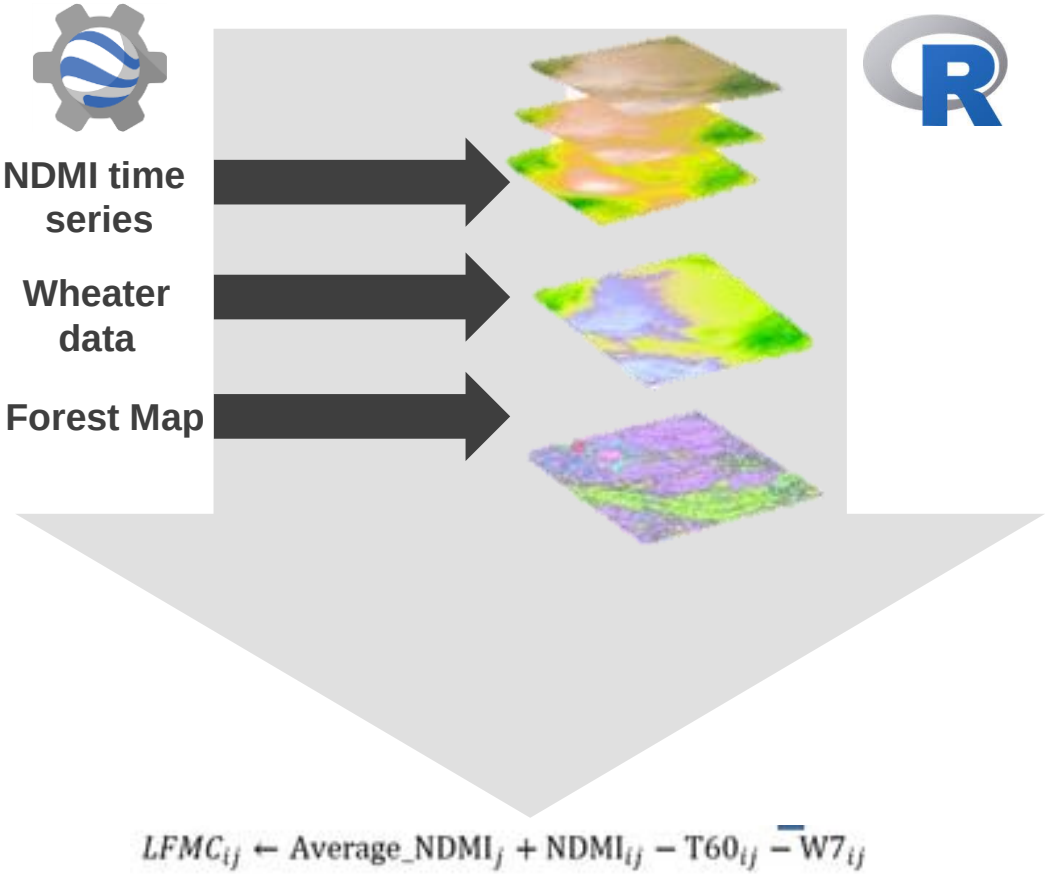


M. Yebra et al. Remote Sensing of Environment 212 (2018) 260–272

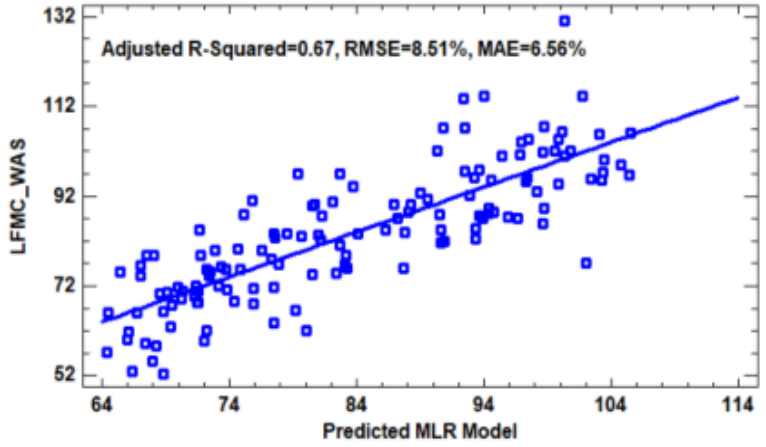
DM: Operational | FM: Readiness

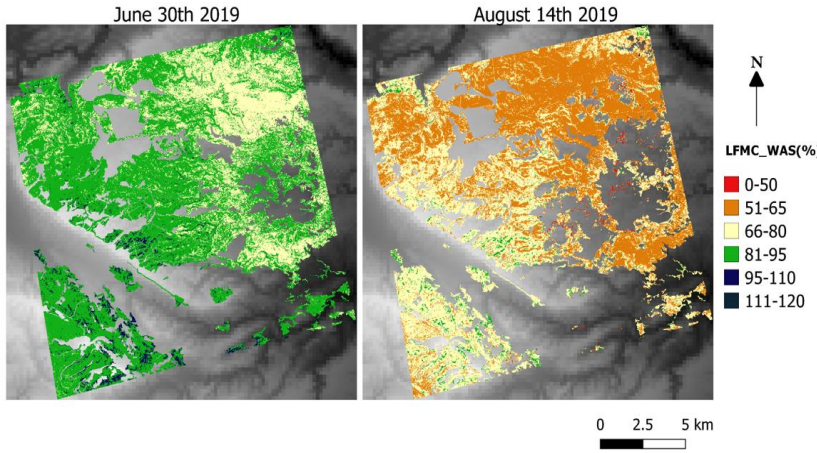


Workflow



$$LFMC_{ij} \leftarrow \text{Average\_NDMI}_j + \text{NDMI}_{ij} - \text{T60}_{ij} - \overline{\text{W7}}_{ij}$$



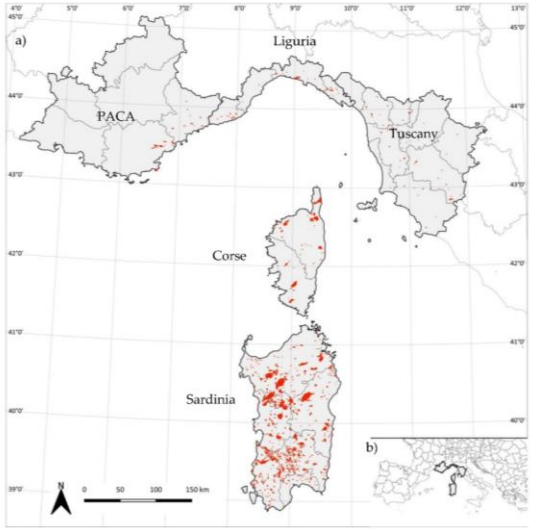


DM: Operational/Tactical | FM: Recovery

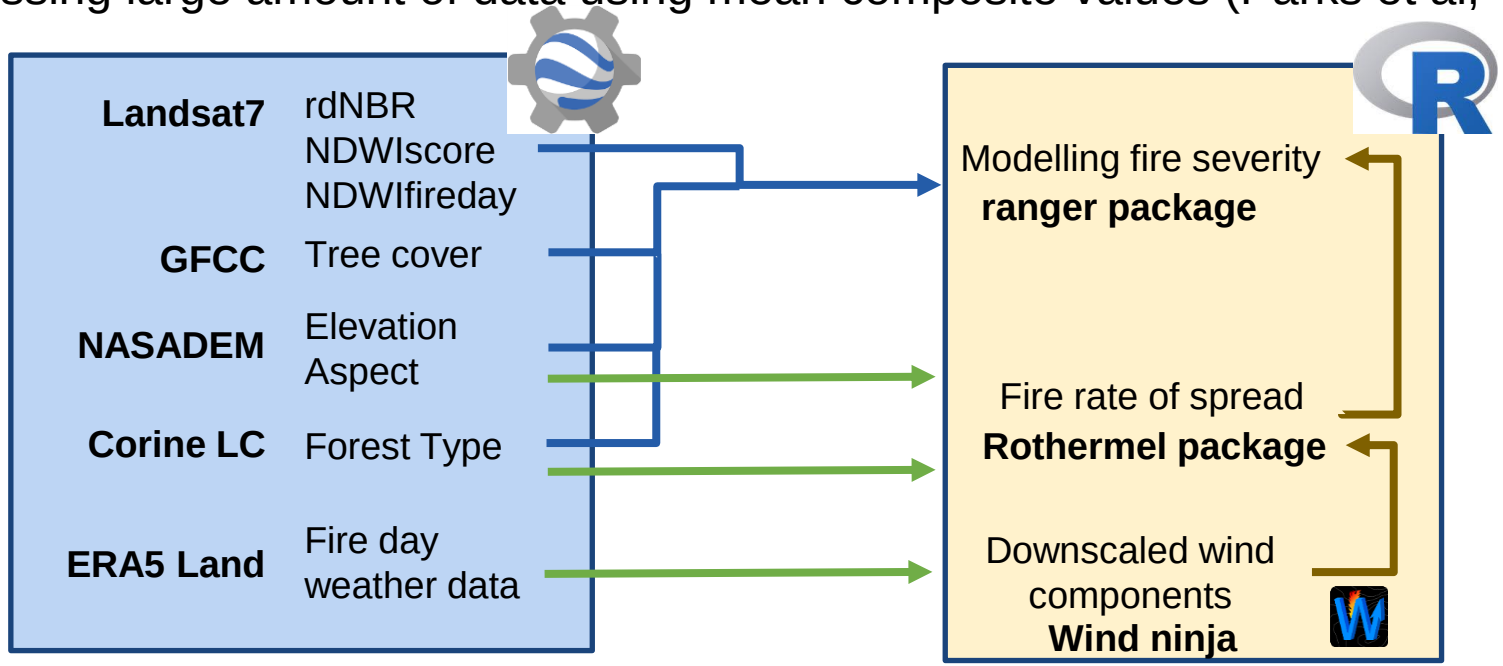
Fire severity

Impact of a fire on the ecosystem that is usually estimated from the amount of plant biomass consumed

- Fiel work → costly and labour intensive, limiting the result robustness
- Remote sensing (NBR and rdNBR) → time consuming downloading-processing, limited on a single fire event
- Google Earth Engine for processing large amount of data using mean composite values (Parks et al, 2018)

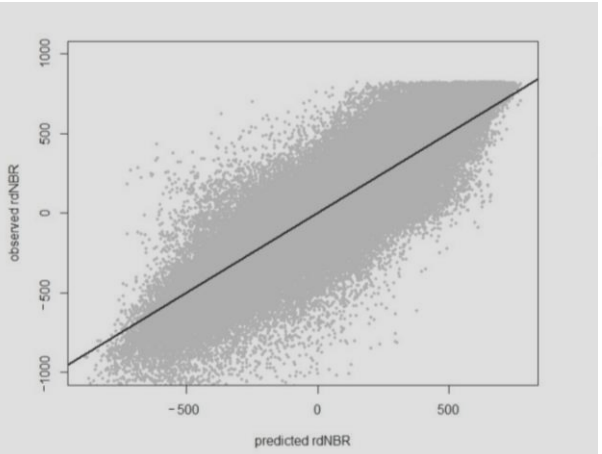


Fire perimeters of Sardinia, Corse, Tuscany, Liguria, Paca >25ha 2004-2017 (1139 fire events)

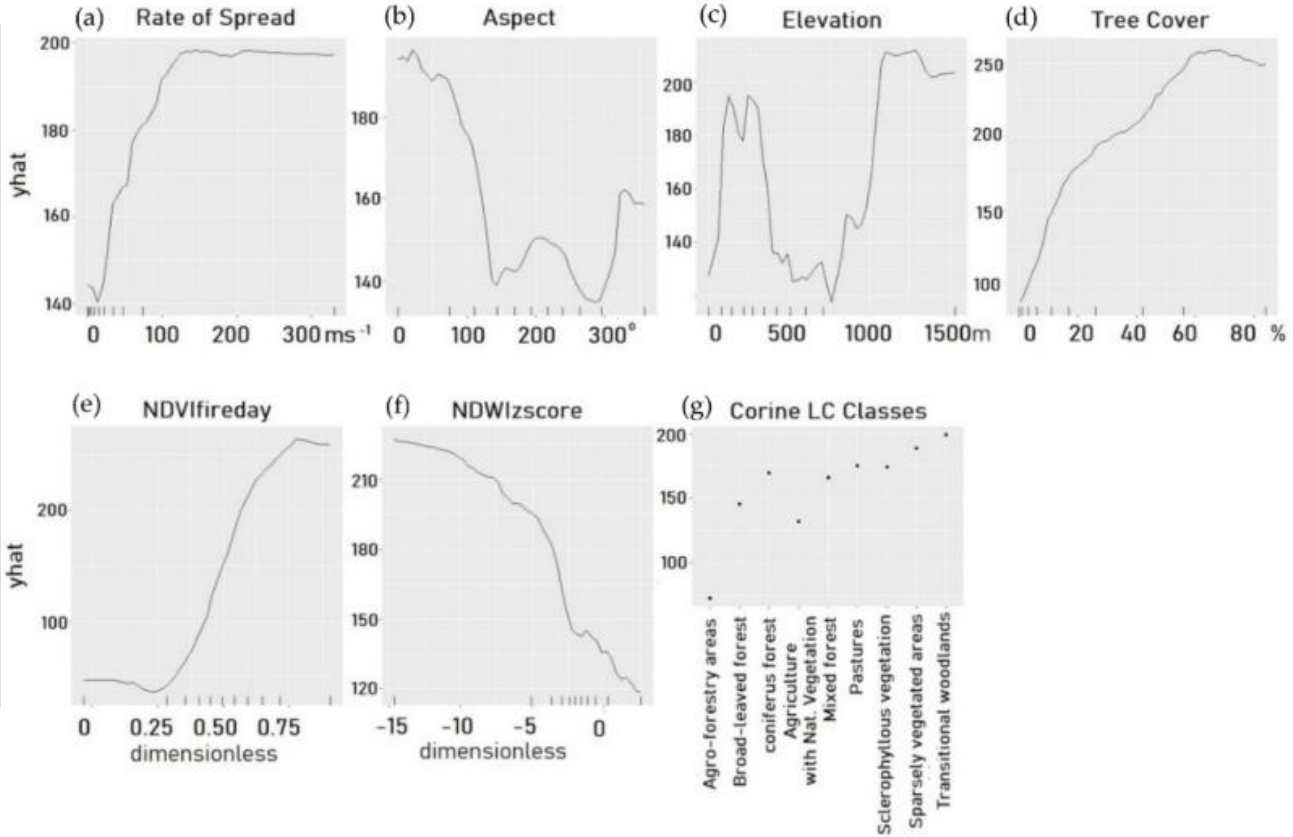


DM: Operational/Tactical | FM: Recovery

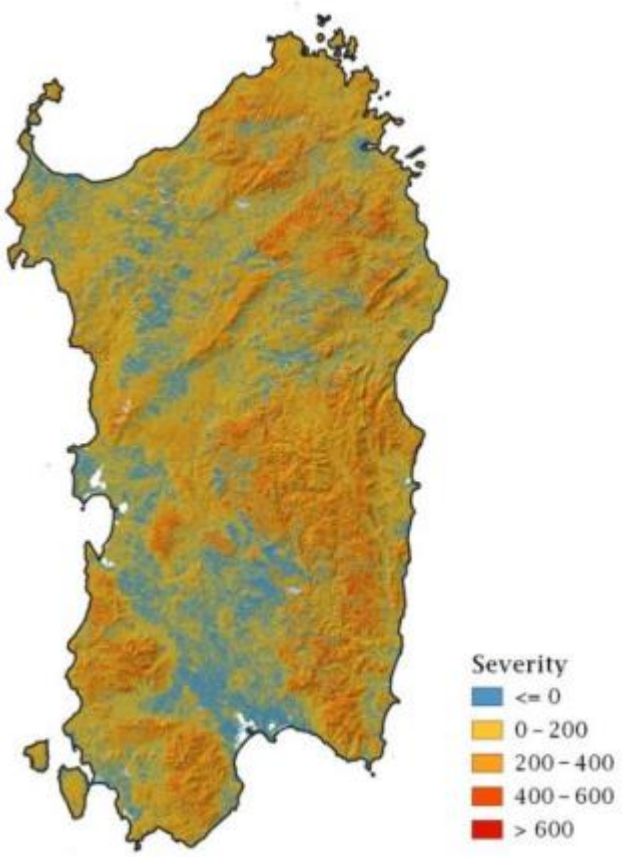
Fire severity



The rdNBR model explained 77% of the variance



The most important variables were tree cover and elevation, followed by the spectral indices NDVIfireday and NDWIzscore.



Potential fire severity for 19th august 2020

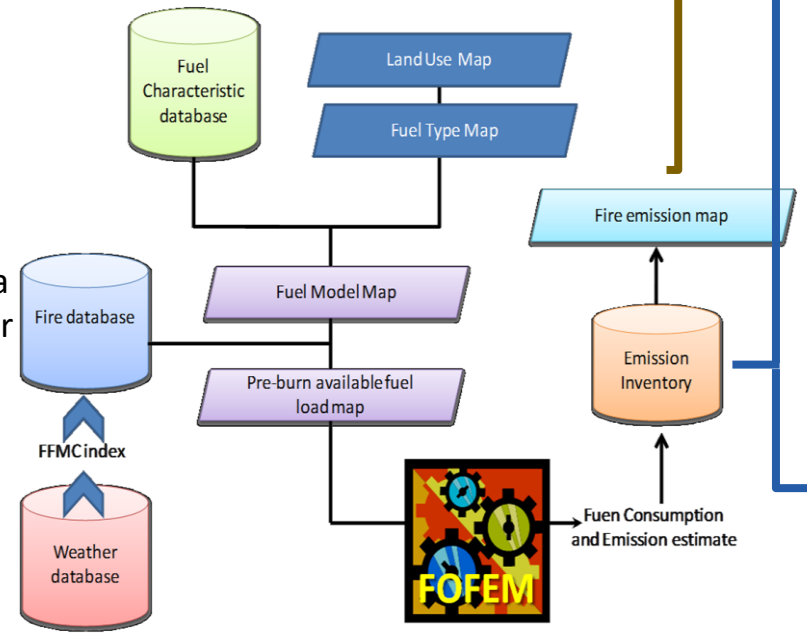
DM: Tactical | FM: Prevention/Adaptation

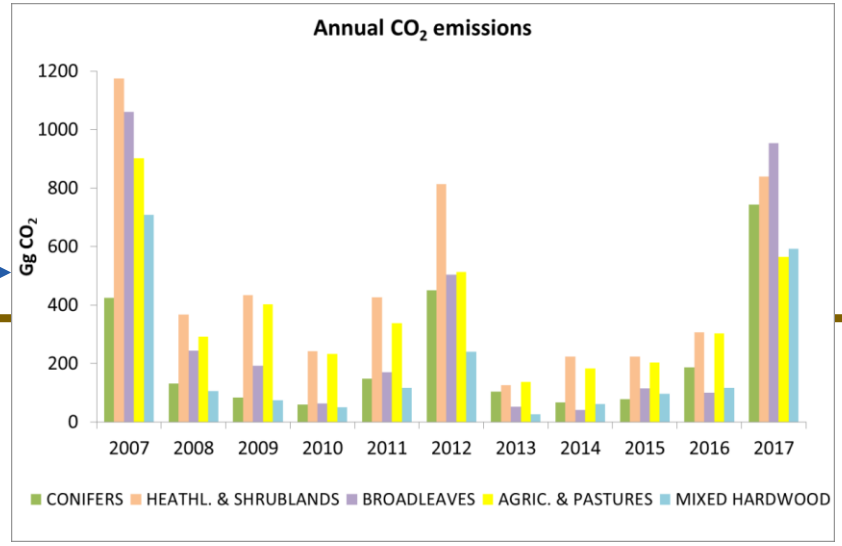
Fire emission

Corine Land Cover 2012 and the descriptive database (Ascoli et al., 2019)

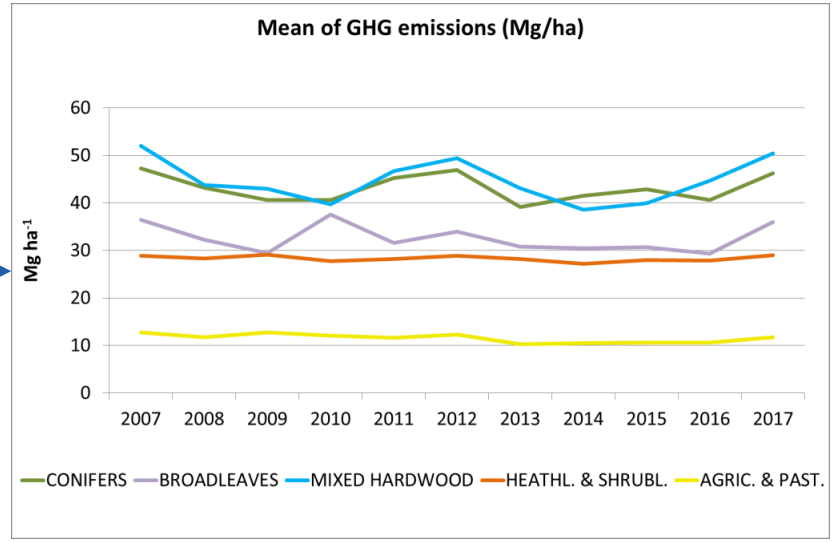
2007-2017 Data from the former Italian Forest Service

Era-Interim Reanalysis

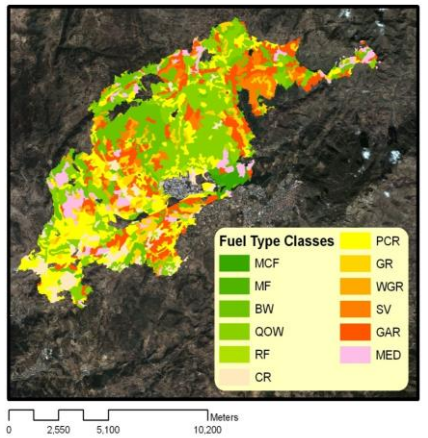


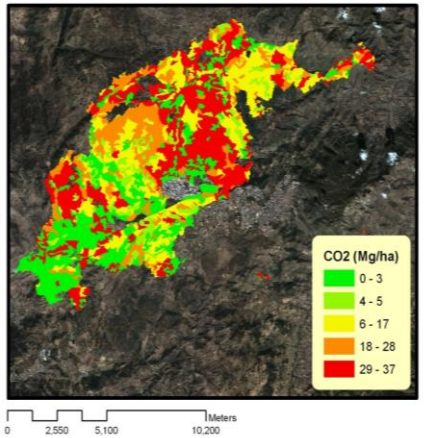


Annual CO_2 emissions (Gg) for the fuel types macro-categories



Annual total emissions (Gg) for the fuel types macro-categories





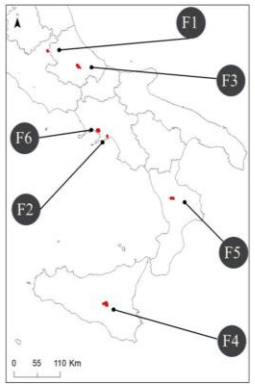
Nuoro fire (2007): Fuel type and CO_2 estimated emission (Mg ha^{-1})

Bacciu et al., 2019 AGU; Scarpa et al., 2020 PhD Thesis

DM: Tactical | FM: Prevention/Adaptation

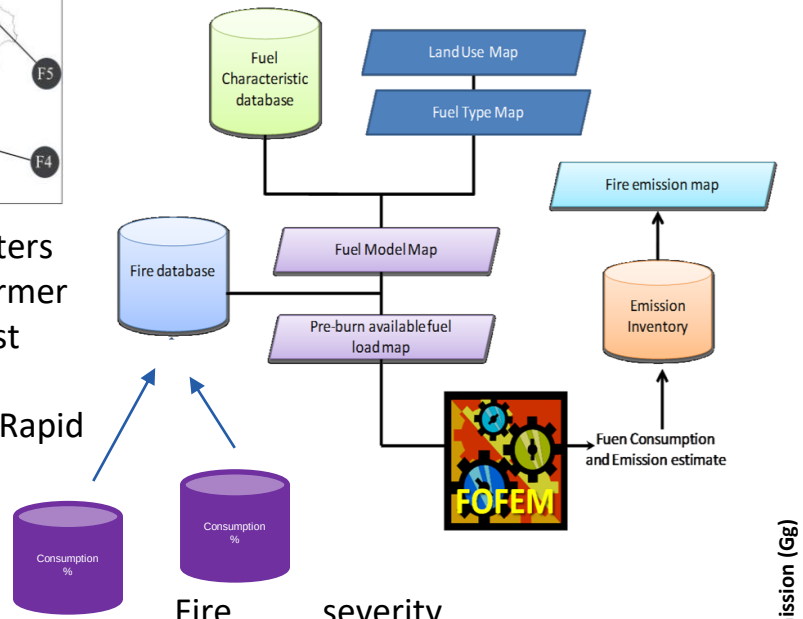
Fire emission

Compare product and approaches of burned area and combustion efficiency evaluating their impact on the GHG and particulate emission estimation.



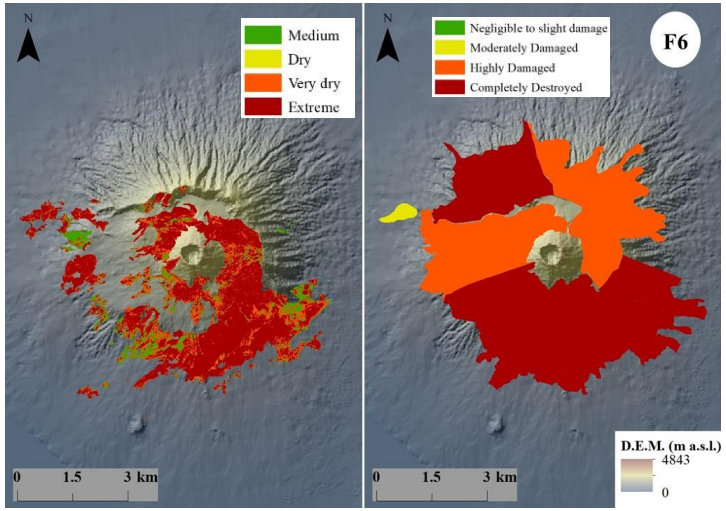
Fire perimeters from the former Italian Forest Service and Copernicus Rapid Mapping

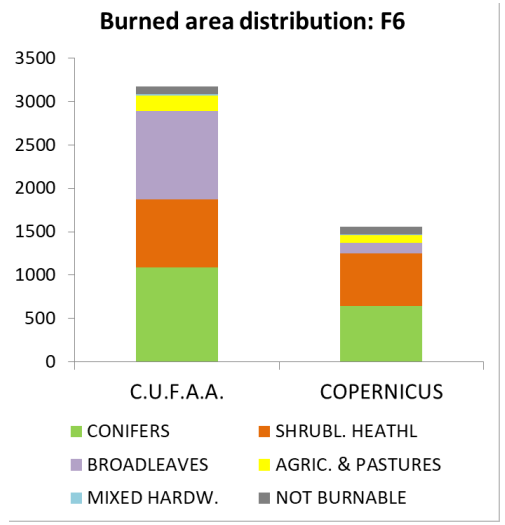
Corine Land Cover 2012 and the descriptive database (Ascoli et al., 2019)

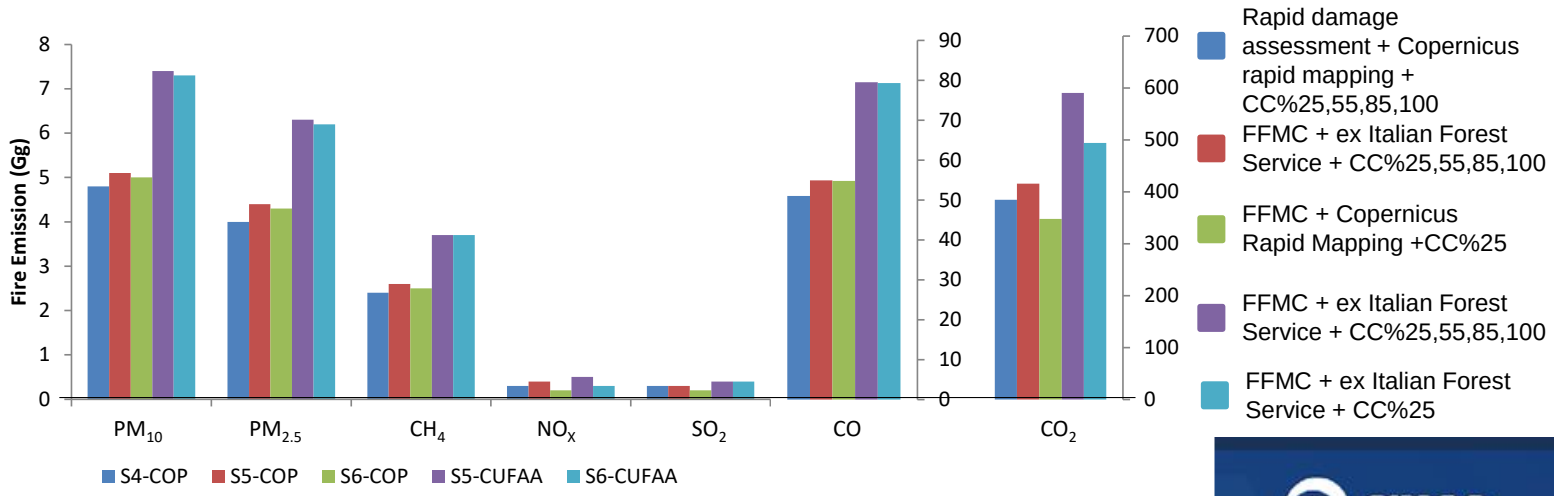


FFMC classes calculated through Era-Interim Reanalysis

Fire severity classes derived from the Rapid Damage Assessment







Bacciu et al., 2020 EGU; Scarpa et al., 2020 PhD Thesis

DM: Tactical | FM: Prevention/Adaptation

Seasonal forecast

Test climate service to inform and support tactic and strategic decision

Model: CMCC SPSv3 + ECMWF SEAS5
Hindcast years: 1993-2015
Ensemble: random selection of 40 members
Resolution: 1°
Lead time: 6-month (1° March – 1° May)
Variables: Tmax, Tmin, Tmean and precipitation, Wind
Validation: ERA5 – 0.25°

Data processing

▪Temporal aggregation (e.g. daily to monthly), ▪ time concatenation (i.e. forecasted period to the previous one), ▪ grid spatial clipping, ▪ climate indicator calculation (FWI), ▪ four post-processing techniques to correct model biases [CSTools]

Performance assessment

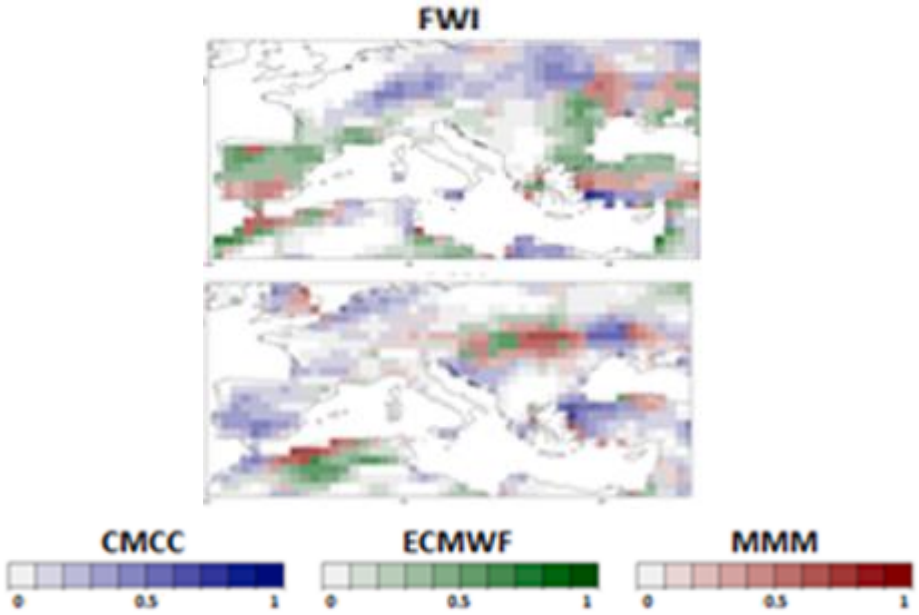
▪ Deterministic (ACC) and probabilistic scores (BCC)
▪ Tercile plots for out-of-the-norm events

Providing information and guidance to users of climate products evaluating main features, skills, and different post-processing techniques for data correction

Costa-Saura JM et al, *Agr. For. Met. 319 (2022) 108921*

DM: Tactical | FM: Prevention/Adaptation

Seasonal forecast



Anomaly correlation coefficient (ACC) between SPSs and ERA5 for both forecast start dates after QM corrections. The figure shows the greatest ACC among models and the multi-model mean (MMM).

Better skills concentrated over Balkans and SW corner of the domain

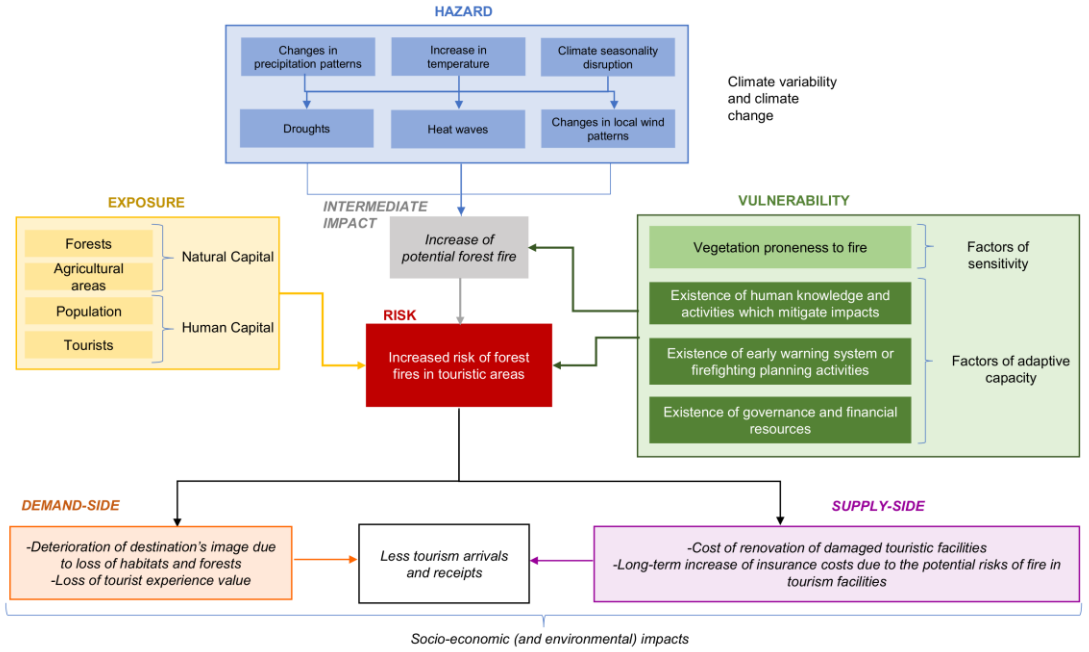
- Similar patterns of bias are observed across different start dates suggesting that systematic errors might be most likely linked to parameterization and model physics rather than initialization conditions
- Combining multiple SPSs might give better results because of accounting for multiple plausible solutions
- Forecasts start date might alter prediction skills and its geographical distribution with significant correlations
- Post-processing techniques such as DET and QM may generally provide results with correlation levels in line with raw data

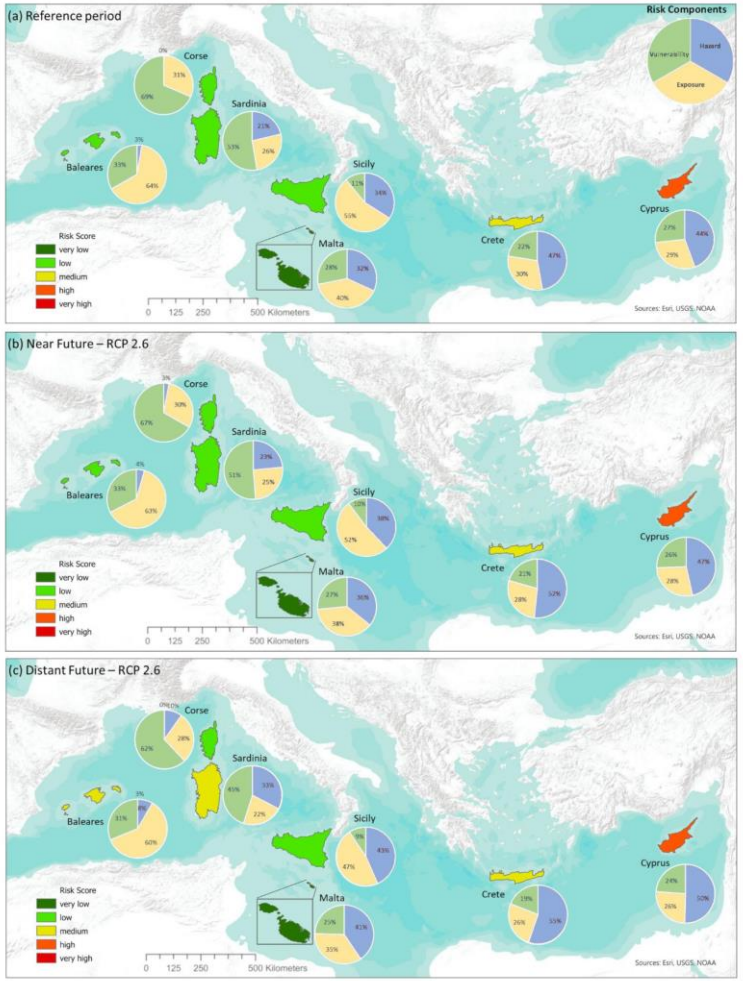
Increasing the understandings on systematic errors = increasing the robustness and consistency of predictions making final users more confident

DM: Strategical | FM: Adaptation

Support for adaptation planning

1. Identifying and selecting indicators;
2. data acquisition and management;
3. normalization of indicator data;
4. weighting
5. and aggregating of indicators;
6. aggregating risk components to risk;
7. presenting the
8. outcomes of the risk assessment.





Bacciu et al., *Sustainability* 2021, 13(18), 10004

… To conclude

- We discussed different fire management services tackling with the three classes of decision making and different fire management phases (from prevention to restoration and adaptation)
- Some products are already operative to guide early response and fire prevention; on other we, but also other institutions, are still working and exploring factors of uncertainties

- EO are key source of information for the different desion-making processes and phases of fire management
- EO are crucial for obtaining homogenous data since it makes it easy to cover large swathes of territory at systematic time intervals, providing a much more comprehensive spatial vision
- EO indispensable as a means of providing policymakers and environmental and sustainability managers with reliable information

… To conclude

- Need for training especially on the tactic and strategic decision making
- Need for strong interactions aimed at tailoring product and services to user needs
- Users expect to access a ready-to-use product, transformed from the raw EO data into usable information-> a critical aspect for transferability-> from RS experts to developers of services

- New easy-to-use platforms (e.g. GEE) can help in managing the large volume of available data and improving mechanisms of desion-making and can enable non-experts to understand the information generated from EO data.
- These new platforms might allow to use a huge amount of data enabling to calibrate robust machine learning models
- Further integration with totally different data products (e.g., climate data product such as seasonal forecast) might bring new opportunities for developing/improving forest services

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Thank you for your attention!