Support Wildfire Management in Mediterranean Territories using Multi-Source Satellite Images

Giovanni Laneve, Ramón Bueno Morles, Valerio Pampanoni, Shaik Riyaaz Uddien

12TH
EARSEL FOREST FIRES SIG
WORKSHOP
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ROME , ITALY

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EARSeL

The S2IGI Project

An Integrated Information System for Wildfire Support and Prevention

- Funded by the Regione Autonoma della Sardegna and POR-FESR 2014-2020
- Developed by the School of Aerospace Engineering, Nurjanatech and CNR-IBIMET
- Aims to support the firefighting activities by providing systems and specialized applications based on satellite technologies

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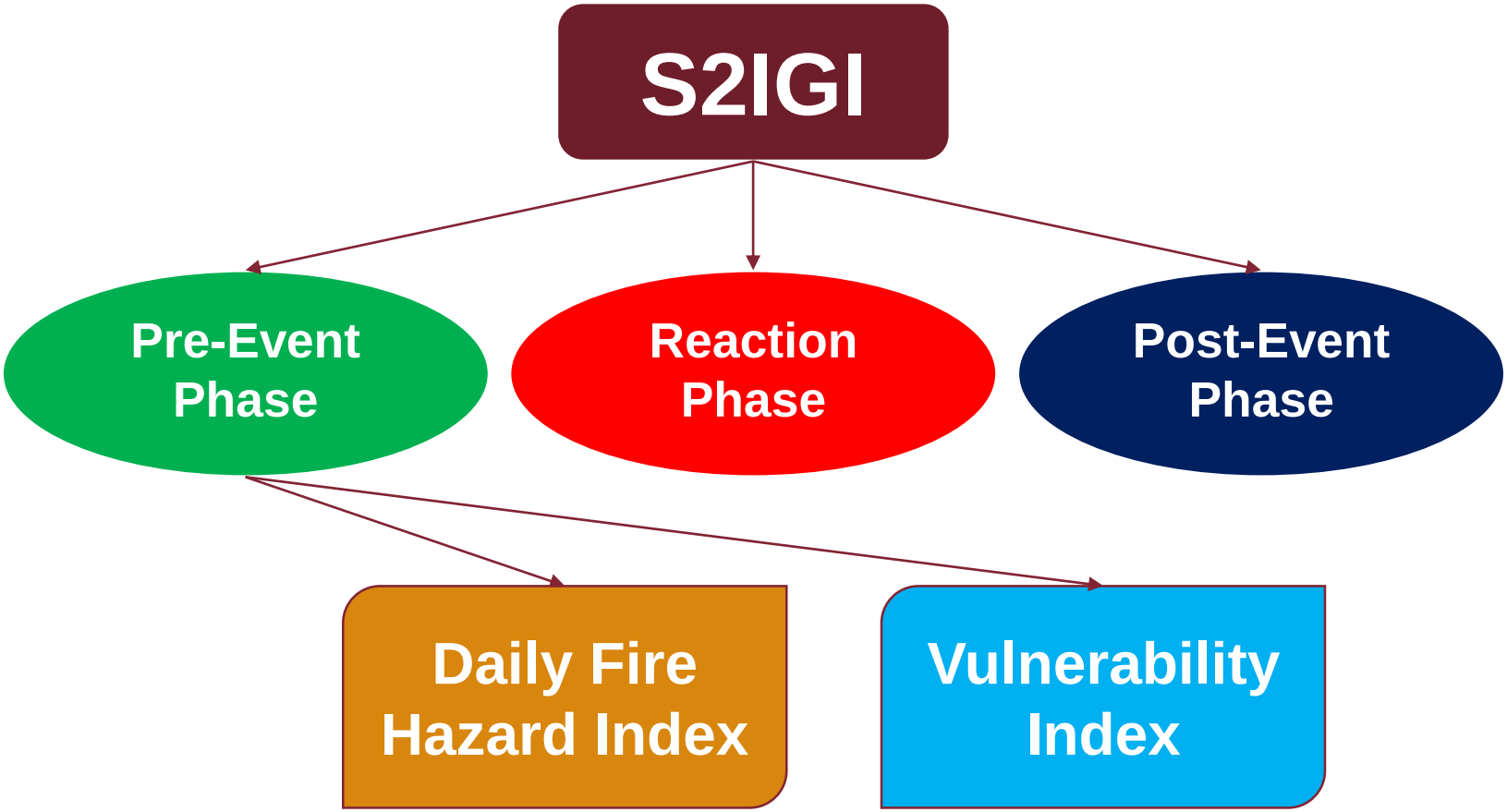
THINKING HIGHER

POR FESR
SARDEGNA 2014-2020

The Fire Hazard and the Vulnerability Index

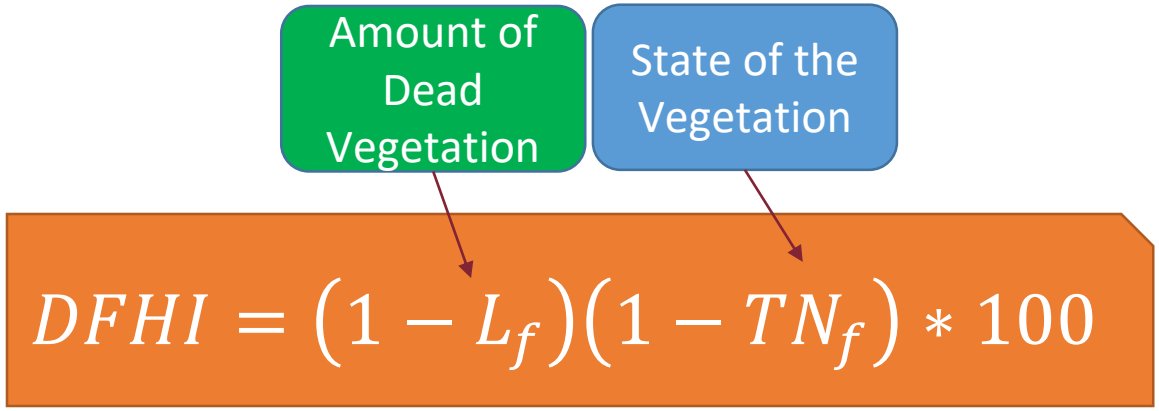
Wildfire Prevention Support



Brief History of the Fire Hazard Indices

The Effort towards Standardization

- *1998*: Joint Research Center of the European Commission advocates for the creation of a standardized method for fire hazard evaluation in Europe
- *2002*: The North-American Fire Potential Index (FPI) was chosen for adaptation on Mediterranean forests (*Sebastian-Lòpez et al. 2002*)
- *2011*: The School of Aerospace Engineering develops the Modified Fire Potential Index (MFPI) which uses also satellite data and accounts for the topography to determine the fire potential (*Laneve et al. 2011*)
- *2019*: The Daily Fire Hazard Index (DFHI) improves upon the MFPI by taking into account the effect of the wind speed on the actual temperature of the vegetation



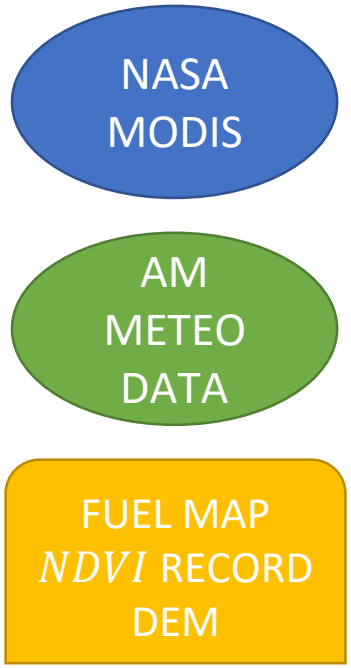
Fire Hazard Classes

Correspondence between DFHI Value and Hazard Classes

DFHI Interval	Hazard Class
0 – 20	No Hazard
20 – 40	Low Hazard
40 – 55	Medium Hazard
55 – 70	High Hazard
70 – 100	Very High Hazard

Calculation Procedure: Data Sources

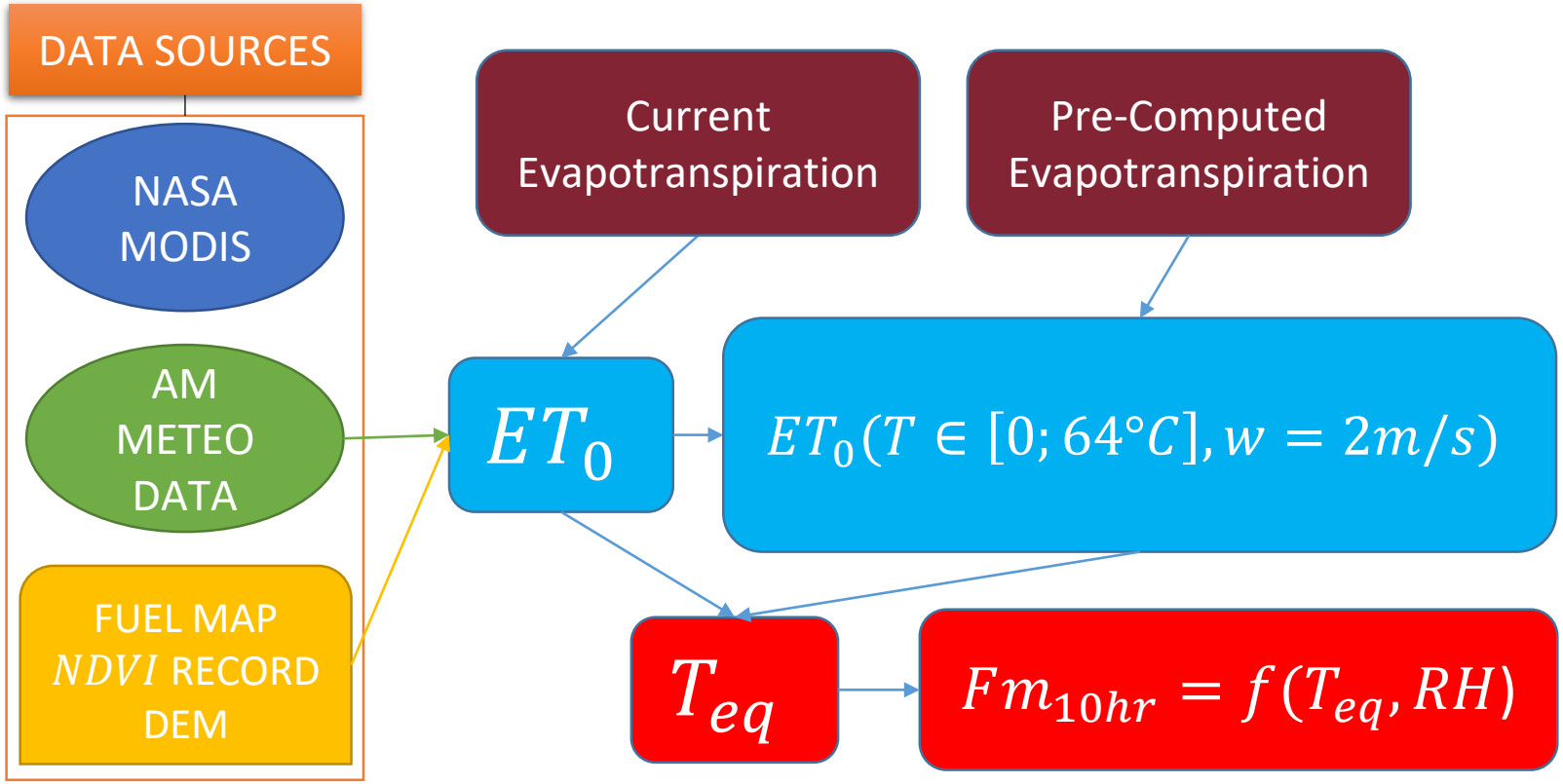
Inputs of the Algorithm



- L2 MODIS reflectances (MOD09GA, MOD09GQ) (*daily frequency, 500x500m, 250x250m*)
- 3-day Weather Forecasts from Aeronautica Militare (Temperatures, Humidity, Wind Speed @10m) (*daily frequency*)
- Fuel Maps, Historical NDVI Records and Latest Digital Elevation Model of the AOI (*latest seasonal update*)

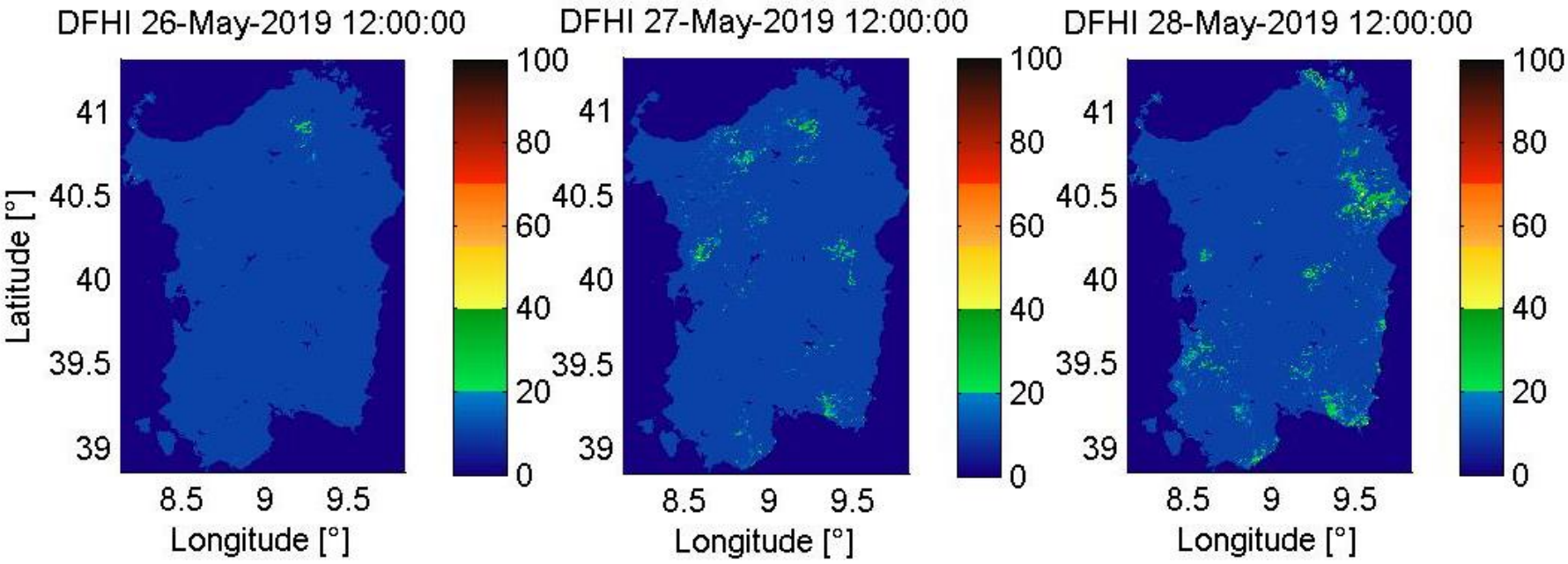
Model Improvements: The Effect of Wind Speed

Reference Evapotranspiration and Equivalent Temperature



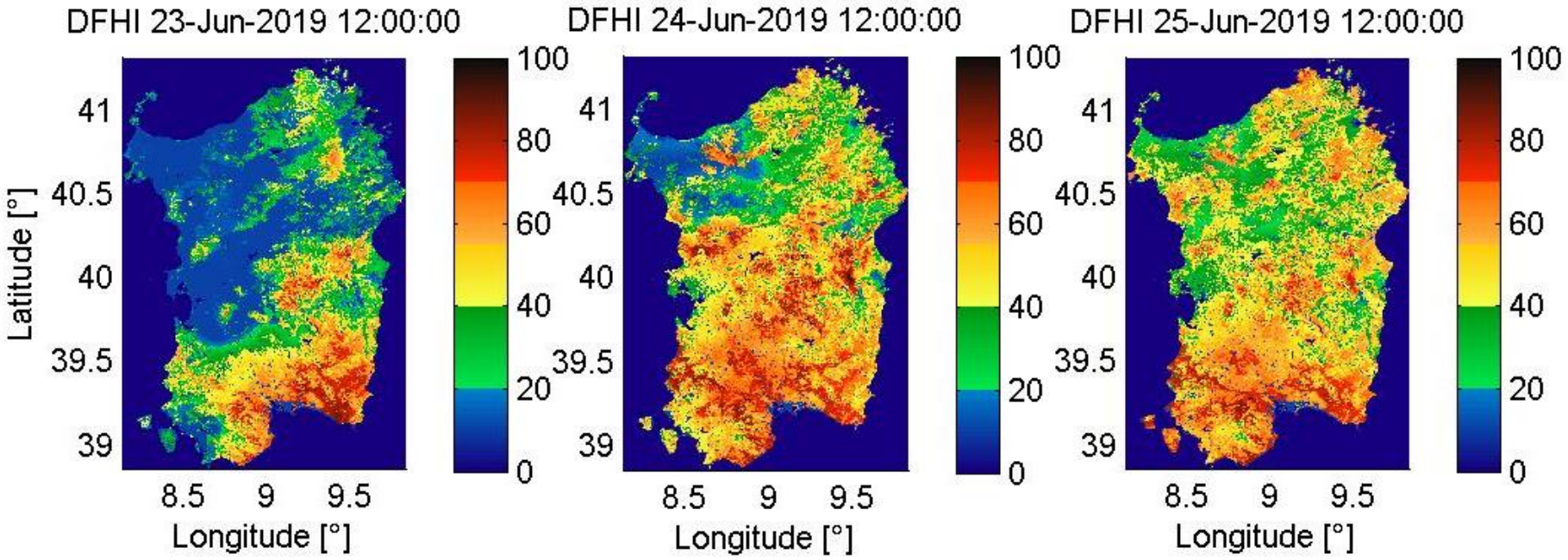
Performance of the New DFHI

Daily Fire Hazard on Rainy Days



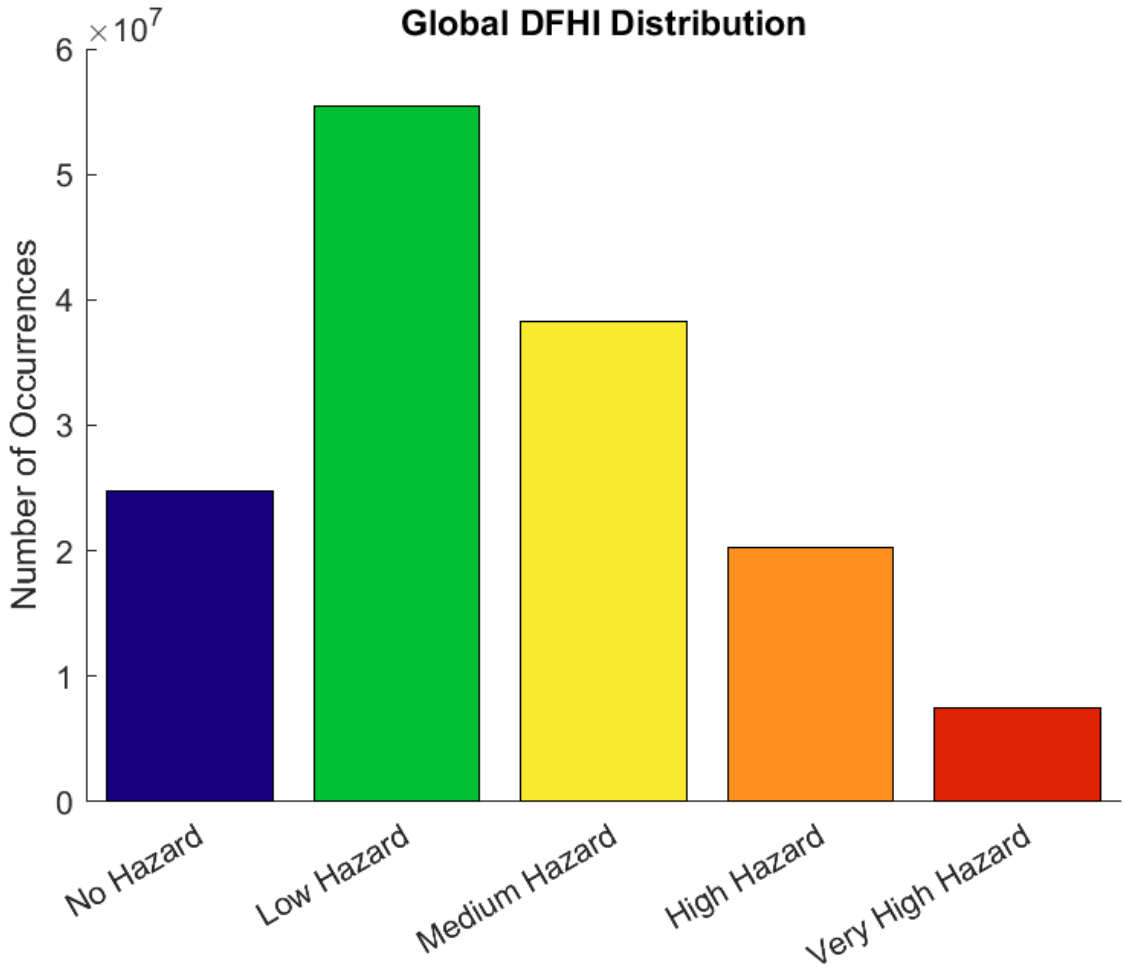
Performance of the New DFHI

Daily Fire Hazard reacts to Raising Temperatures



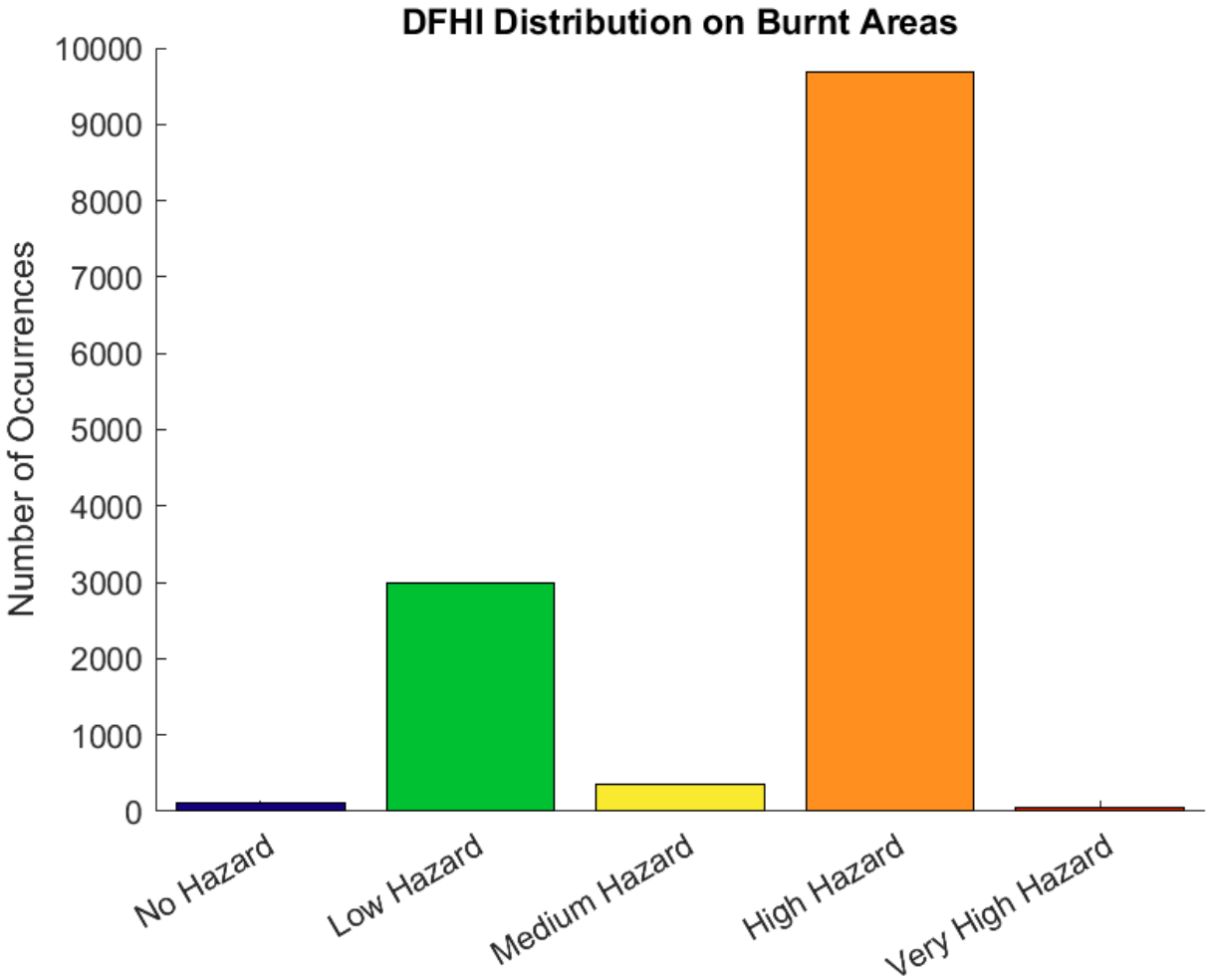
Distribution of DFHI Values

Global Index Distribution in the 2017 Fire Season



Distribution of DFHI Values

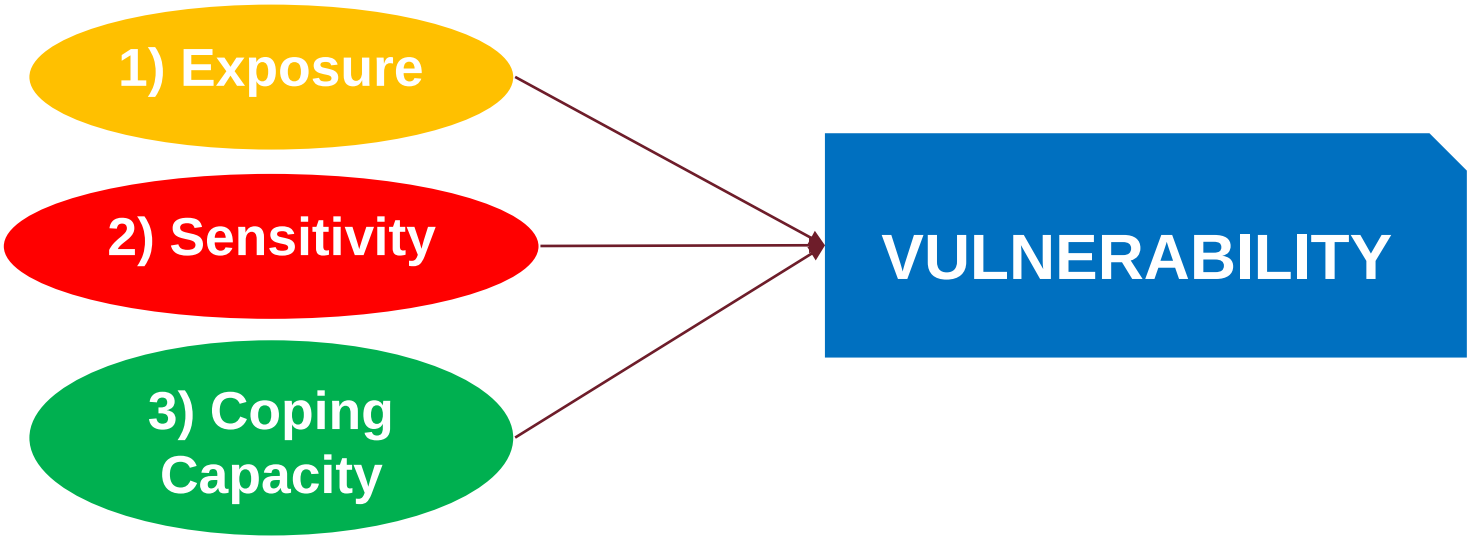
Index Distribution restricted on 2017 Burnt Areas



Vulnerability

- The United Nations (UNISDR, 2009) defines vulnerability as "*the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards*".

- Comprehensive approach combining **social**, **environmental**, **economic** and **institutional** variables, divided into three categories:



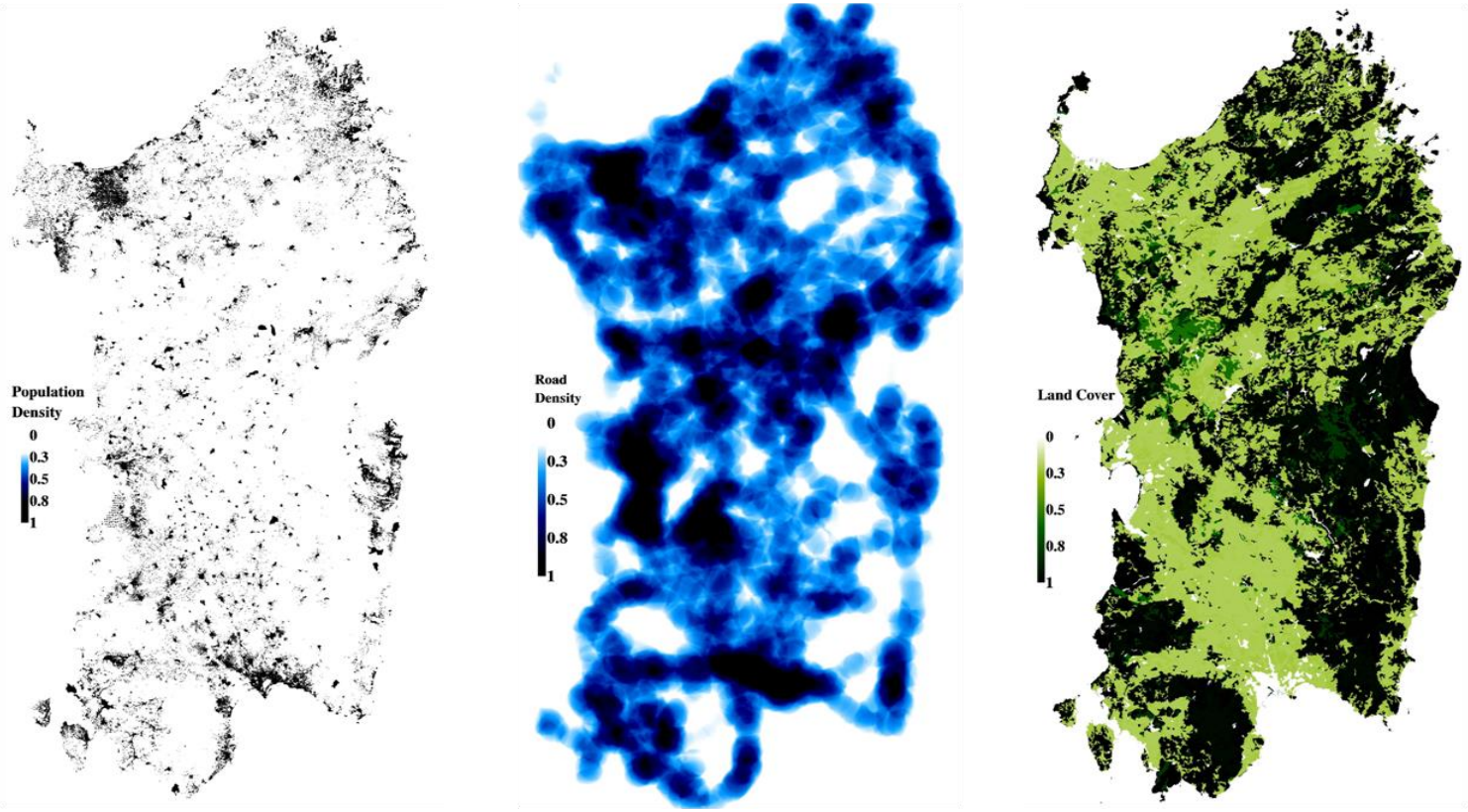
Vulnerability

Exposure Variables	Sensitivity Variables	Coping Capacity Variables
• Population Density • Building Density • Roads Density • Land cover type • Presence of protected areas	• Population • Elderly (> 64 years) • Education level • % of People working in primary sector • Protected Areas (JRC) • Number of classifications (national, international) • International Union for Conservation of Nature Categories (IUCN)	• Density of Forest access roads • Nr. Firefighters / forest area • Surveillance towers(visibility area)

Exposure Processing

ID	Variables	Processing
1	**Population density**	Population density map available at 1ha resolution; the vulnerability grid at 1ha was overlapped and each cell received the corresponding value of population density;
2	**Categories of land cover**	6 categories of land cover were created by aggregating CLC classes; a specific weighting was given to each category depending on their relation with fire and based on literature review;
3	**Buildings density**	Number of buildings calculated per ha for the minimum spatial unit available (municipality, LAU5 or below);
4	**Roads density**	Length of roads per ha for each cell of the vulnerability grid;
5	**Area occupied by protected areas**	The polygons of all the classified protected areas (Natura 2000 ZSP and SCA, UNESCO Biosphere Reserve, national classifications and Ramsar wetlands) were merged and overlapped with the vulnerability grid.

Map of Population density, Road density and Land cover, with normalized values divided in 5 classes, for the AOI of Sardinia

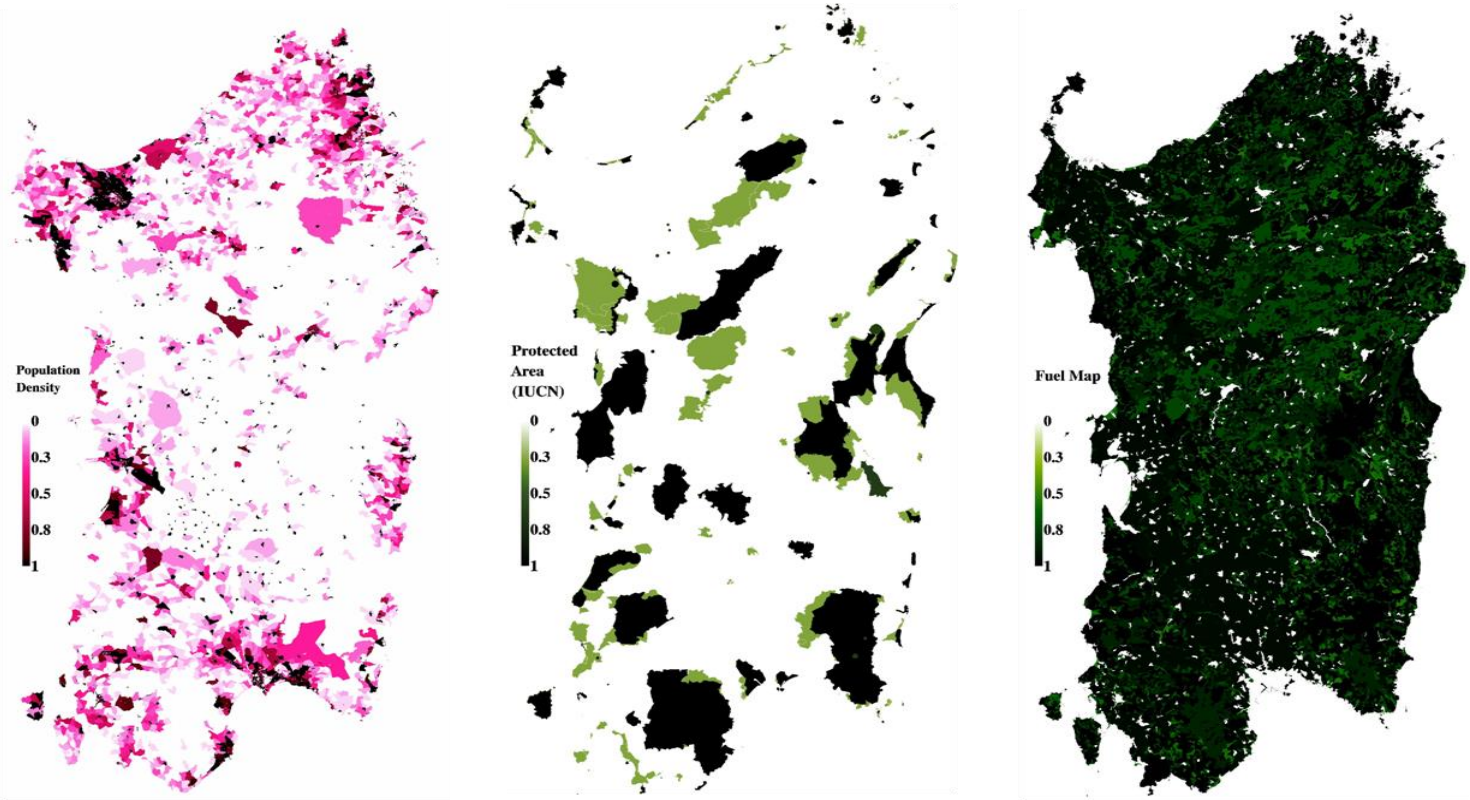


$$\boldsymbol{Exposure} = (\boldsymbol{Population\ density} \cdot \mathbf{0.2}) + (\boldsymbol{Land\ cover} \cdot \mathbf{0.2}) + (\boldsymbol{Buildings} \cdot \mathbf{0.2}) + (\boldsymbol{Roads} \cdot \mathbf{0.2}) + (\boldsymbol{Protected\ areas} \cdot \mathbf{0.2})$$

Sensitivity

No	Parameters	Dimension	Variables	Justification	Sources
1	**Protected Natural Areas**	Environmental	Number of classifications of protection (1 to 5)	Number of classifications in each cell, from Natura 2000 SPA and SCA, UNESCO Biosphere Reserve, Ramsar wetlands and national classification	http://www.protectedplanet.net National sources (www.sardegnageoportale.it/)
			Level of sensitivity by IUCN category (1 to 6)	Each IUCN category is weighted according to the level of protection and management objectives it corresponds to	http://www.iucn.org
2	**Fuel**	Environmental	Level of fireproness	Each category is weighted according to the level of fire proneness	Oliveira et al., 2014
3	**Population**	Social	% Elderly (>64 years)	Elderly people are more susceptible to injuries and require special care.	www.istat.it

Map of Population density, Protected Areas and Fuel Map, with normalized values divided in 5 classes, for the AOI of Sardinia



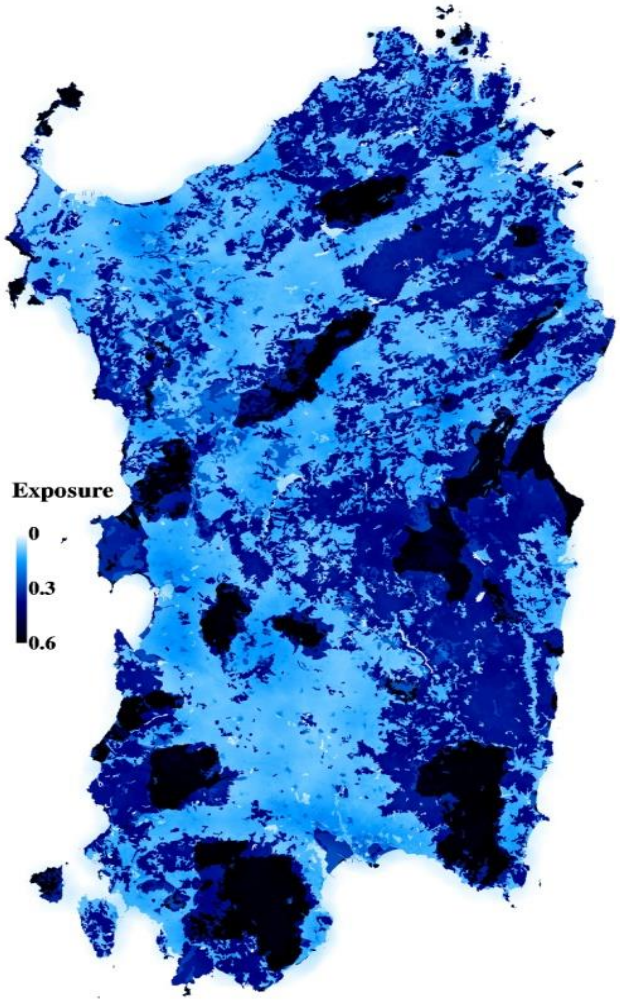
$$\boldsymbol{Sensitivity} = (\boldsymbol{Population\ sensitivity} \cdot \mathbf{0.4}) + (\boldsymbol{fuel} \cdot \mathbf{0.4}) + (\boldsymbol{protected\ areas\ sensitivity} \cdot \mathbf{0.2})$$

Coping Capacity Variables

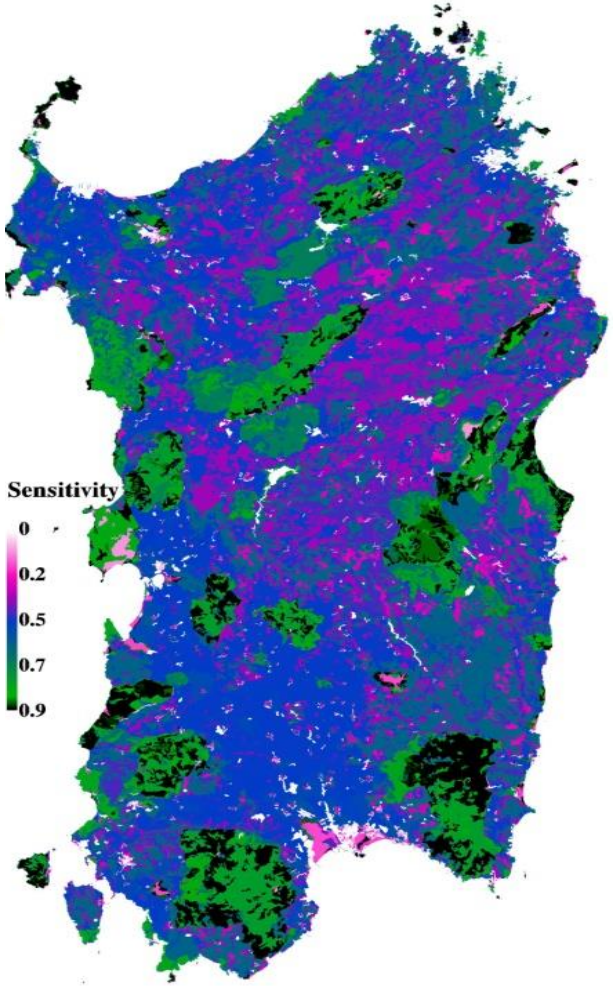
No	Dimension	Variables	Source
1	Surveillance	Sedi_postazioni_avvistamento_Forestas_2019 (**SS**) (Height of the towers – 15 m)	
2	Firefighters	Sedi_organizzazioni_volontari_2019 (**FF1**)	
3		Sedi_presidi_VVF_2019 (**FF2**)	
4		Sedi_squadre_Forestas_2019 (**FF3**)	
5		Sedi_Stazioni_Forestali_2019 (**FF4**)	
6		Compagnie_barracellari_2019 (**FF5**)	

$$\boldsymbol{Coping\ Capacity} = \mathbf{1} - [(\boldsymbol{FF1} \cdot \mathbf{1/6}) + (\boldsymbol{FF2} \cdot \mathbf{1/6}) + (\boldsymbol{FF3} \cdot \mathbf{1/6}) + (\boldsymbol{FF4} \cdot \mathbf{1/6}) + (\boldsymbol{FF5} \cdot \mathbf{1/6}) + (\boldsymbol{SS} \cdot \mathbf{1/6})]$$

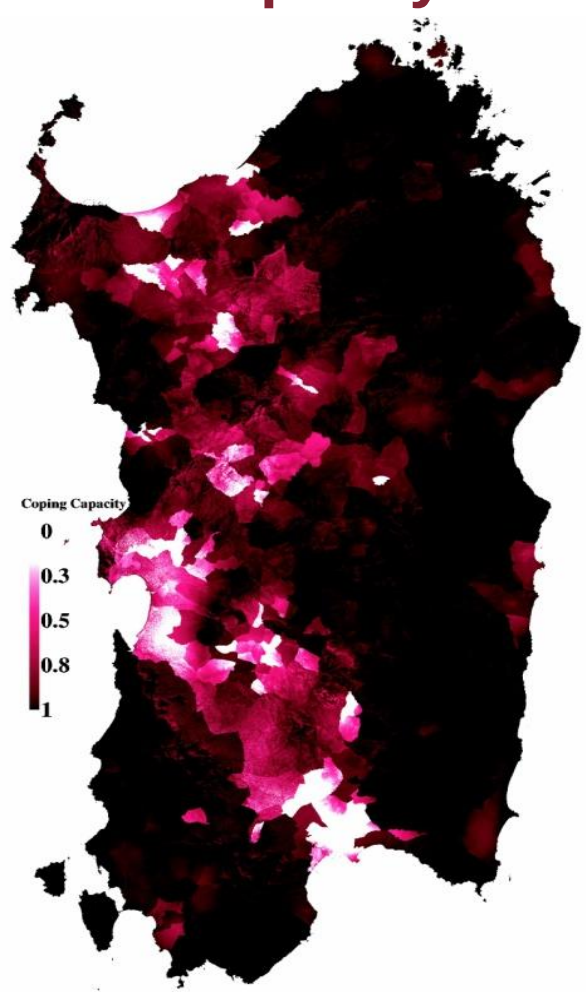
Exposure



Sensitivity



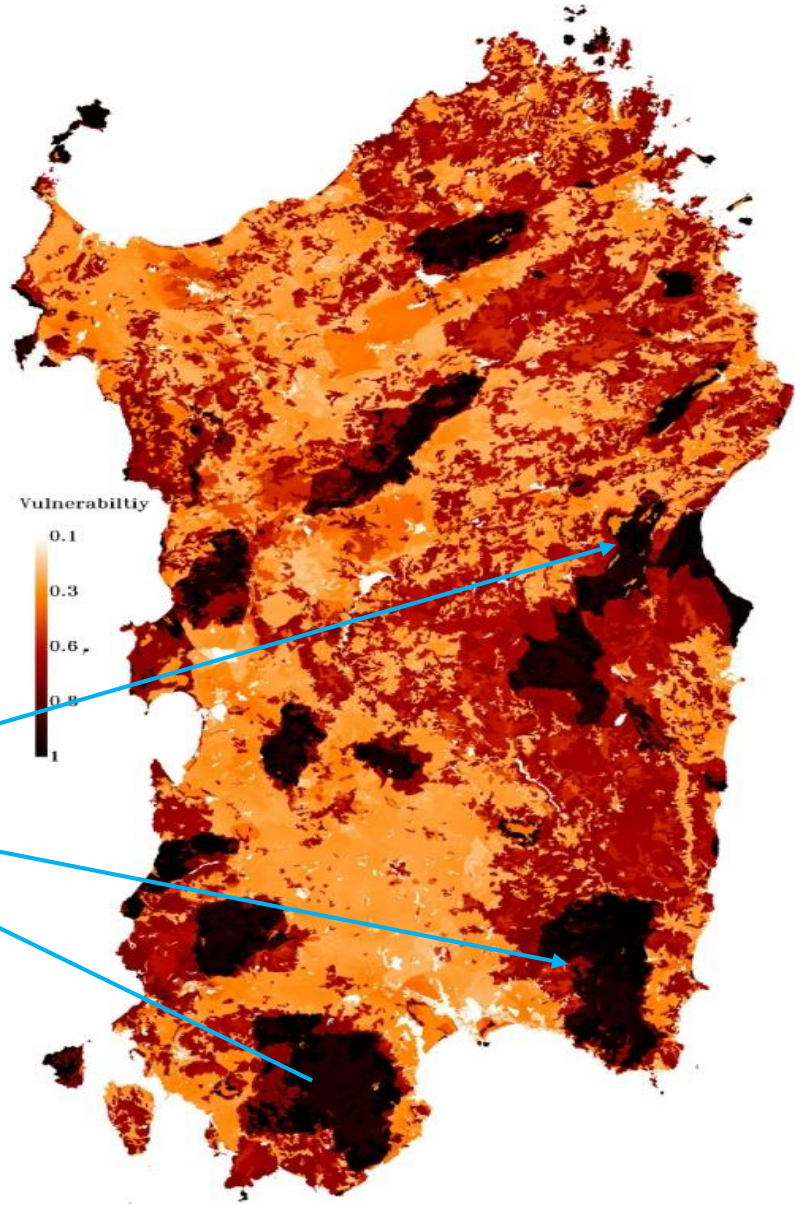
Coping Capacity



Vulnerability Map

$$Vulnerability = \left(Exposure \cdot \frac{1}{3}\right) + \left(Sensitivity \cdot \frac{1}{3}\right) + \left(Coping\ Capacity \cdot \frac{1}{3}\right)$$

Both the Orosei and Cagliari Gulf were heavily affected by wildfires in the latest fire season!



Conclusions

- Improvements on the DFHI model resulted in more accurate and reliable estimate of the state of the vegetation
- Statistical distribution of the DFHI values shows no bias towards high risk areas
- The Vulnerability Index algorithm can realistically integrate data from different sources and datasets
- Each component can be updated as soon as new data becomes available (fuel maps, burned areas)

Thank You for Your Attention

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