



IMFIRE

INTELLIGENT MANAGEMENT FOR WILDFIRES

Project Ref. PCIF/SSI/0151/2018

<https://adai.pt/imfire>

1st Year Results and Milestones

Carlos Viegas

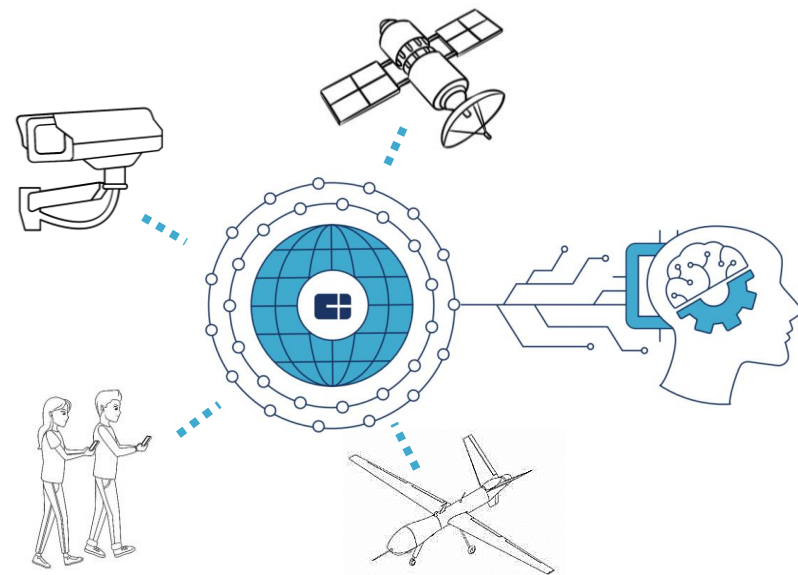
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IMFire project aims

Development of a **Decision Support System for Wildfire management**, combining **scientific knowledge** with state-of-the-art **artificial intelligence** tools:

- 1- **New fire behaviour and spread prediction models and windfield models** with the inclusion of extreme fire phenomena, and including **Machine Learning** and **Cloud Computing**;
- 2- Efficient mechanisms for **fetching remote data** from web sources (satellite, UAV and terrain) in combination with **Big Data** and **High Performance Computing (HPC)** tools.



IMFire outcome

Web-based platform, adaptable to any region in the world, suited for civil protection authorities for the integrated and intelligent management of wildfires, in their several stages:

- 1) **Prevention** – Accurate fire risk assessment;
- 2) **Planning** – Realtime accurate fire spread predictions;
- 3) **Combat** – Numerical and statistical analysis of possible combat strategies and their probability of success.

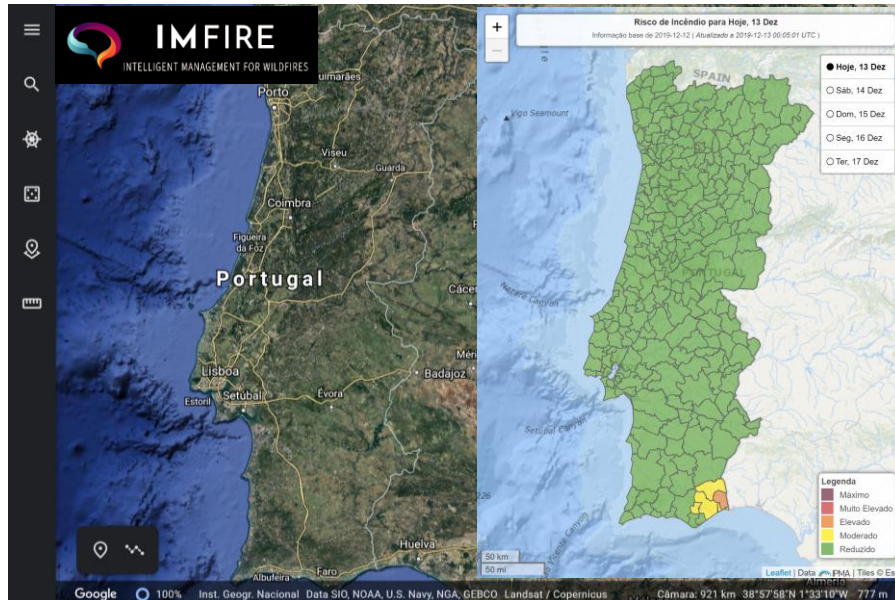


Prevention – Accurate fire risk assessment

Web-based platform
(Google Earth type front-end)

Algorithms
(FWI + Historical data + AI/ML)

Layers
(maps)



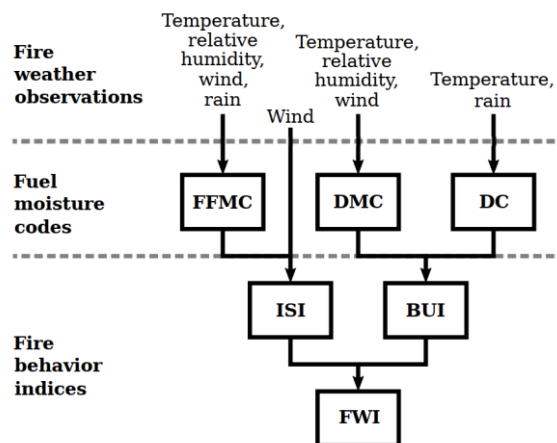
→ Calibrated fire risk index map

Prevention – Accurate fire risk assessment

Approach

FWI – Fire Weather Index

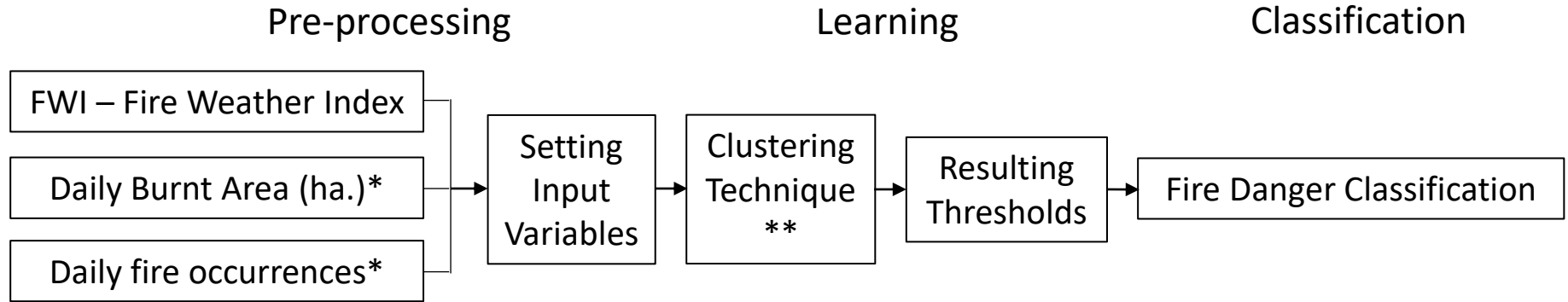
Fire Danger Classification



Danger Class	Canada (Van Wagner, 1987)	Europe (Joint Research Centre, 2020)
Very Low	$0 < FWI < 2$	$0 < FWI < 5.2$
Low	$2 \leq FWI < 5$	$5.2 \leq FWI < 11.2$
Moderate	$5 \leq FWI < 9$	$11.2 \leq FWI < 21.3$
High	$9 \leq FWI < 17$	$21.3 \leq FWI < 38$
Very High	$17 \leq FWI < 30$	$38 \leq FWI < 50$
Extreme	$FWI \geq 30$	$FWI \geq 50$

Prevention – Accurate fire risk assessment

Approach



*Data from 2006 to 2015
for 769 NUTS3 regions

**4 clustering methods:

KMS: k-means;

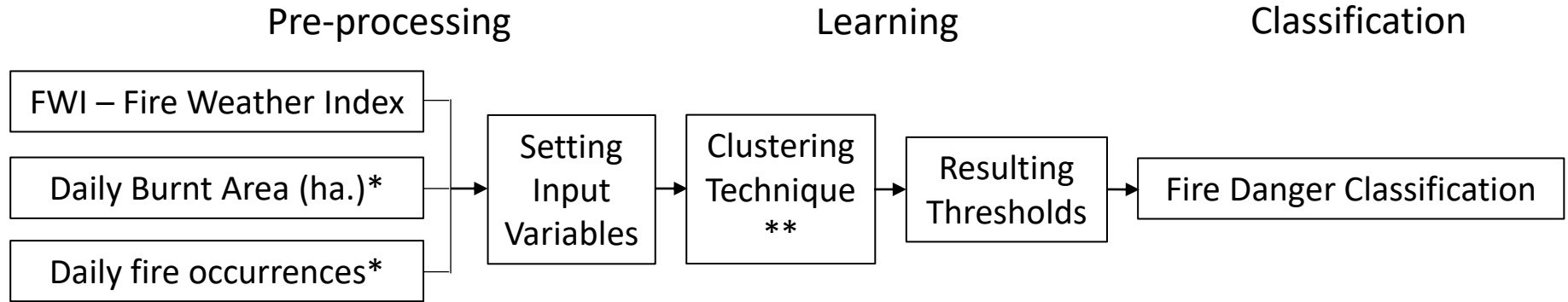
FCM: Fuzzy c-means;

GMM: Gaussian mixture models;

DCS: Data clouds

Prevention – Accurate fire risk assessment

Approach

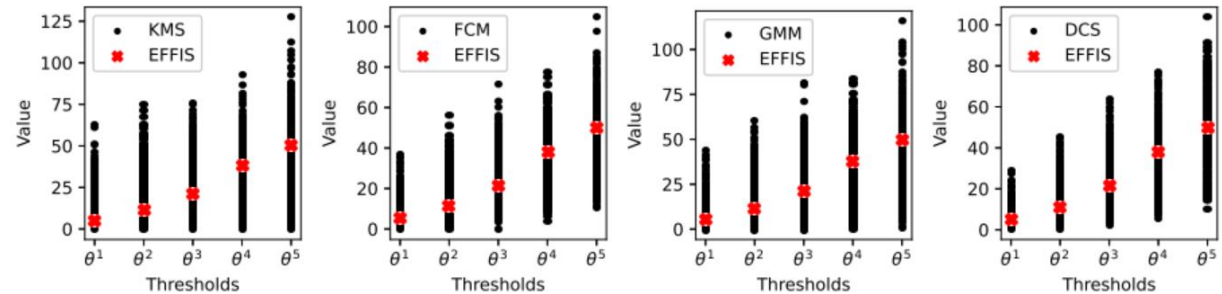


*Data from 2006 to 2015 for 769 NUTS3 regions

**4 clustering methods:

- KMS:** k-means;
- FCM:** Fuzzy c-means;
- GMM:** Gaussian mixture models;
- DCS:** Data clouds

*** **EFFIS** European Forest Fire Information System



Prevention – Accurate fire risk assessment

Approach - Validation

Validation 1: Evaluating days with burnt area B.A. ≥ 1000 [ha]

Validation 2: Evaluate the 10% of the total days with the highest burnt area values

Days with fire danger classes of "Very High" or "Extreme" are **correctly classified** if associated with large wildfires

Season	T.O.	Validation 1					EFFIS	Validation 2				
		Clustering technique				EFFIS		Clustering technique				EFFIS
		KMS	FCM	GMM	DCS			KMS	FCM	GMM	DCS	
Hot	max	80.59	48.71	47.42	22.40	58.68	66.45	42.99	52.61	38.72	32.20	
	mean	86.71	65.17	73.88	71.61		71.60	52.15	58.57	49.49		
Cold	max	56.00	36.65	30.39	11.18	2.35	63.49	28.58	37.16	38.89	28.49	
	mean	60.00	45.16	44.49	27.06		63.08	32.66	43.01	28.11		

Prevention – Accurate fire risk assessment

Achievements

Conference paper:

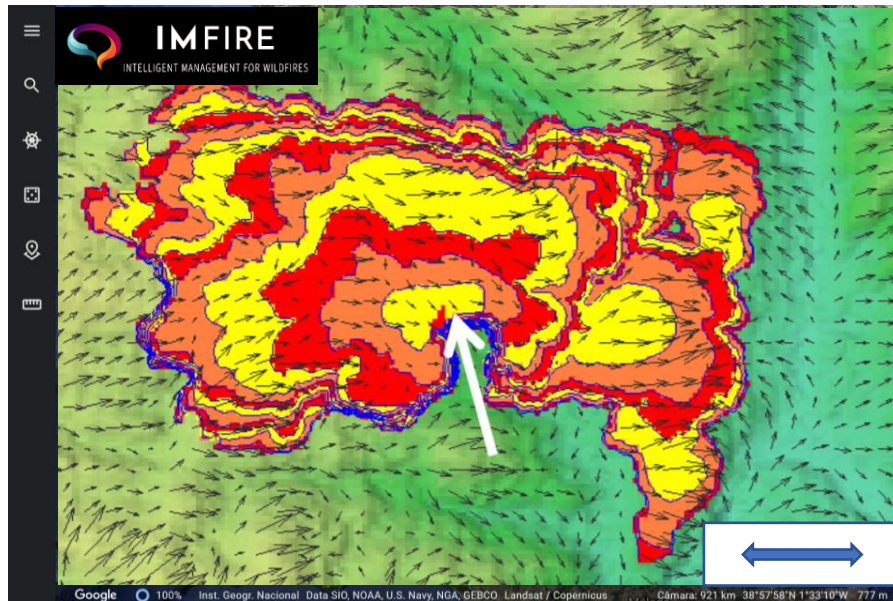
Júnior, J. S., Paulo, J., Mendes, J., Alves, D., & Ribeiro, L. M. (2020, December). Automatic Calibration of Forest Fire Weather Index For Independent Customizable Regions Based on Historical Records. In **2020 IEEE Third International Conference on Artificial Intelligence and Knowledge Engineering (AIKE)** (pp. 1-8). IEEE.

Journal paper:

Jorge S. S. Júnior, João Ruivo Paulo, Jérôme Mendes, Daniela Alves, Luís Mário Ribeiro and Carlos Viegas, "Automatic Forest Fire Danger Rating Calibration: Exploring Clustering Techniques For Regionally Customizable Fire Danger Classification", **Expert Systems With Applications** [Under Review]

Planning – Realtime accurate fire spread predictions

Web-based platform (Google Earth type front-end)



Algorithms

(Real-time data

+

Propagation Models

+

Wind field Models

+

Extreme Fire Behaviour Models

+

AI/ML)

Layers

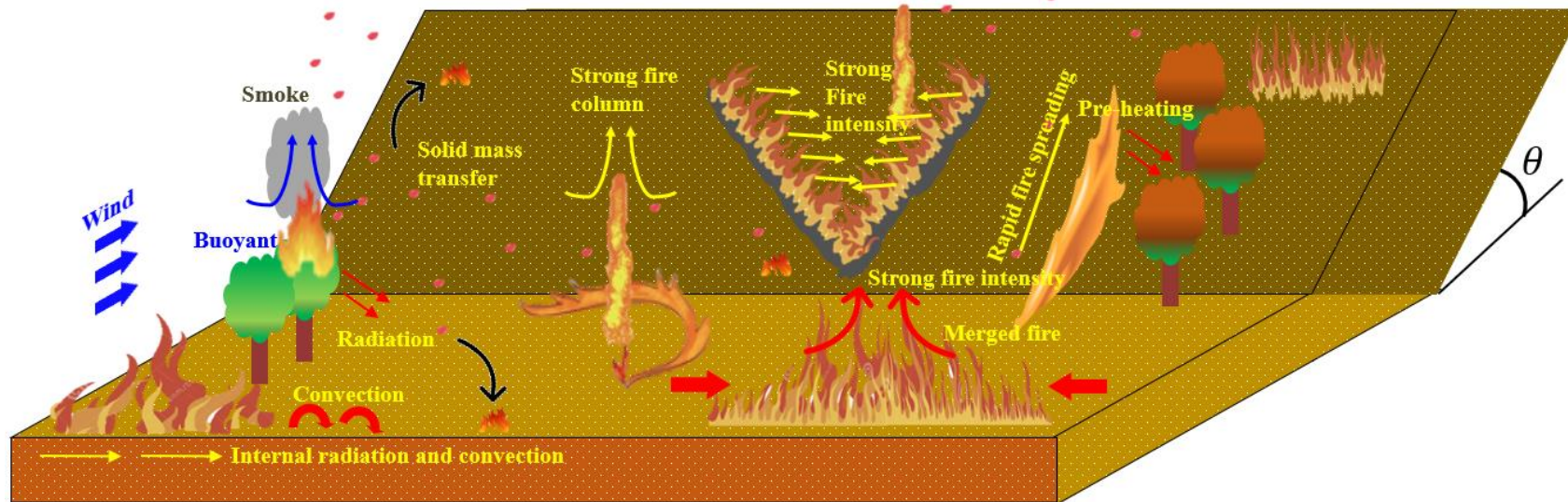
(maps)

Fire propagation
prediction



Planning – Realtime accurate fire spread predictions – Fire Propagation Models

Approach



Planning – Realtime accurate fire spread predictions – Fire Propagation Models

Approach

Simulator	Surface Fire Model	Crown Fire Model	Spotting Model	Wind Simulation Model	Response to changes in fire environment
FARSITE	Rothermel (1972)	Rothermel (1991) Van Wagner (1977)	Albini (1979)	No, Need 3 rd party tools	Limited
Flam Map	Rothermel (1972)	Rothermel (1991) Van Wagner (1977)	N/A	N/A	N/A
BehavePlus	Rothermel (1972)	Thomas (1963) Rothermel (1991) Van Wagner (1977) Finney (1998)	Albini (1979) Chase (1981)	N/A	N/A
Phoenix Rapid fire	CSIRO grassland fire spread model McArthur Mk5 forest fire model	N/A	Yes, Deterministic spotting model	N/A	Yes

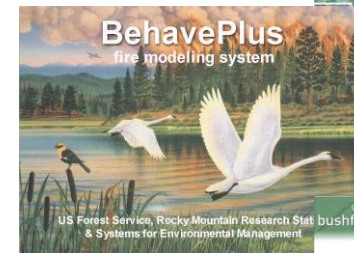


Figure 160. PHOENIX RapidFire: Opening page listing disclaimer and terms of use.



Planning – Realtime accurate fire spread predictions – Fire Propagation Models

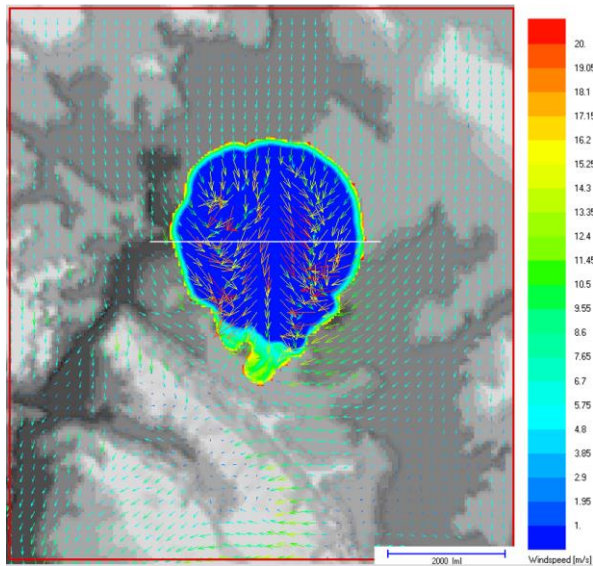
Approach

Simulator	Surface Fire Model	Crown Fire Model	Spotting Model	Wind Simulation Model	Response to changes in fire environment	Fire Whirl	Eruptive Fire	Merging Fire	Junction Fire
IMFire	Rothermel (1972)	Rothermel (1991) Van Wagner (1977) Finney (1998)	Albini (1979) Chase (1981)	Nuatmos 2D Canyon 3D	Yes	Yes	Yes	Yes	Yes
FARSITE	Rothermel (1972)	Rothermel (1991) Van Wagner (1977)	Albini (1979)	No, Need 3 rd party tools	Limited	N/A	N/A	N/A	N/A
Flam Map	Rothermel (1972)	Rothermel (1991) Van Wagner (1977)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BehavePlus	Rothermel (1972)	Thomas (1963) Rothermel (1991) Van Wagner (1977) Finney (1998)	Albini (1979) Chase (1981)	N/A	N/A	N/A	N/A	N/A	N/A
Phoenix Rapid fire	CSIRO grassland fire spread model McArthur Mk5 forest fire model	N/A	Yes, Deterministic spotting model	N/A	Yes	N/A	N/A	N/A	N/A

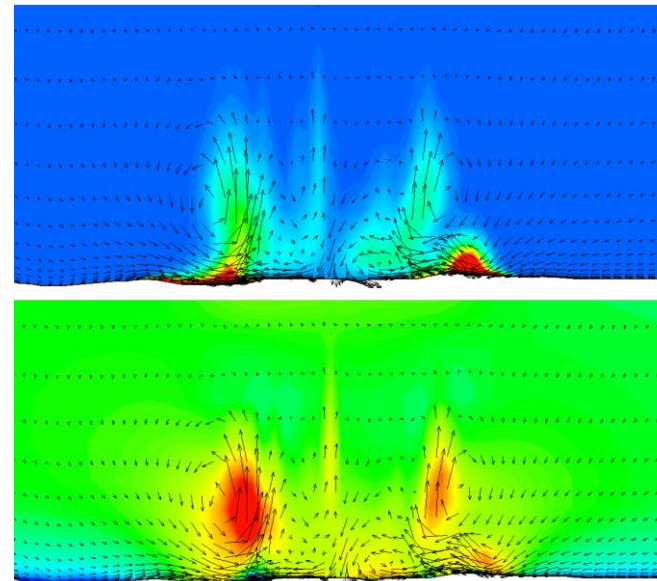
Planning – Realtime accurate fire spread predictions – 3D Wind Field Models

Approach

- Fire and wind field interact in a complex manner, due to buoyancy effects created by the fire heat release
- Navier-Stokes solvers are the way to capture the influence that fire plays on the wind field.
- The two-way coupling between wind and fire should be wisely managed to keep calculation times amenable



Fire shape and wind field 10m above ground. Fire region is coloured according to rate of heat release. White line represents the transect used.



Temperature and Velocity Magnitude Field on a vertical plane perpendicular to incident wind direction, passing through fire shape centre

Sources: (Lopes AMG et al., 2017) (Lopes AMG et al., 2019)

Planning – Realtime accurate fire spread predictions

Achievements



IMFire API Status: Beta Online

- *For integration of advanced fire simulations in existing decision support platforms*
- *Inputs: ignition coordinates, local wind data (optional)*
- *Automatically fetches local wind data from IPMA, fuel and topography map data from own database*
- *Returns: fire perimeter for every 15 min (shape files/raster/vector)*

Journal paper:

Viegas, X., Raposo, J., Ribeiro, C., Reis, L., Abouali, A., Ribeiro, L., Viegas, C. On the Intermittent Nature of Forest Fires Spread, submitted to the **International Journal of Wildland Fire** [under review]

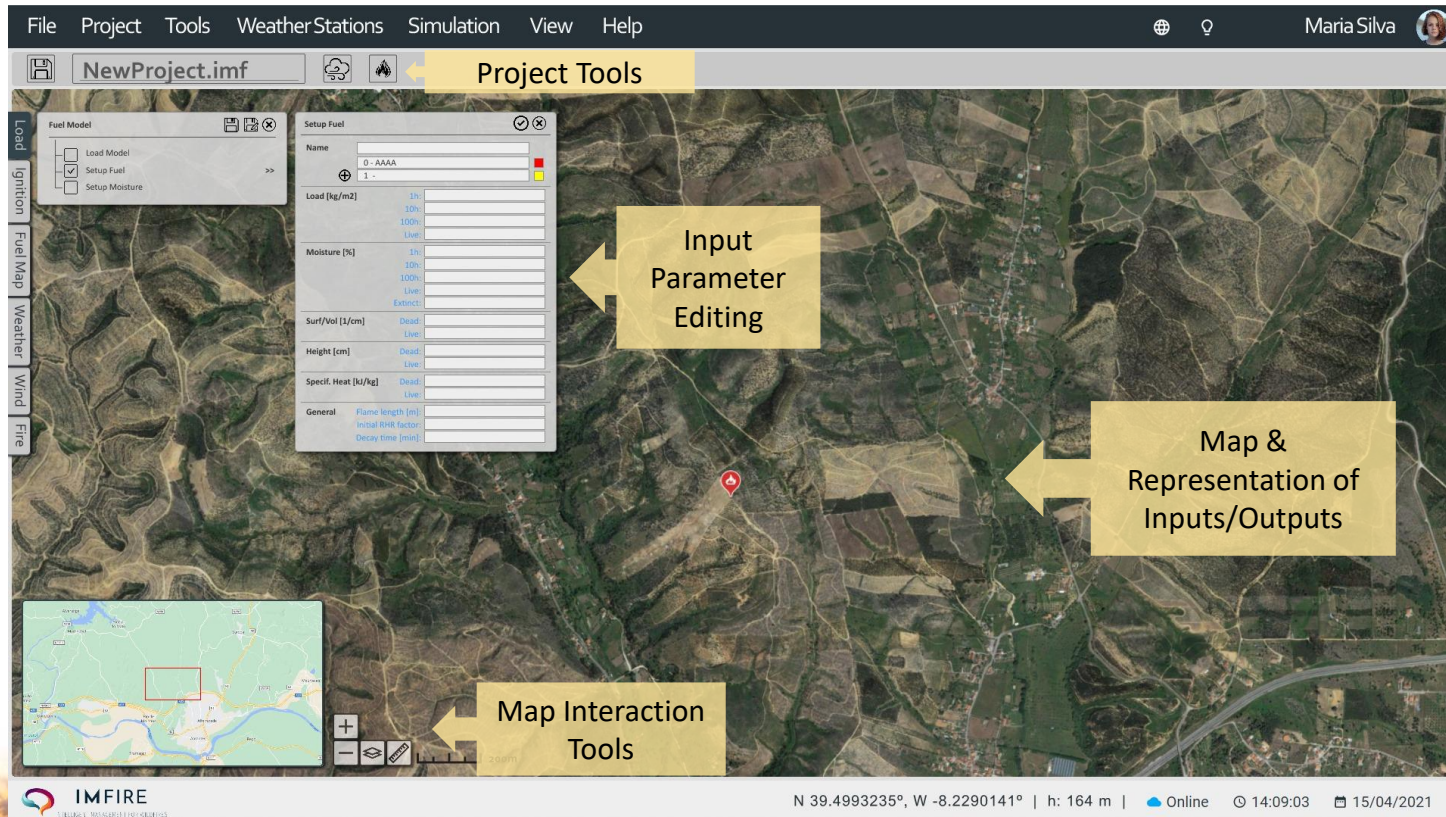
Planning – Realtime accurate fire spread predictions

Achievements



IMFire Platform Status: Beta under development

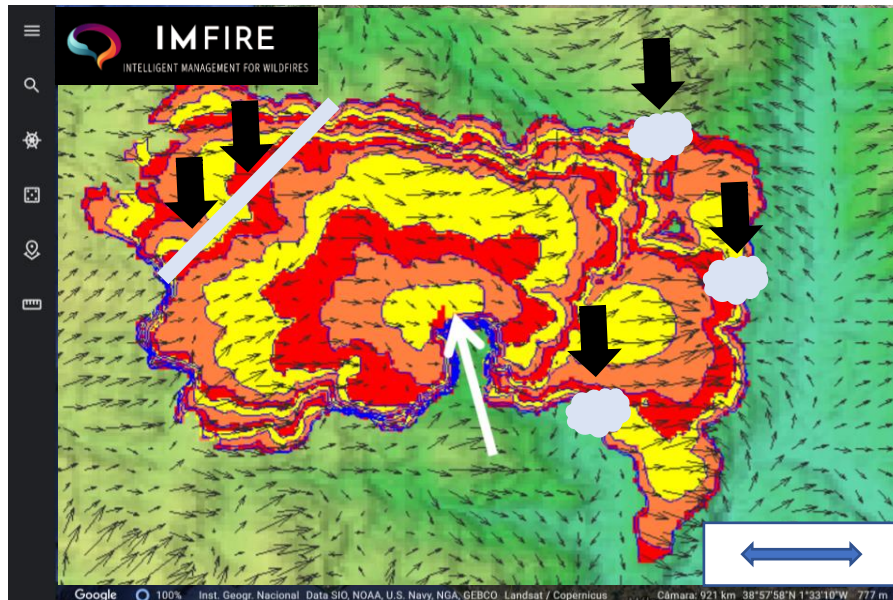
- *Soon to be released for testing by partner entities – www.imfire.pt*



The screenshot displays the IMFIRE software interface. At the top, there is a menu bar with 'File', 'Project', 'Tools', 'Weather Stations', 'Simulation', 'View', and 'Help'. Below the menu is a toolbar with icons for file operations and simulation. The main window shows a satellite map of a landscape with a red location pin. A 'Setup Fuel' dialog box is open, allowing for parameter editing. The dialog includes fields for Name, Load (kg/m²), Moisture (%), Surf/Vol (l/cm), Height (cm), Specif. Heat (kJ/kg), and General settings like Flame length, Initial RRK factor, and Decay time. A vertical toolbar on the left contains icons for Fuel Model, Ignition, Fuel Map, Weather, Wind, and Fire. A smaller map in the bottom-left corner shows the current map's location within a larger regional context. Annotations with yellow arrows point to the 'Setup Fuel' dialog box (labeled 'Input Parameter Editing'), the main satellite map (labeled 'Map & Representation of Inputs/Outputs'), and the bottom-left map (labeled 'Map Interaction Tools').

Combat – Numerical and statistical analysis of possible combat strategies and their probability of success

Web-based platform (Google Earth type front-end)



Algorithms

(Real-time data

+

Propagation Models

+

Wind field Models

+

Extreme Fire Behaviour Models

+

Firefighting Strategy Models

+

IA/ML)

Layers

(maps)

Fire suppression lines

Drop zones

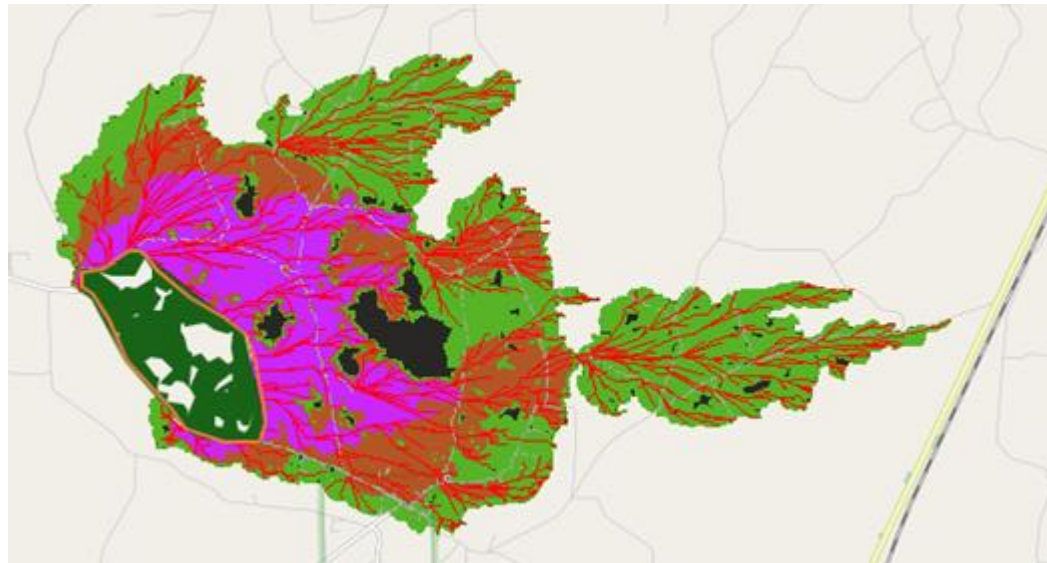
Combat means distribution



Combat – Numerical and statistical analysis of possible combat strategies and their probability of success

Approach

- *Simulate the fire suppression using a network optimisation process.*
- *Minimum Travel Time Fire Spread (MTT) displays the most significant fire spread pathways across your burned area.*
- *Act on most significant fire spread pathways, taking into account real time assessment of fire fighting means, efficiency and risk.*



(source: IFTDSS)

Collaborations

- Definition of End-User Requirements
- Testing and validation



Autoridade Nacional de Emergência e Proteção Civil
(signed collaboration protocol)



@fire International Disaster Response Germany (German non-profit, non-governmental civil protection organisation)



Indiana Department of Natural Resources Division of Forestry (Government Agency)

Collaborations

- Sources of data
- Establishment of fire data standards



FCT Project FIREFRONT - RealTime Forest Fire Mapping and Spread Forecast Using Unmanned Aerial Vehicles (PCIF/SSI/0096/2017)
(signed collaboration protocol)



FCT Project EYE IN THE SKY - (PCIF/SSI/0103/2018)



Project RePlant - Grounding Collaborative Strategies for Integrated Management of Forests & Fire (Compete/Portugal 2020)

Collaborations

- Wind field modelling



menzio GmbH
(signed collaboration protocol)



News and media

- Digital and Printed Magazine Portugal em Destaque, May 2021

PORTUGAL

EM DESTAQUE

Acknowledgements



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Consortium



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João Aveiro (ADDF)

Lúcia Lisboa (THALES)

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Jorge Pereira (ISR-UC)

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1st Year Results and Milestones

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