Les méthodes actuelles / outils pour caractériser le danger d'incendie, le comportement et les risques

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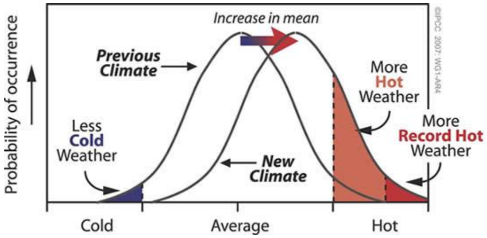
« PREMIER ATELIER SUR LES INCENDIES DE FORET ET LE CHANGEMENT CLIMATIQUE »

Project Funded by the European Union

Increased frequency of extreme weather



Lengthening of fire seasons

Land use / land cover changes

Loss of confidence in using agricultural fires

Increased pressure in coastal and urban areas

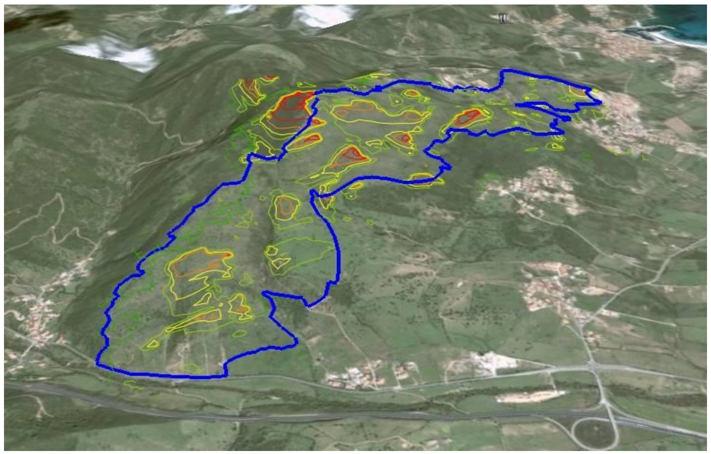
Increment of fire suppression budgets

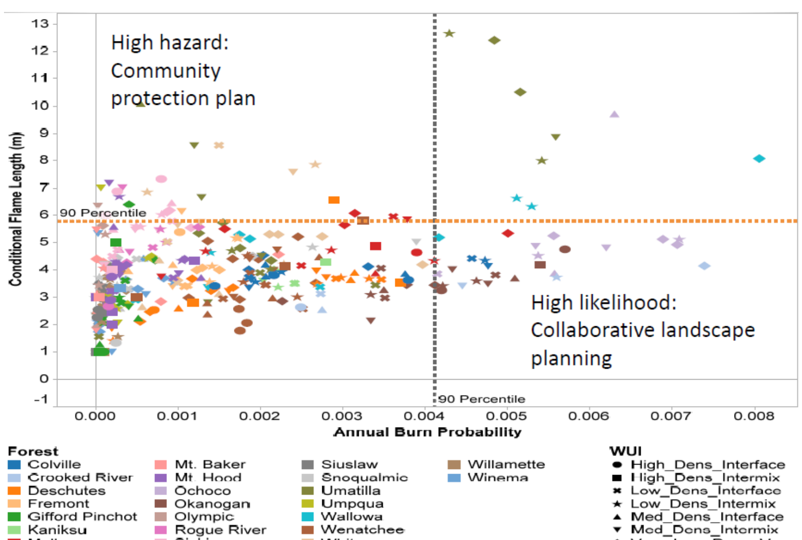
Lacking land management and build-up of unmanaged fuelbeds

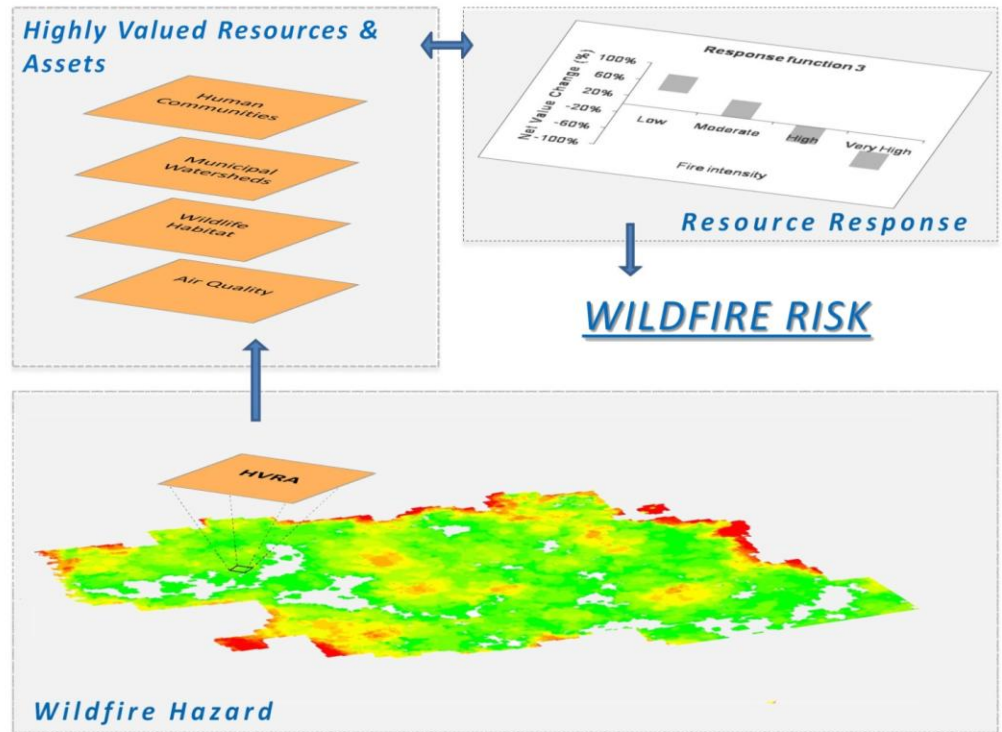
Ageing population in forest/rural areas

Foreword

The growing incidence of large fires impacting forests and urban interfaces over the past decades has led to extensive research on wildfire risk

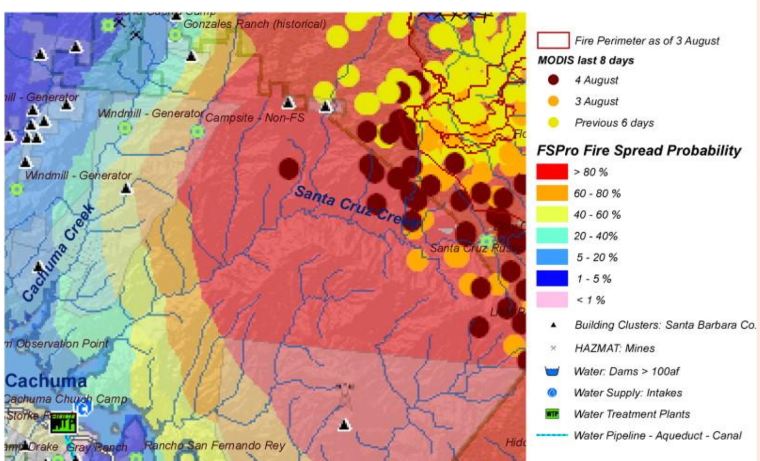


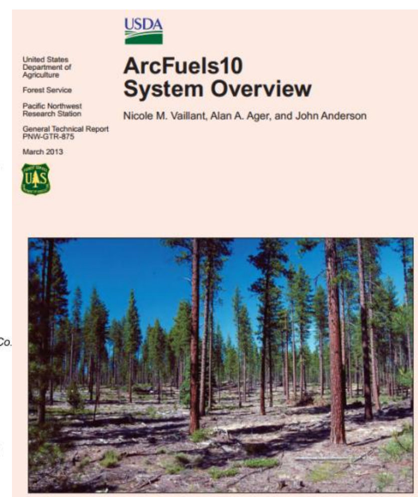


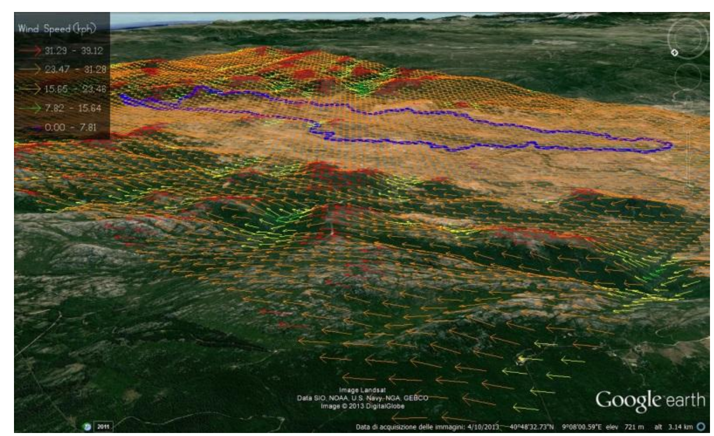


Foreword

Simulation models and tools are now routinely used to analyze potential fire behavior and develop risk assessment and mitigation strategies, over a range of scales, from forest stands (few hectares) to very large landscapes (thousand km^2)







Foreword

Quantifying Risk for Wildfire Management

Definition of Risk

- Risk is the chance that «something bad» will happen
- It combines likelihood with effects
- It is an expectation, and therefore units are expectations (€, $, hectares, people, things, etc.)
- Developed for disaster management and insurance where uncertainty is high (e.g.: large wildfires)

(Ager 2013)

Foreword

Quantifying Risk for Wildfire Management

Wildfire Risk = probability of a fire of a specific intensity x the loss at that intensity; often called expected loss

$$E(L) = \sum_i p(f_i) * R(f_i)$$

with…

$p(f_i) =$ Probability of burning intensity level *i* "Exposure"

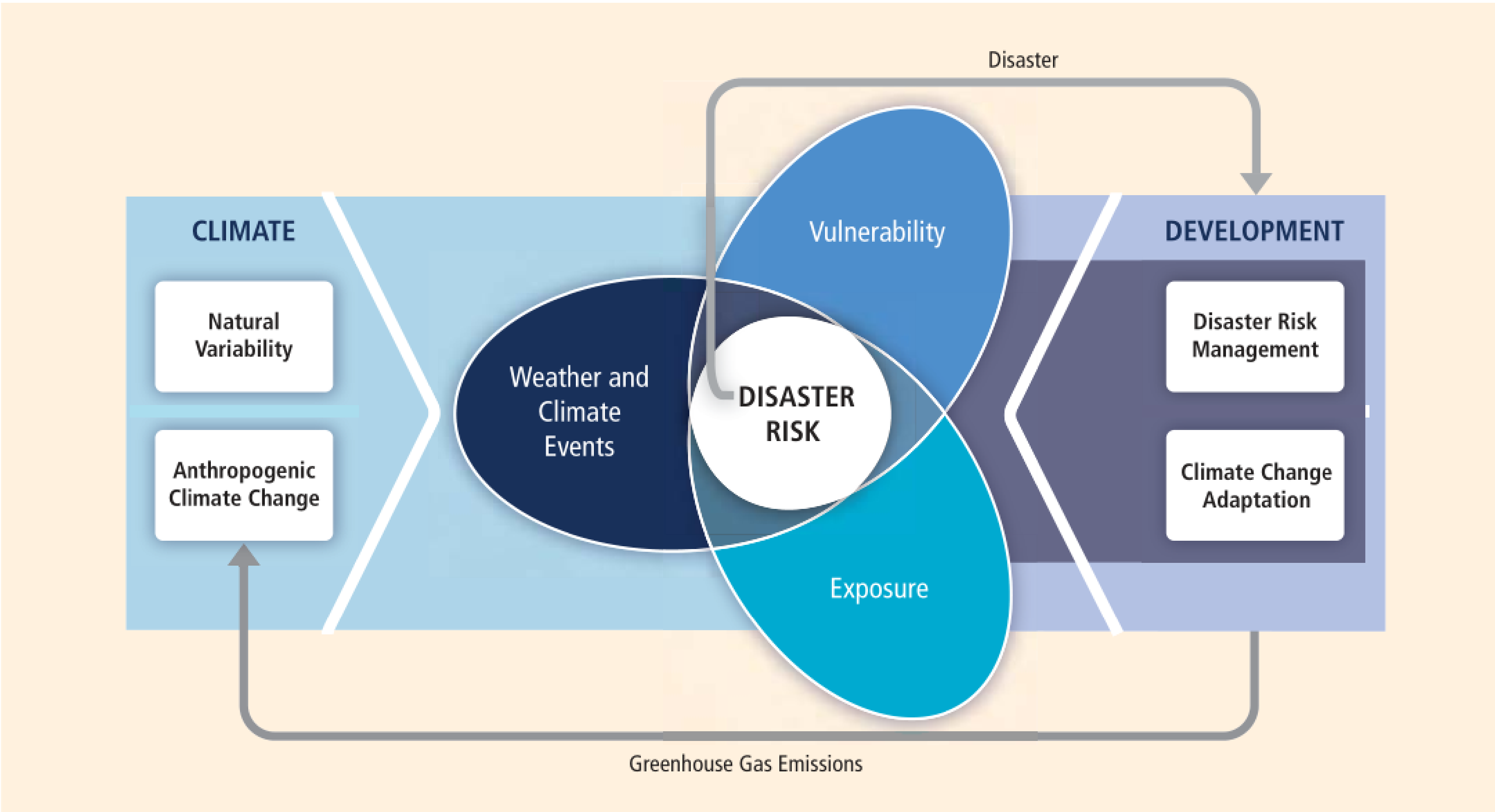
$R(f_i) =$ Response for intensity *i* "Susceptibility"

$E(L) =$ Expected loss "Risk"

(Finney 2013)

We sum over *i* because fire can arrive at many intensities at a particular location

Definition of Disaster Risk for IPCC



The key concepts and scope of the IPCC report (2013). The figure indicates schematically key concepts involved in disaster risk management and climate change adaptation, and the interaction of these with sustainable development

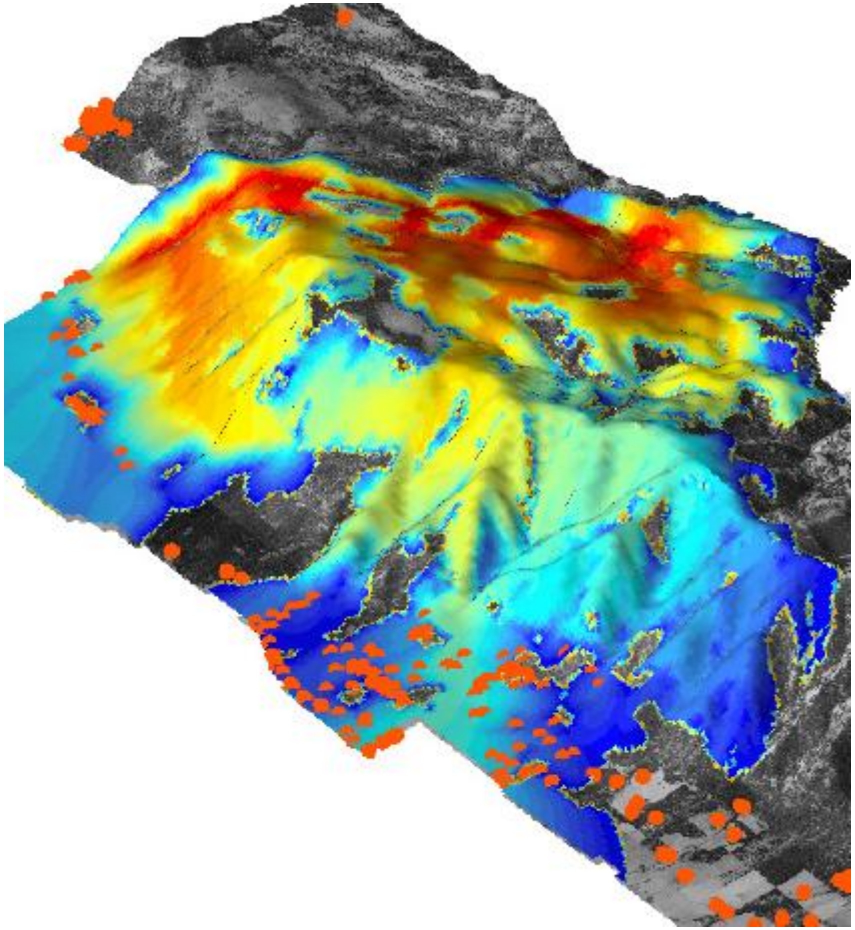
(IPCC 2013)

Foreword

Quantifying Risk for Wildfire Management

How do we estimate fire exposure and vulnerability?

$$E(L) = \sum_i p(f_i) * R(f_i)$$



Historical wildfire data and reports are generally insufficient to map burn probability and intensity at fine scales

In recent years, several studies have used fire models

Foreword

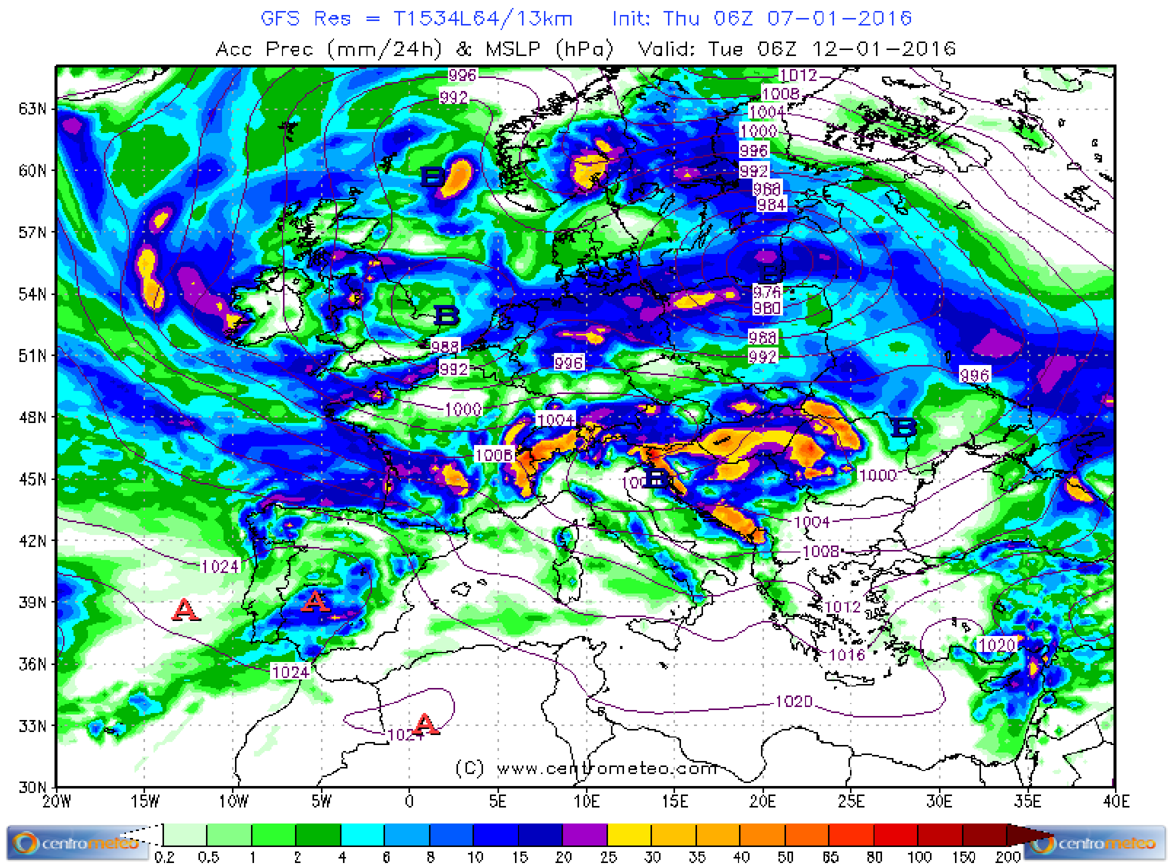
What is a model?

a) A model is a simplification of reality, and is based on a set of assumptions

Foreword

What is a model?

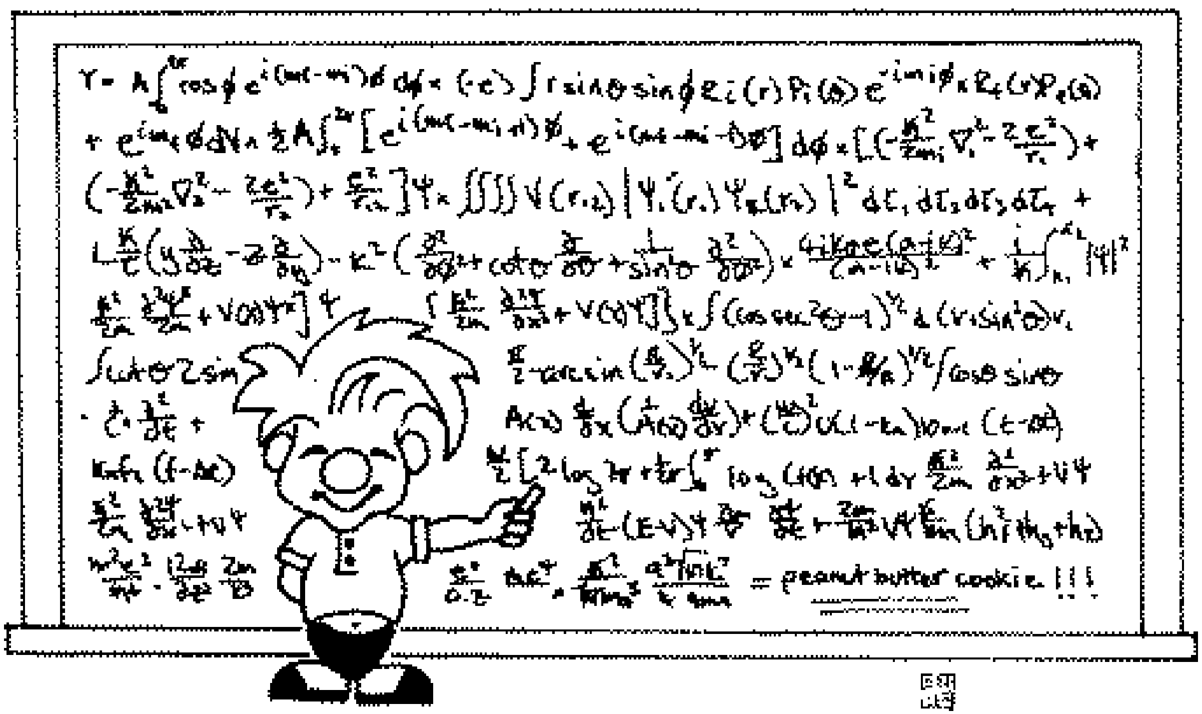
b) All models are wrong (only reality is right)



Foreword

What is a model?

c) More complicated models are not necessarily better



Foreword

What is a model?

d) Specific Purpose

- <u>Practical</u>, for operational prediction (easy to use for most people, practical set of inputs, limited run times, useful for training)
- <u>Research models</u>, for fundamental understandings (used to understand how things work, high run times, high performance computers, not easy for «standard» users)

Foreword

What is a model?

e) Models can be useful even if fundamentals are wrong
f) Models can be made to produce anything we want

Foreword

Different kind of models

Physical Models (Theoretical)

- Physical framework
- Based on known theoretical relations
- Fine-scale processes compared to scale of prediction
- Many processes with explicit assumptions
- Many parameters can't be known

Empirical Models (Statistical)

- Observations (laboratory or field), related statistically to predictive variables
- At the scale of the phenomena
- Useful within the range of conditions developed under
- Cannot be used for other phenomena

Semi-Empirical Models

All fire models are based on some empiricism!

(Finney 2013)

Foreword

Fire risk modeling is a process with several steps

First of all…

a) Define the **objective** or question that is relevant for your purpose;

b) Evaluate if modeling is **necessary** or not

c) Gather spatial and temporal data of your study area, and evaluate **input quality and consistence**

d) Check if the model inputs correspond to the data collected

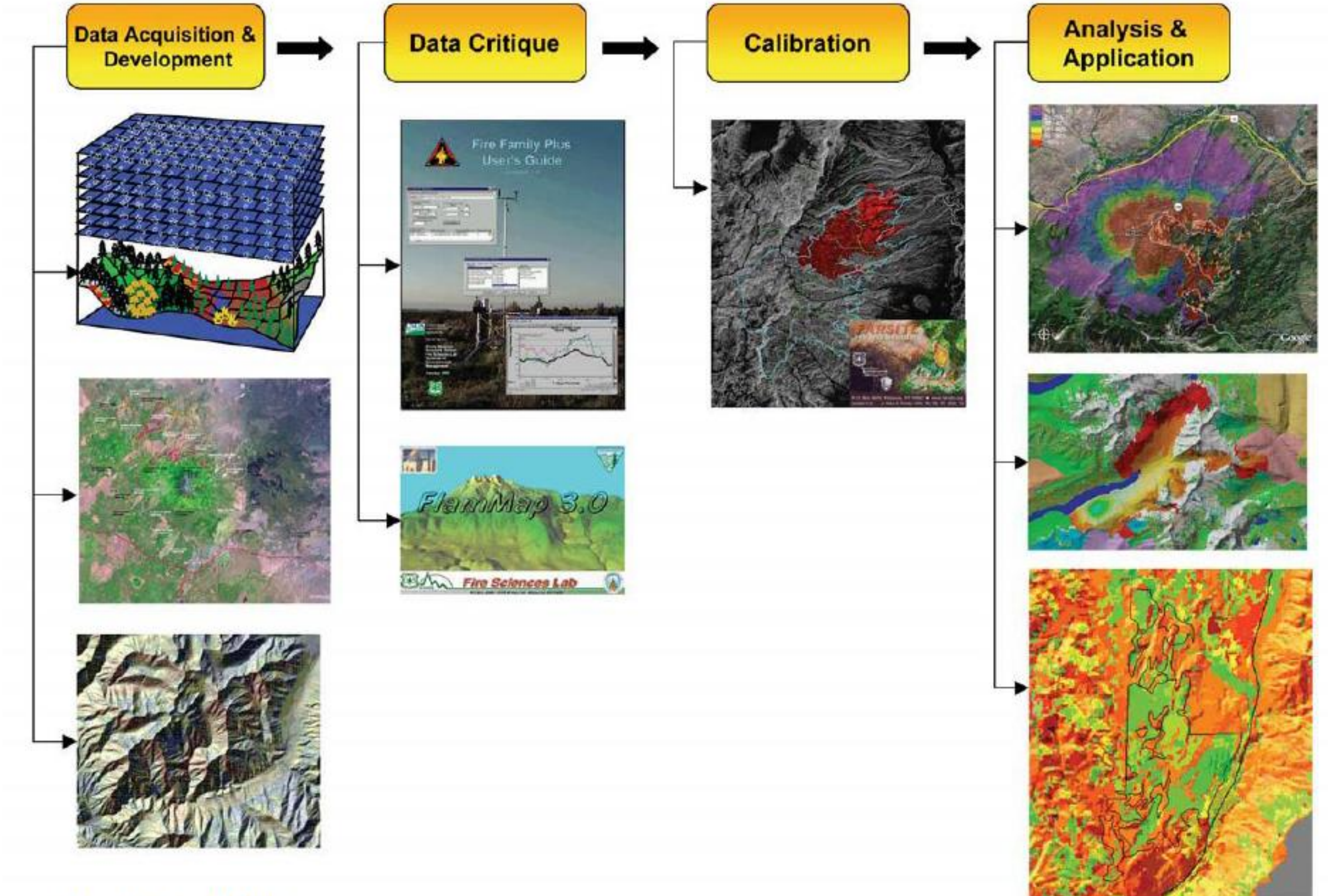
d) Analyze what are the **model outputs** and if they can help answering your objective or questions

e) **Select the fire model**

(Finney 2013)

Foreword

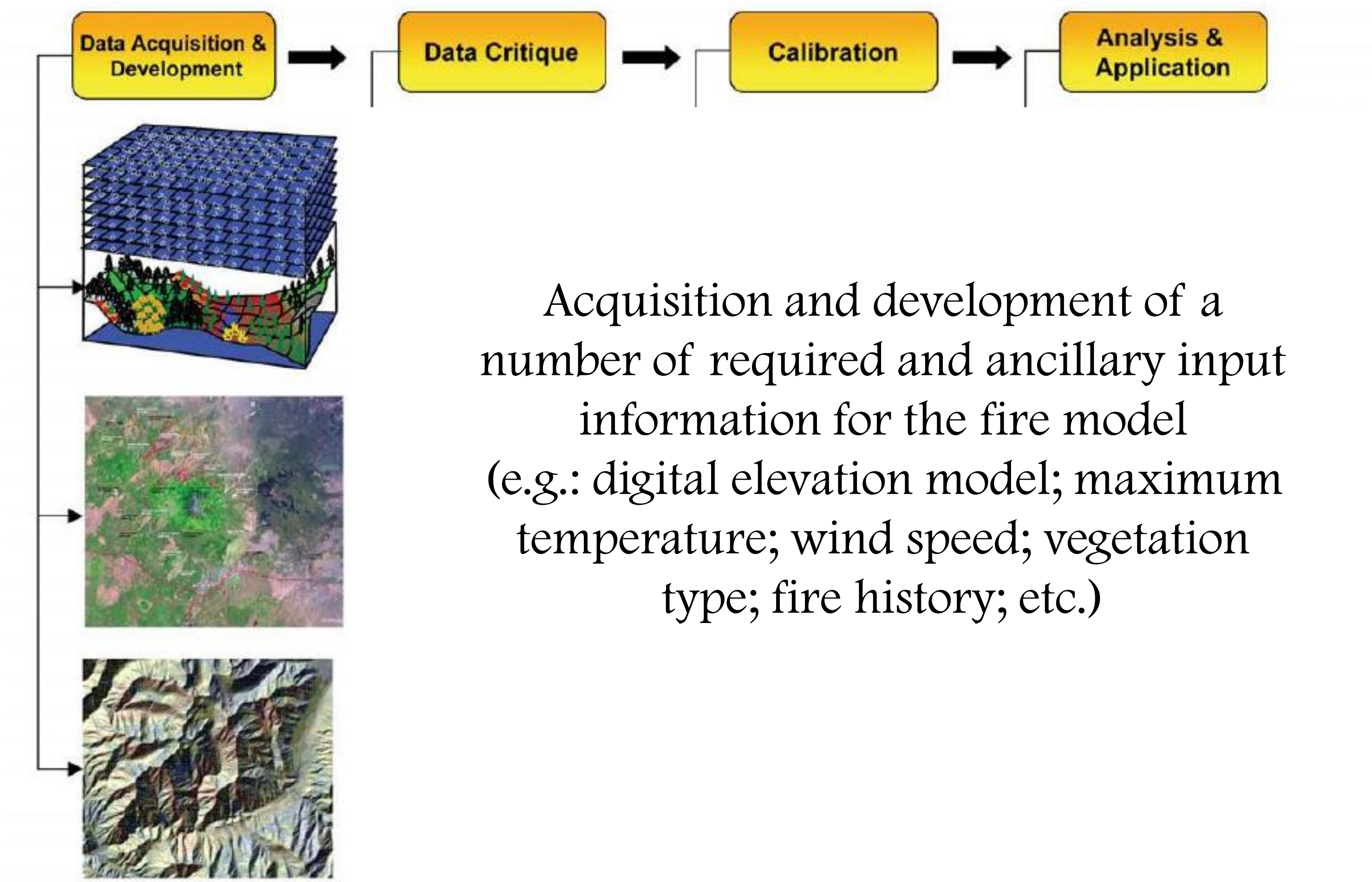
Fire risk modeling is a process with several steps



Stratton, 2006

Foreword

Fire risk modeling is a process with several steps

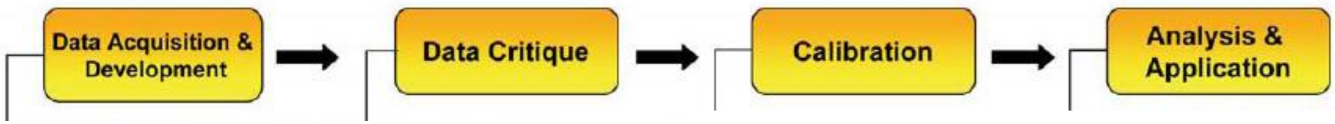


Stratton, 2006

Acquisition and development of a number of required and ancillary input information for the fire model (e.g.: digital elevation model; maximum temperature; wind speed; vegetation type; fire history; etc.)

Foreword

Fire risk modeling is a process with several steps

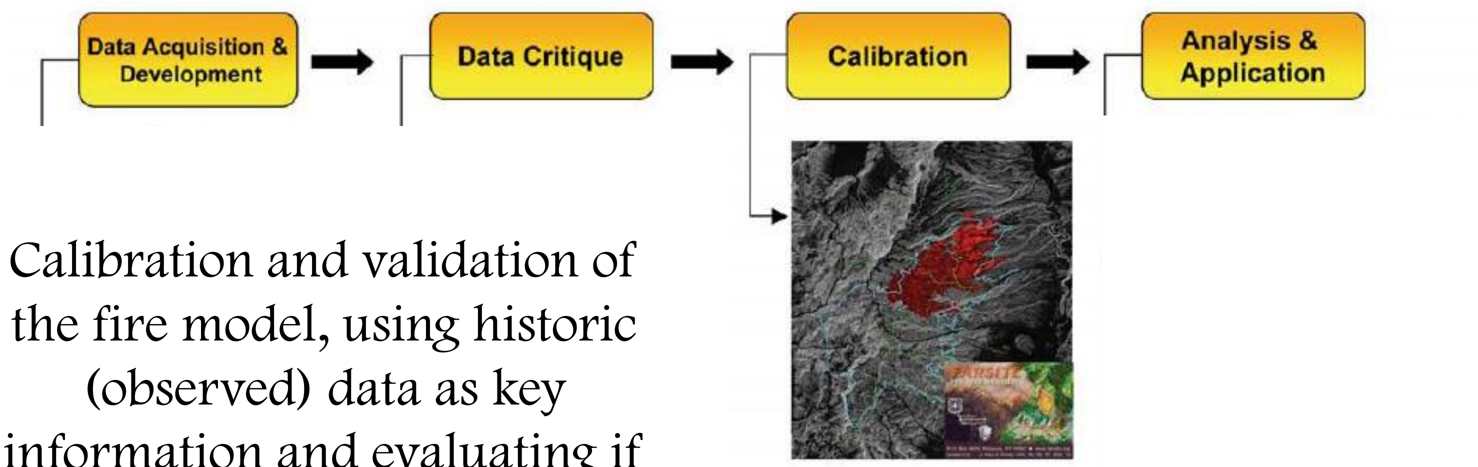


Critical analysis of the limitations, errors, gaps, and simplifications of the data used as inputs for the model and of the outputs obtained

Stratton, 2006

Foreword

Fire risk modeling is a process with several steps

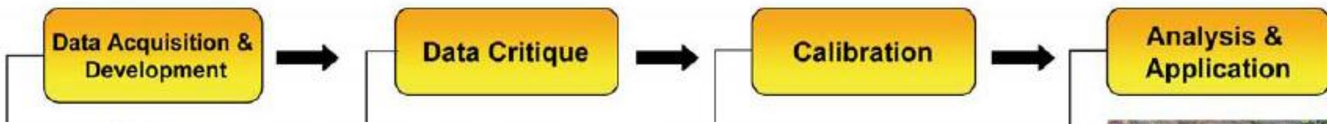


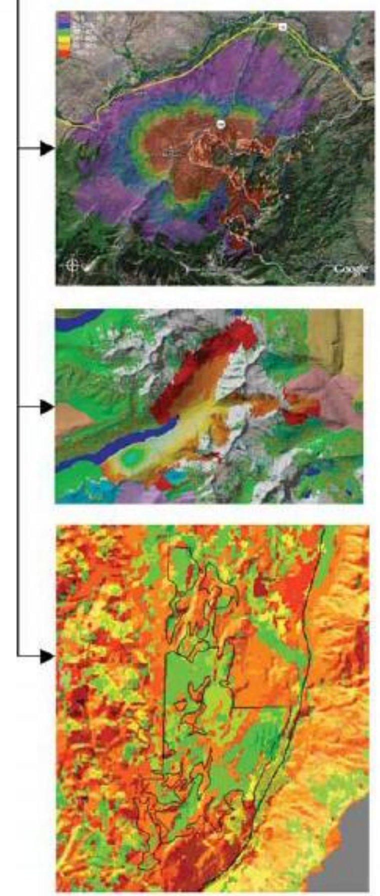
Calibration and validation of the fire model, using historic (observed) data as key information and evaluating if (and how much) the model outputs match the observed phenomena

Stratton, 2006

Foreword

Fire risk modeling is a process with several steps





1) Analysis and assessment of fire risk, hazard, behavior, danger, at a specific scale
2) Informing fire managers about specific threats (extreme fire behaviour, high fire danger, hot-spots, etc.)
3) Applications to diverse fields (fuel treatments, land planning, investigation, training, etc.)

Stratton, 2006

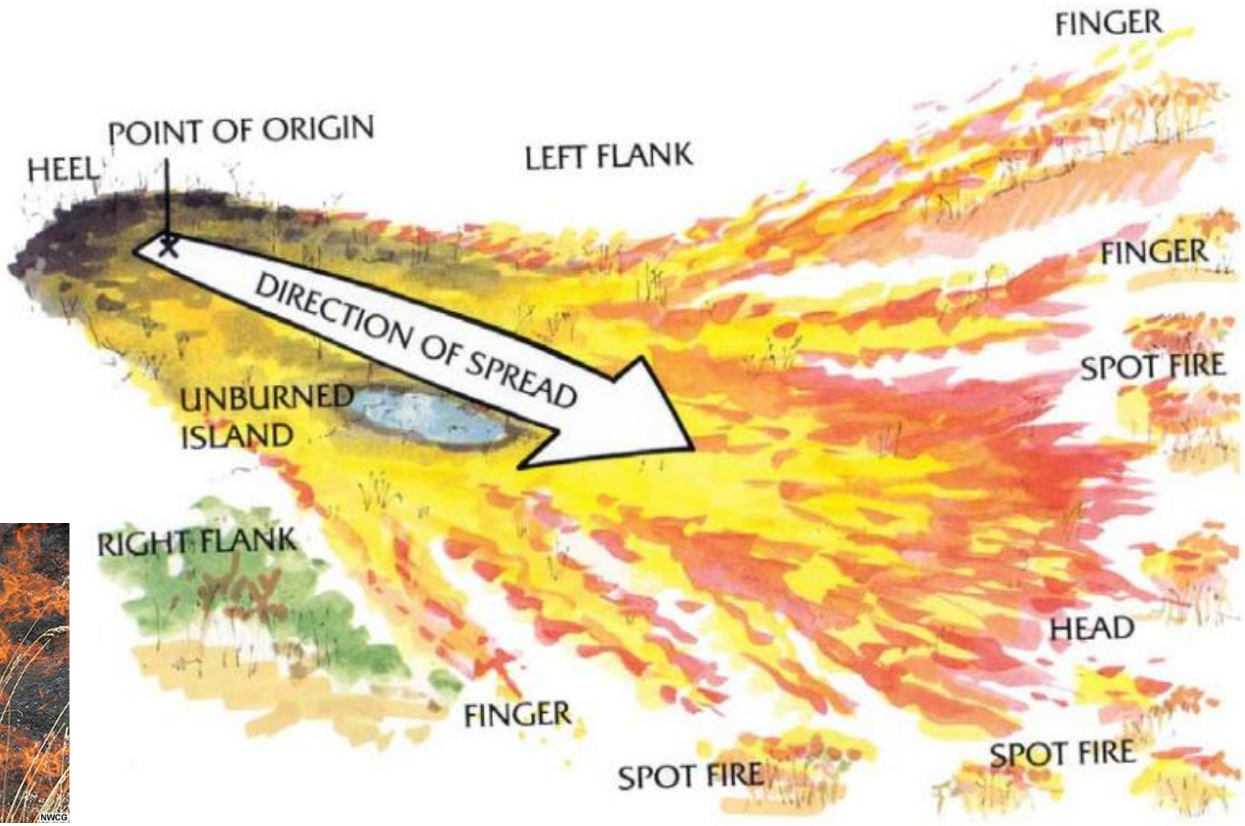
Tools to assess wildfire issues

Main Goal		Main Applications
Fire spread and behaviour modeling	→	- fire spread and behaviour projections using future scenarios - assessing fire mitigation strategies (prescribed fires, fuel reduction, etc.) - quantifyng fire exposure and risk - identification of hot-spots - etc.
Fire danger modeling	→	- daily/seasonal fire danger forecast - fire danger projections with future scenarios - etc.

Fire Spread and Behavior

How do we characterize fire spread and behavior?

Parts of a Wildfire



Fire Spread and Behavior

How do we characterize fire spread and behavior?

Fire Shape and Size

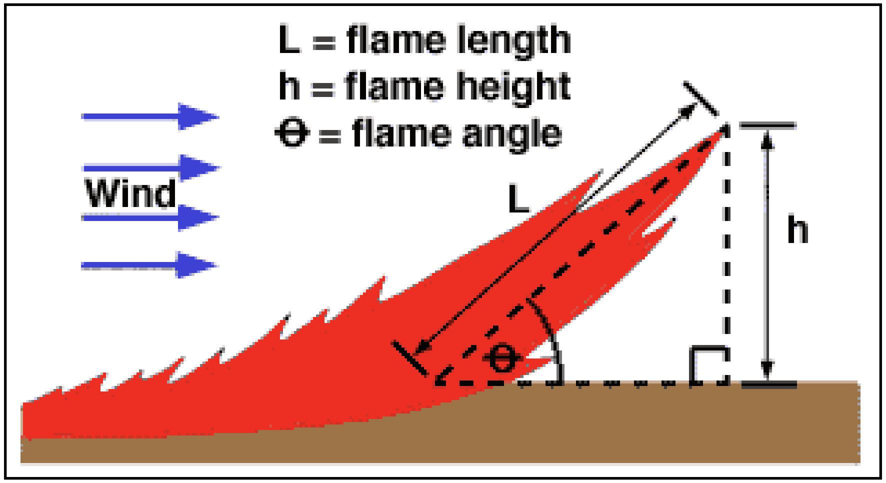
Elliptical Fires under Uniform Conditions

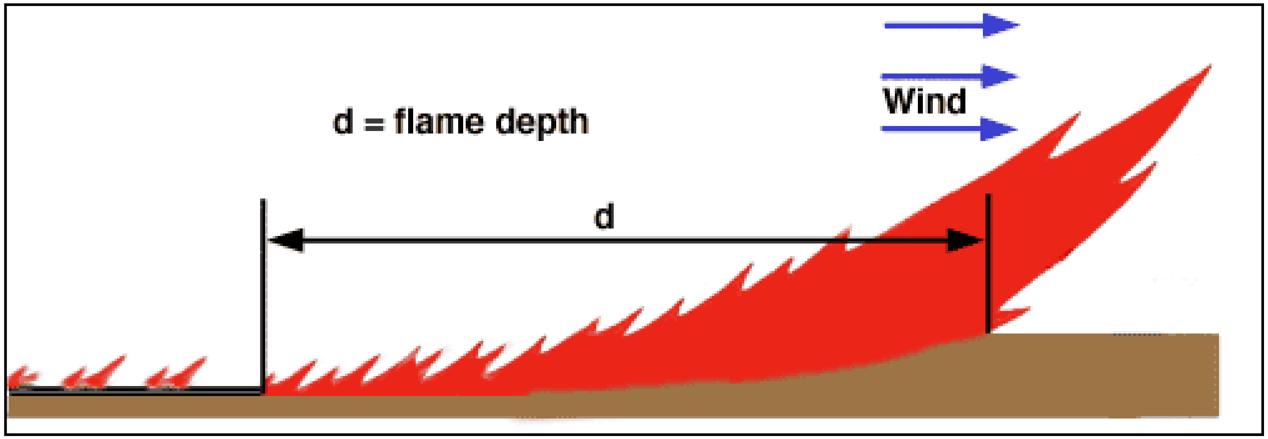
- ✓ Fire Size = **f(spread rate, timestep)**
- ✓ Fire Shape **(Eccentricity) = f(wind-slope vector)**
- ✓ Ignition at rear focus of ellipse

Fire Spread and Behavior

How do we characterize fire spread and behavior?

Flame Characteristics



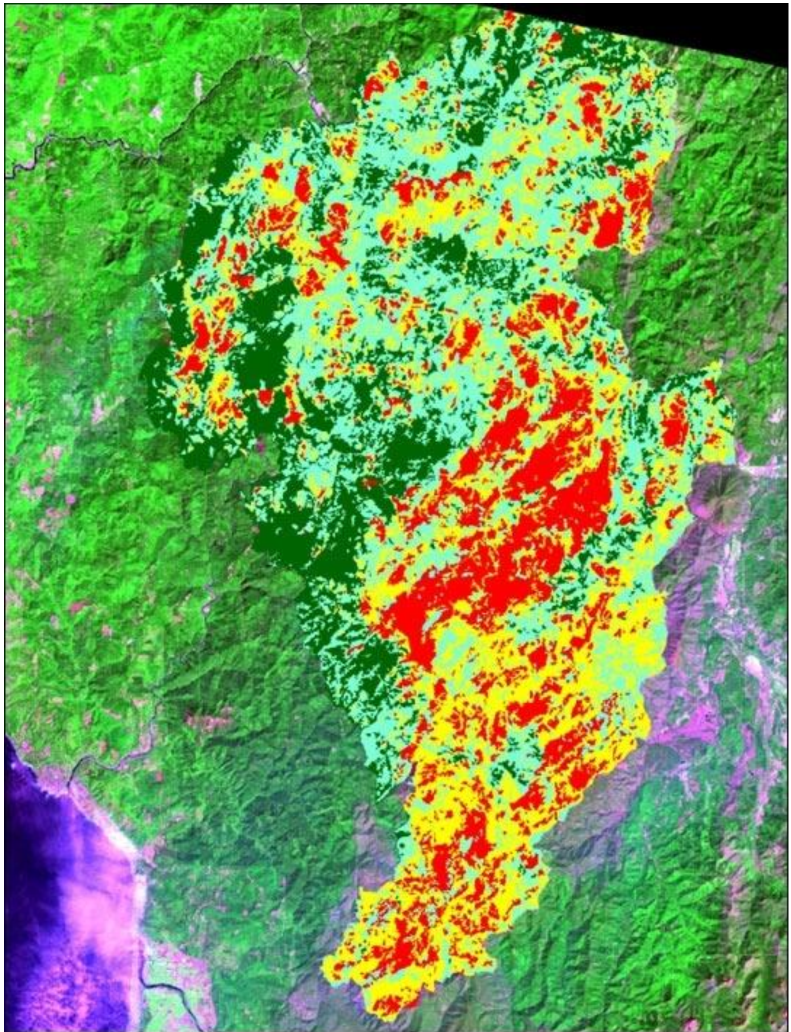


Fire Spread and Behavior

How do we characterize fire spread and behavior?

Behavior Characteristics

1) Rate of Spread (m min^{-1})
2) Spread Direction (°)
3) Flame Length (m)
4) Fireline Intensity (kW m^{-1})
5) Heat per Unit Area (kJ m^{-2})
6) Crown Fire Occurrence (y/n)



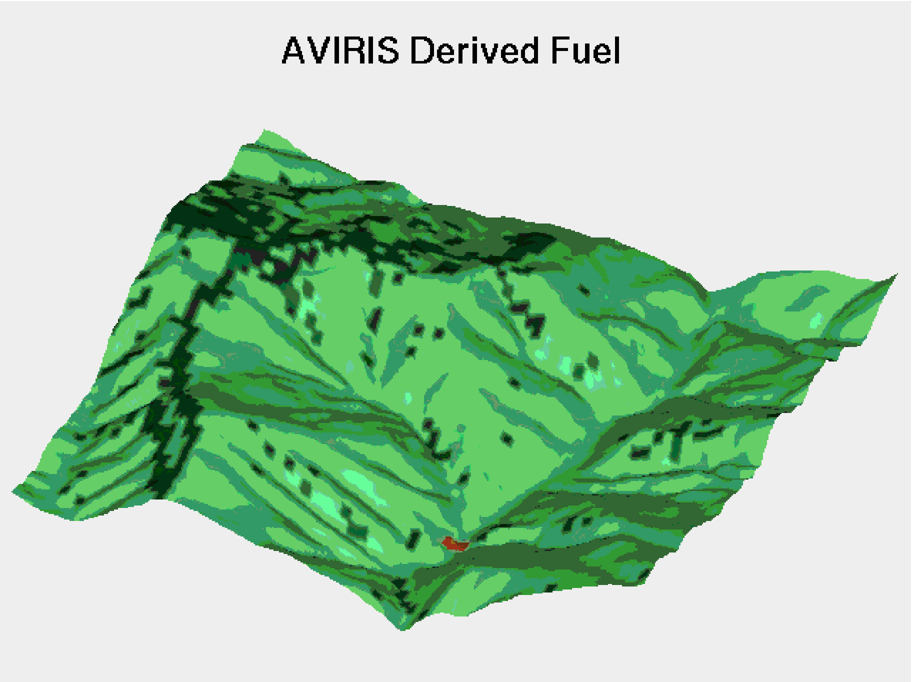
Fire Spread and Behavior Modeling

The **fire spread and behavior models** are software applications which are capable:

1) to predict the quantitative features used to describe the spread and behavior of a fire through the landscape (e.g.: ROS; FLI; etc.)

2) to predict the shape and/or the spatial extent of a wildland fire

3) to inform fire managers and researchers by considering a wide range of environmental and management conditions and scenarios (historic, real time, hypotethical, future)



Fire Spread and Behavior Modeling

A fire simulator is composed by

A) Fire Simulation Technique

It represents the technique by which the parameters describing both fire spread and behaviour are compounded at landscape-level

B) Fire Prediction Model

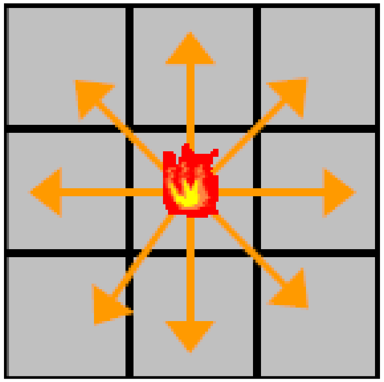
It is the core of the simulator, and simulates the fire propagation and behavior by considering a set of environmental conditions as inputs

Fire Spread and Behavior Modeling

A) Fire Simulation Technique

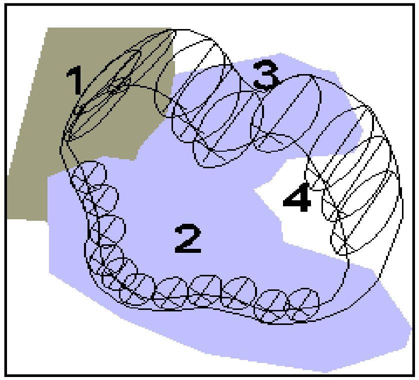
It represents the technique by which the parameters describing both fire spread and behavior are compounded at landscape-level

Landscape composed by a given number of cells



Bond Percolation and Cellular Automata (Cellular Models)

Landscape as a continuum medium



Elliptical Wave Propagation and Minimum Travel Time

Fire Spread and Behavior Modeling

B) Fire Prediction Model

It is composed by a set of equations the solutions of which give predicted fire behavior and spread data (rate of spread, fireline intensity, etc)

The outputs are strongly dependent on the environmental conditions (winds, fuel load, fuel moisture, etc)

Two main classifications of Fire Prediction Models

Fire Spread and Behavior Modeling

B) Fire Prediction Model

i) Physical System Modelling

Surface Fires

The most investigated and diffuse fire models

Fire Spread and Behavior Modeling

B) Fire Prediction Model

i) Physical System Modelling

Surface Fires

Fire Spread and Behavior Modeling

B) Fire Prediction Model

i) Physical System Modelling

Crown Fires

Very difficult to be studied

Fire Spread and Behavior Modeling

B) Fire Prediction Model

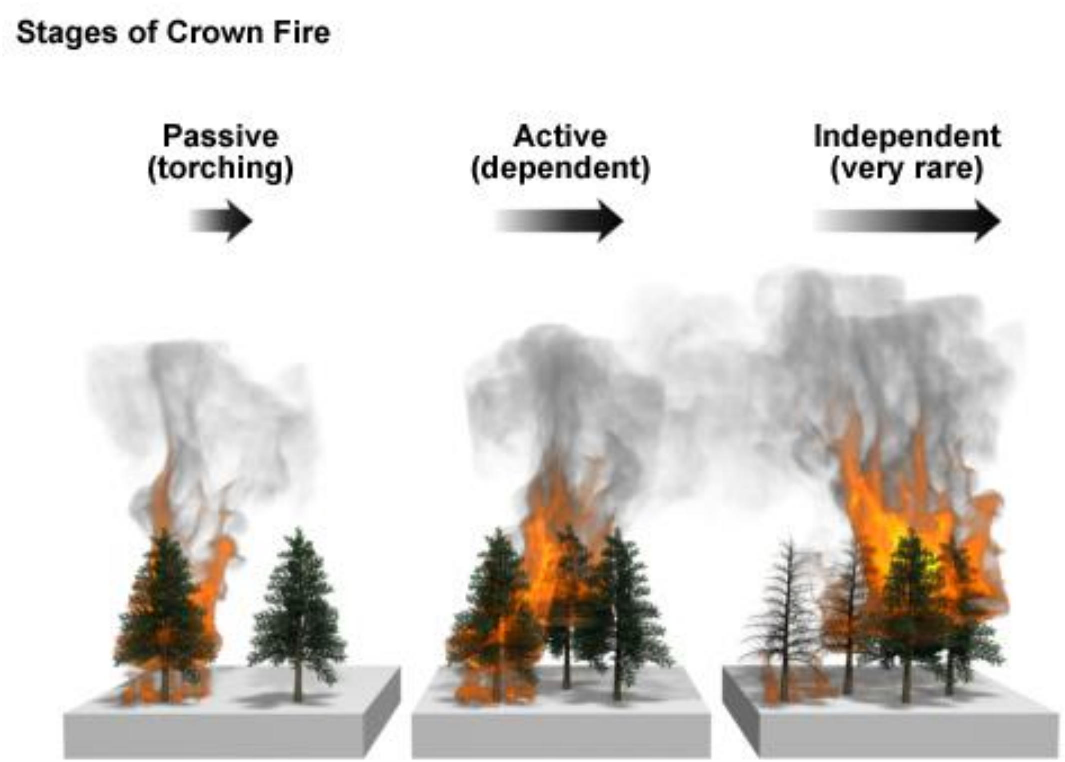
i) Physical System Modelling

Crown Fires

Passive

Active

Independent



Fire Spread and Behavior Modeling

B) Fire Prediction Model

i) Physical System Modelling

Ground Fires

Fire Spread and Behavior Modeling

B) Fire Prediction Model

i) Physical System Modelling

Spot Fires

Very very difficult to be studied!

Fire Spread and Behavior Modeling

B) Fire Prediction Model

ii) Heat Transfer Modelling

Physical Models (Theoretical)

Empirical Models (Statistical)

Semi-Empirical Models (Semi-Physical)

→ Rothermel's Equation (1972)

(Pastor et al., 2003)

Fire Spread and Behavior Modeling

Rothermel's Equation (1972)

$$R = \frac{I_r \pi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

R = rate of spread (in m min^{-1}), the forward rate of propagation of the surface fire front, in stationary conditions

I_r = reaction intensity, the energy release rate per unit area of flame front;

π = propagating flux ratio, the fraction of energy released responsible for neighboring fuel heating and ignition;

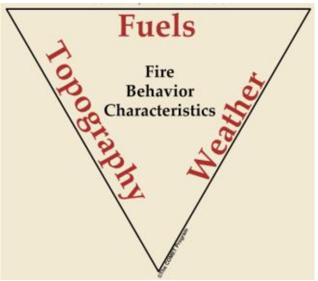
Φ_w, Φ_s = adimensional factors linked to wind and slope;

ρ_b = bulk density, the dry mass of fuel per unit volume;

ε = effective heating number, the ratio between the bulk density and the mass of fuel involved in the ignition process;

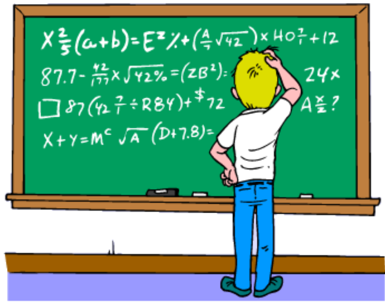
Q_{ig} = heat of pre-ignition, the heat required to bring the unit weight of fuel to ignition.

Fire Spread and Behavior Modeling



Rothermel's Equation (1972)

$$R = \frac{I_r \pi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}} = \frac{I_r \pi}{\rho_b \varepsilon Q_{ig}} + \frac{I_r \pi \phi_w}{\rho_b \varepsilon Q_{ig}} + \frac{I_r \pi \phi_s}{\rho_b \varepsilon Q_{ig}}$$



Fire rate of spread

Rate of spread fraction mainly determined by fuelbed and fuel particles characteristics

Rate of spread fraction mainly linked with the wind speed

Rate of spread fraction mainly determined by the slope

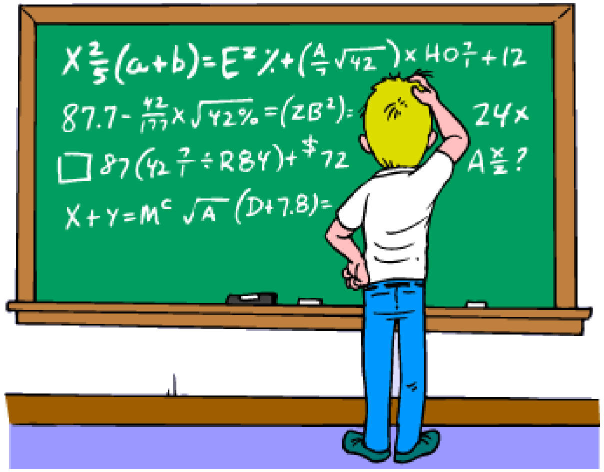
Fire Spread and Behavior Modeling

Rothermel's Equation (1972)

$$R = \frac{I_r \pi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

Total heat released by the combustion process in a defined system (landscape with given environmental conditions)

Heat that the system is able to adorb (strongly related to fuel characteristics)

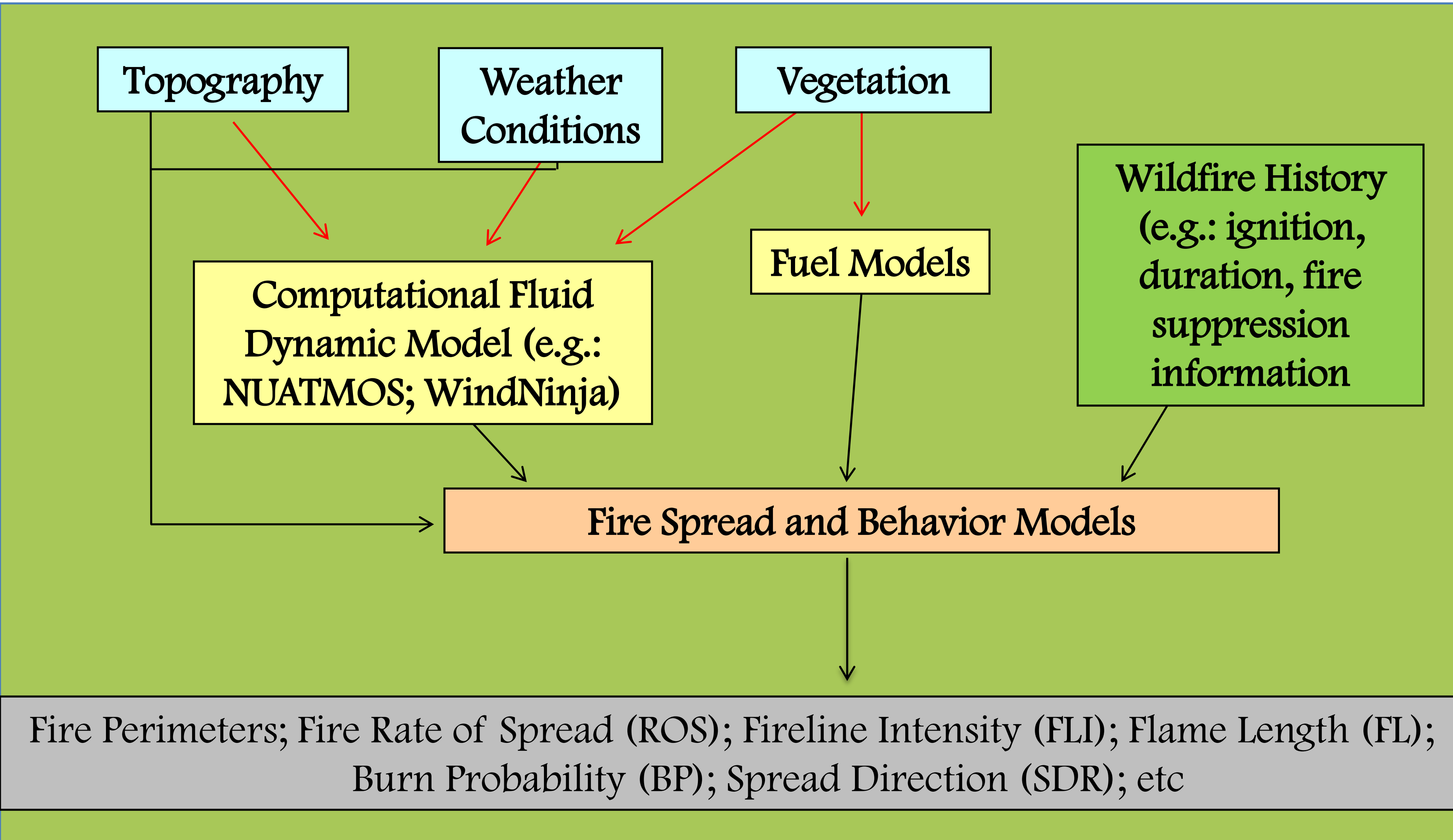


Fire Spread and Behavior Modeling

NAME	*COUNTRY*	*AUTHORS*	*MAIN CHARACTERISTICS*	
BURN	United States	Veach et al. (1994)	SFM Rothermel	Cellular simulation technique (cellular automaton)
CARDIN	Spain	Martìnez Millàn et al. (1991)	SFM Rothermel	Cellular simulation technique
DYNAFIRE	United States	Kalabokidis et al. (1991)	SFM Rothermel	Cellular simulation technique (cellular automaton)
EMBYR	United States	Hargrove et al. (2000)	SFM Hargrove et al.	SM Albini; Cellular simulation technique (bond percolation)
FARSITE	United States	Finney (1994)	SFM Rothermel CFIM Finney	SM Albini; Wave simulation technique; CFSM Scott and Reinhardt
FIREGIS	Portugal	Almeida et al. (1997)	SFM Rothermel	Cellular simulation technique (cellular automaton)
FIREMAP	United States	Ball and Guertin (1992)	SFM Rothermel	Cellular simulation technique (cellular automaton)
FIRESTATION	Portugal	Lopes et al. (1998)	SFM Rothermel	Cellular simulation technique
FLAMMAP	United States	Finney (2003)	SFM Rothermel CFIM Finney	Wave simulation technique; CFSM Scott and Reinhardt
GEOFOGO	Portugal	Vasconcelos et al. (1998)	SFM Rothermel	Cellular simulation technique
INTEGRATED INFLAME SOFTWARE SYSTEM	European Union	Viegas (2000)	Viegas et al.; Marguerit and Guillaume	Cellular simulation technique
MEFISTO-AIOLOS-F	Greece	Lymberopoulos et al. (1996)	SFM Croba et al.	Cellular simulation technique
PFAS	Canada	Anderson (2002)	SFM Forestry Canada Fire Danger Group	CFSM Forestry Canada Fire Danger Group; Cellular simulation technique
PROMETHEUS	Canada	Canadian Wildland Fire Growth Model Project Team (1999)	SFM Forestry Canada Fire Danger Group	CFSM Forestry Canada Fire Danger Group; Wave simulation technique
PYROCART	New Zealand	Perry et al. (1999)	SFM Rothermel	Cellular simulation technique
SIROFIRE	Australia	Coleman and Sullivan (1995)	SFM McArthur	Wave simulation technique
SPARKS	Switzerland	Schöning (1996)	SFM Rothermel	Cellular simulation technique
SPREAD	Portugal	Mendes-Lopes et al. (2000)	SFM Rothermel	Cellular autom. simulation technique
WILDFIRE	Canada	Wallace (1993)	SFM Forestry Canada Fire Danger Group	CFSM Forestry Canada Fire Danger Group
SFM = surface fire model; CFIM = crown fire ignition model; CFSM = crown fire spread model; SM = spotting model				

Fire Spread and Behavior Modeling

Fire Spread and Behavior Models: Workflow



Fire Spread and Behavior Modeling

Fire Spread Modelling Issues related to the Input Data

Spatial and temporal variability of weather conditions (particularly wind speed and direction)

Topography does not change in time but only in space, and represents an "easy" input

a) Spatio-temporal variability and heterogeneity of vegetation (species, age, moisture, heigth, canopy cover, etc.)
b) Several information to describe the fuel characteristics (load, moisture, moisture of extinction, SAV ratio, heat content, etc.)
c) Need to "create" reference (custom) fuel models
d) Few studies on Mediterranean fuel types (e.g. Mediterranean maquis)

Fire Spread and Behavior Modeling

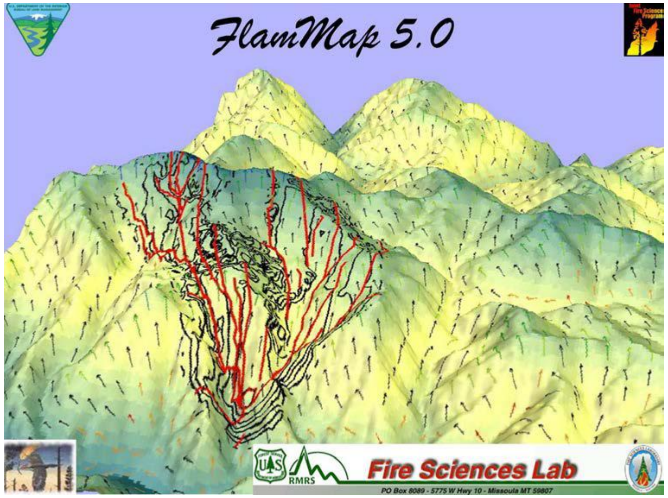
FARSITE (Finney, 1998)

Based on the semi-empirical fire model of Rothermel (1972) for surface fire spread

The spatial growth of the fire perimeter is simulated by the elliptical wave propagation technique

- Surface fire modelling
- Crown fire modelling
- Spot fires modelling
- Post frontal combustion
- Fire acceleration

Fire Spread and Behavior Modeling



FlamMap (Finney 2006)

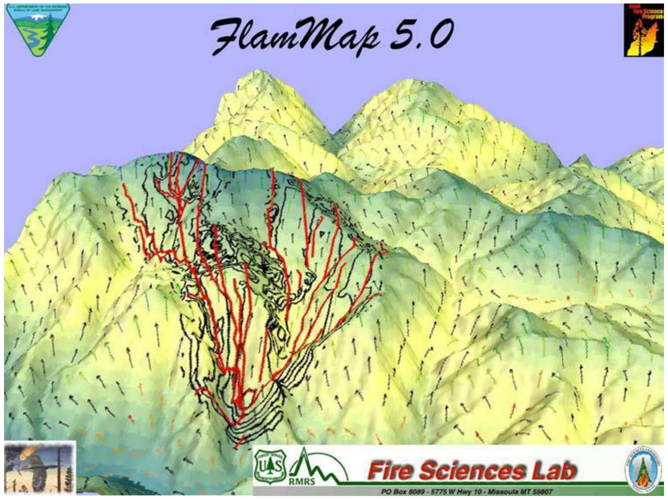
Based on the semi-empirical fire model of Rothermel (1972) for surface fire spread

A fire behavior mapping and analysis program that computes potential fire behavior characteristics (such as spread rate, flame length, and fireline intensity) over an entire landscape using constant weather and fuel moisture conditions for an instant in time

a) Basic FlamMap

b)MTT FlamMap

Fire Spread and Behavior Modeling



FlamMap (Finney 2006)

a) Basic FlamMap

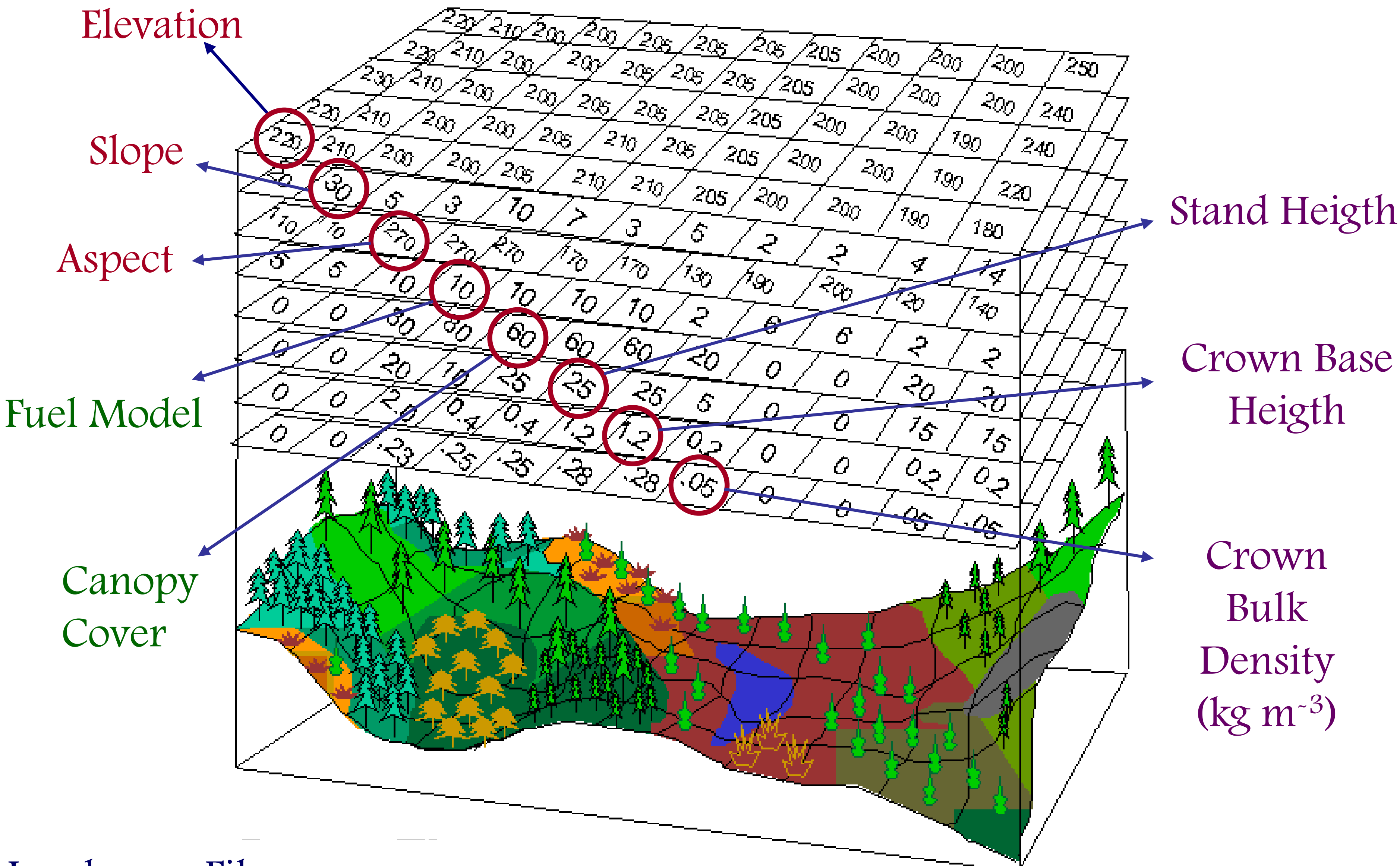
It is not a fire growth simulation model. It provides fire behavior characteristics for every cell, as if the entire landscape was burning all at the same time. (FARSITE provides fire behavior characteristics within the simulated fire perimeter)

b) MTT FlamMap

It is spatial and provides fire growth across the landscape for short periods of time for a single set of wind and fuel moisture conditions. It also calculates fire flow paths

New command-line versions of MTT FlamMap (Randig)

Fire Spread and Behavior Modeling



Landscape File

Finney, 1998

Fire Spread and Behavior Modeling

Weather Conditions → Dynamic

Input Data

Wind Speed (km/h) and Direction (0° – 360°)

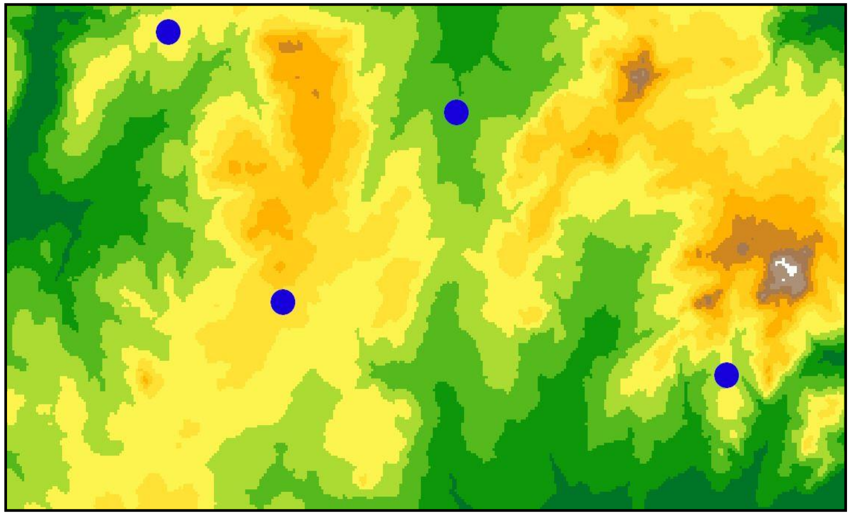
Minimum and Maximum Temperatures (°C)

Minimum and Maximum Relative Humidity (%)

Cloud Cover (%)

Rain (mm)

Raster Format (ascii files) or constant values for each weather station



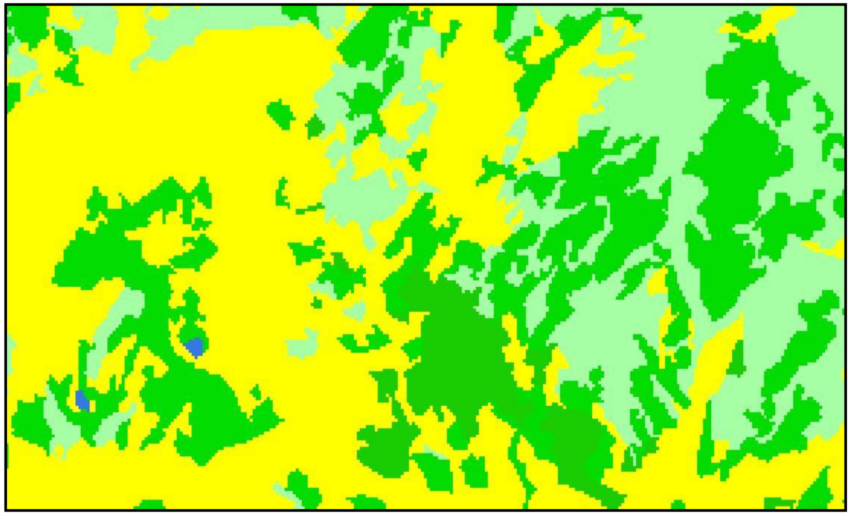
Fire Spread and Behavior Modeling

Fuels → Dynamic /Static

Input Data

- Fuel Load (t ha^{-1})
- SAV Ratios (cm^{-1})
- Fuelbed Depth (m)
- Moisture of Extinction (% DW)
- Heat Content (kJ kg^{-1})
- Canopy Cover (%)
- Moisture (% DW)

Raster Format (ascii files)



Fire Spread and Behavior Modeling

Fuels → Dynamic /Static

Input Data

Timelag Classes
0÷0.6 cm (1hr)
0.6÷2.5 cm (10hr)
2.5÷7.6 cm (100hr)
> 7.6 cm (1000 hr)

Fuel Load, SAV Ratio

Fire Spread and Behavior Modeling

Fire data → Dynamic / Static

Input Data

Ignition point

Aerial and terrestrial attacks

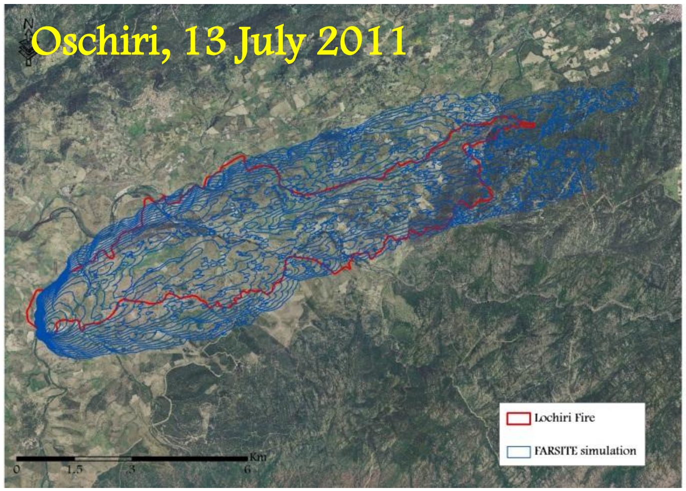
Barrier creation

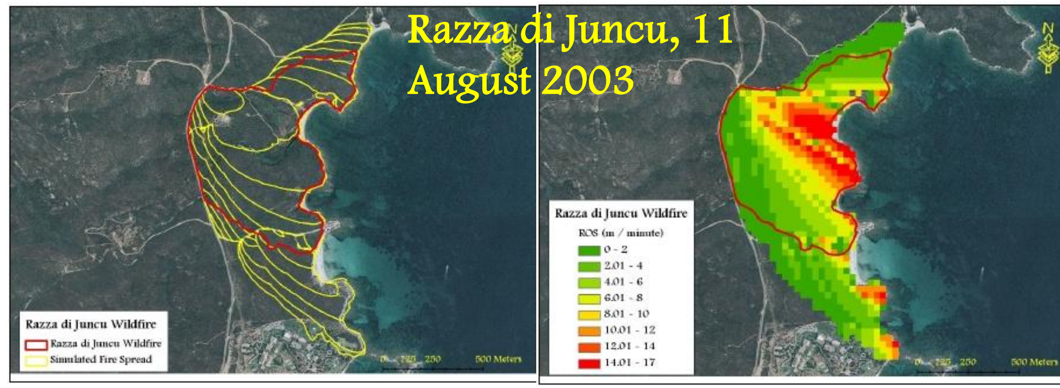
Other fire information or observations

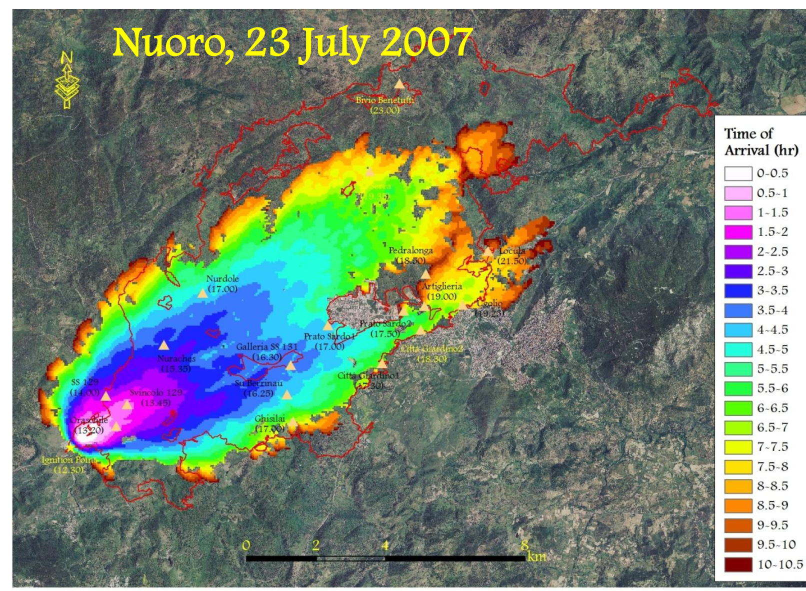
Raster or Vector Format (ascii files)

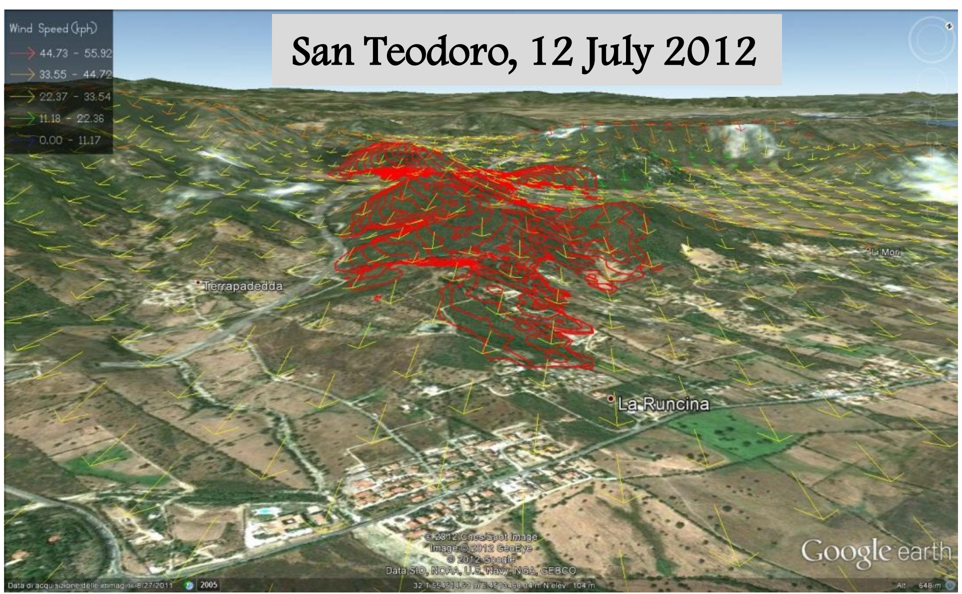
Fire Spread and Behavior Modeling

Need to calibrate and validate the fire spread models…







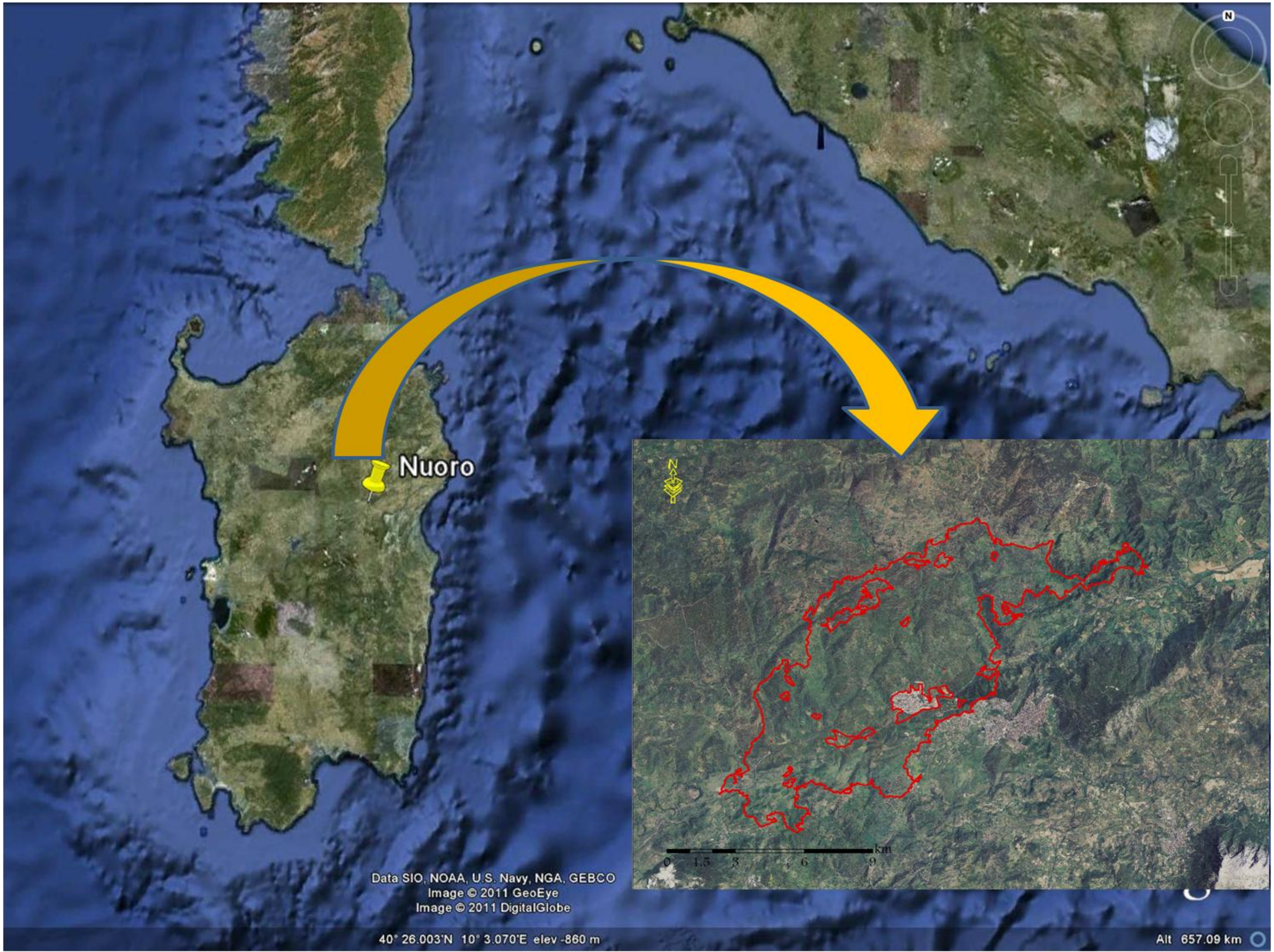


(Salis et al.; Arca et al.; Alcasena et al.; Jahdi et al.)

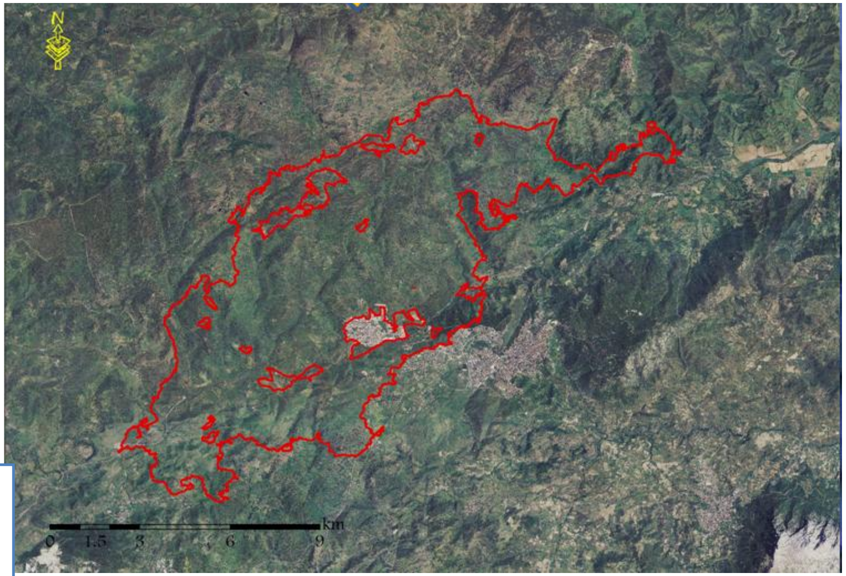
Fire Spread and Behavior Modeling

Nuoro wildfire

23 July 2007



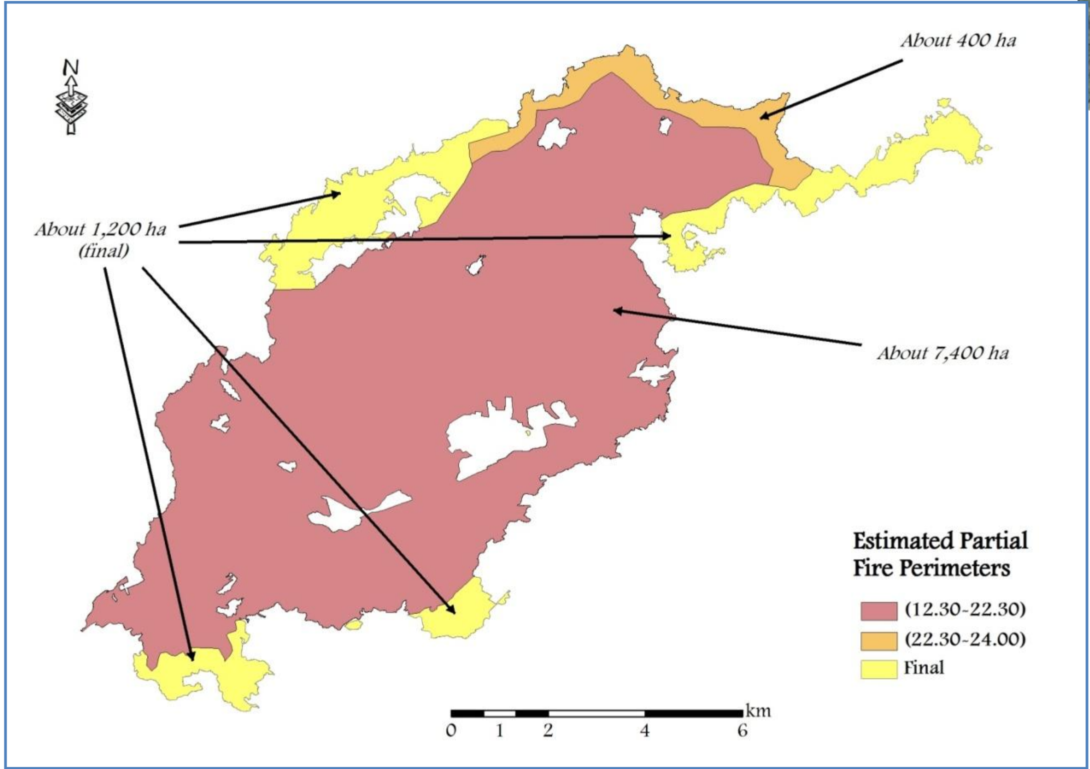
Fire Spread and Behavior Modeling



About 24 hours of propagation

9,000 ha of burned areas

About 7,400 ha in 10 hours



Several damages to values and civil protection problems

Manca, 2011

Fire Spread and Behavior Modeling

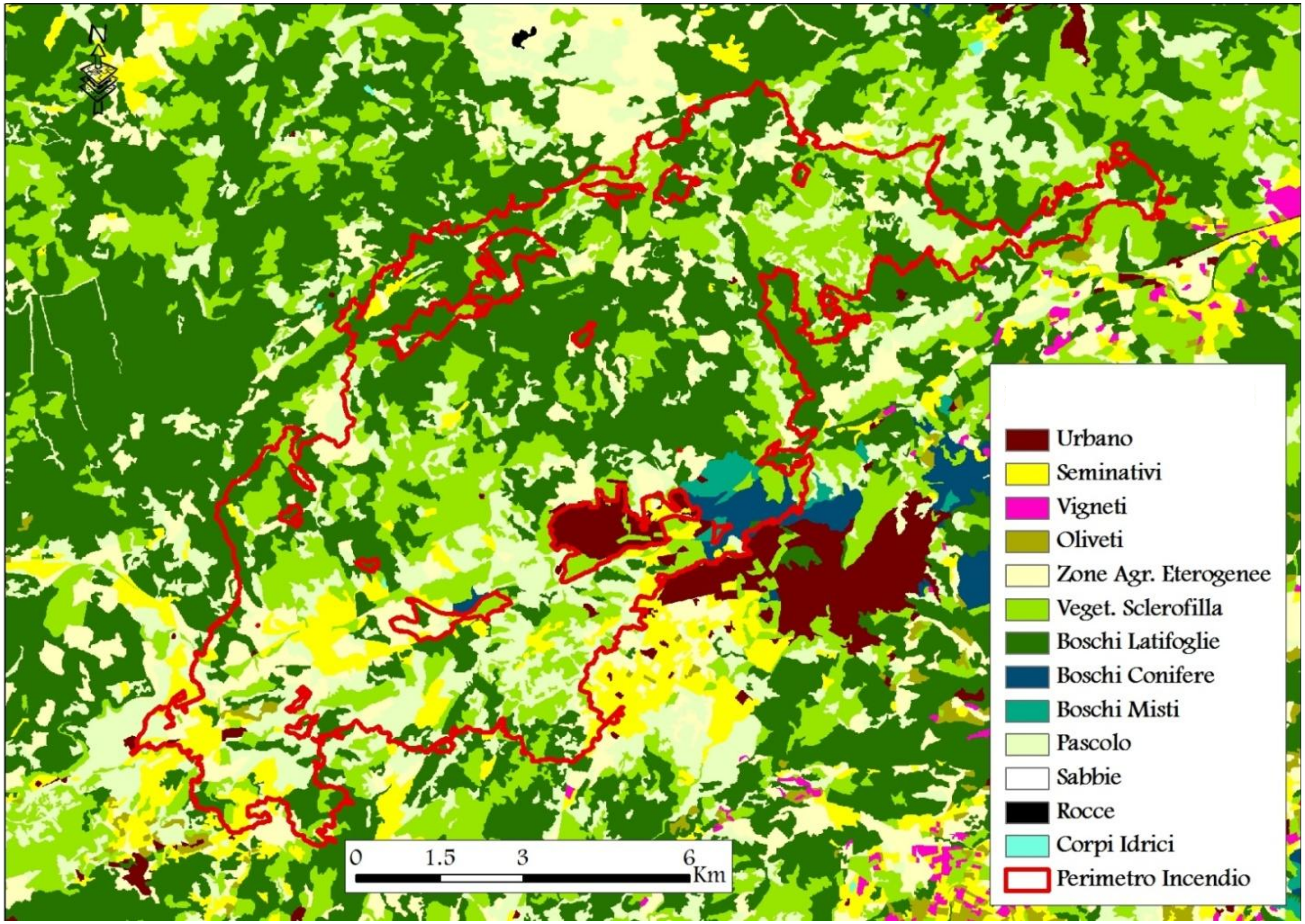
Courtesy of Sardinia Forest Service

Fire Spread and Behavior Modeling

Courtesy of Sardinia Forest Service

Fire Spread and Behavior Modeling

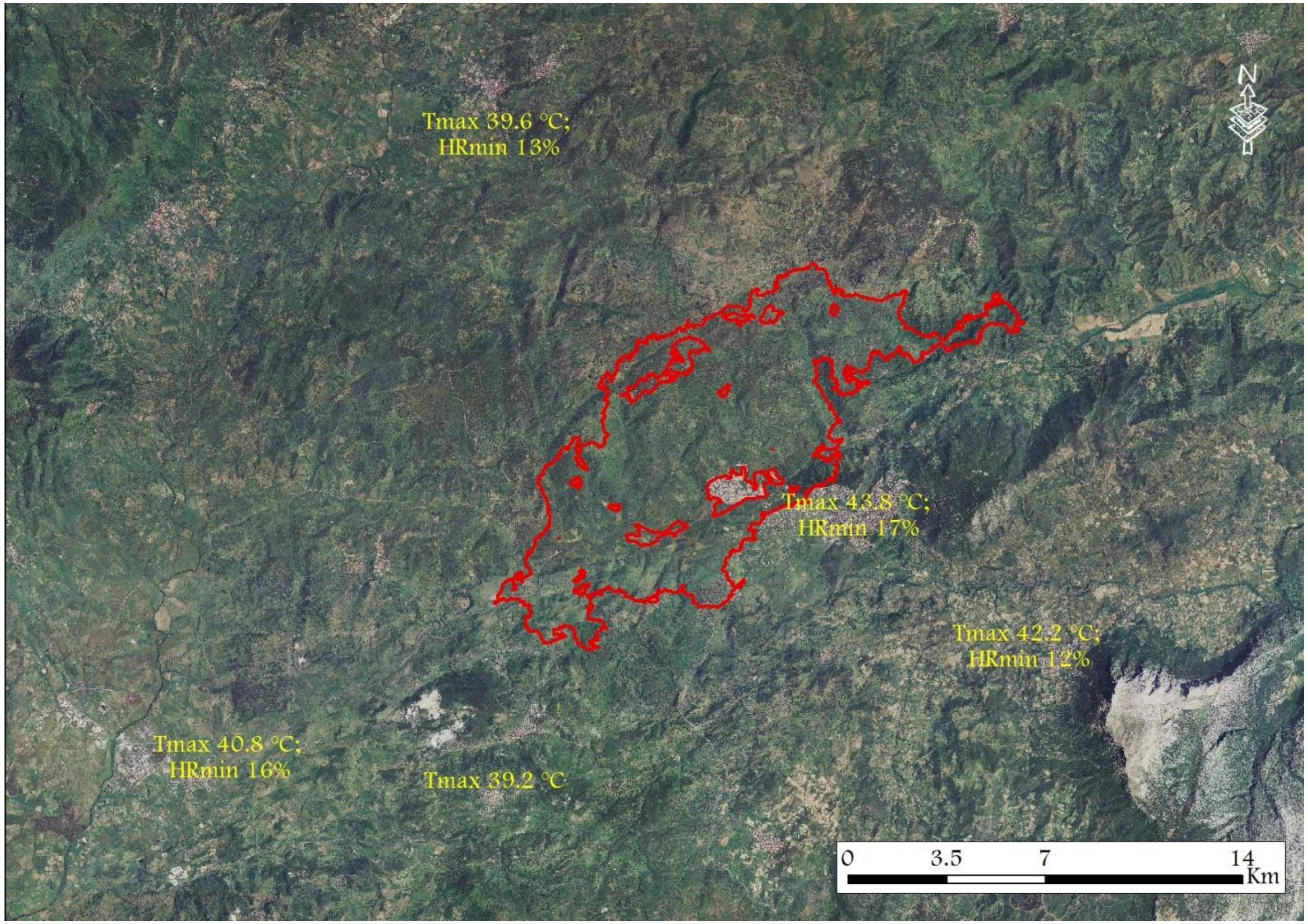
The vegetation is characterised by a mix of pastures, cork oak forests and Mediterranean maquis



Manca, 2011

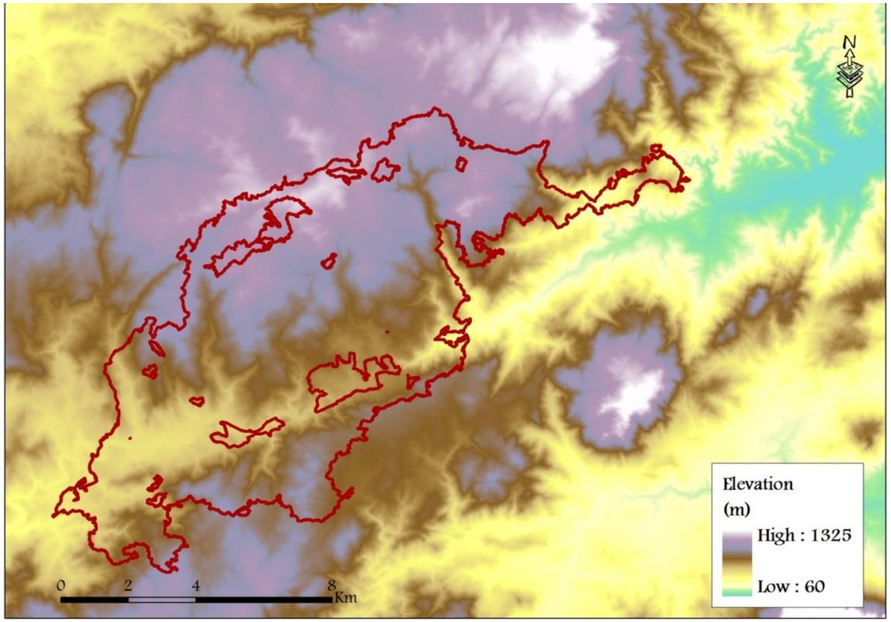
Fire Spread and Behavior Modeling

Extreme weather conditions with very high maximum temperatures (>40° C), low relative humidity (<20%), strong winds (35 kmh) from SW



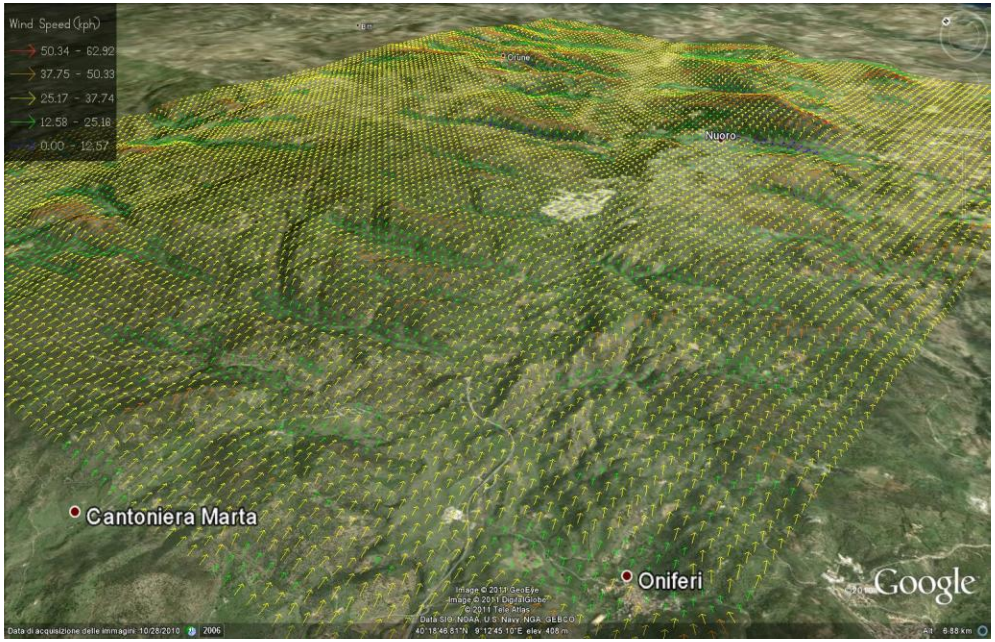
Manca, 2011

Fire Spread and Behavior Modeling

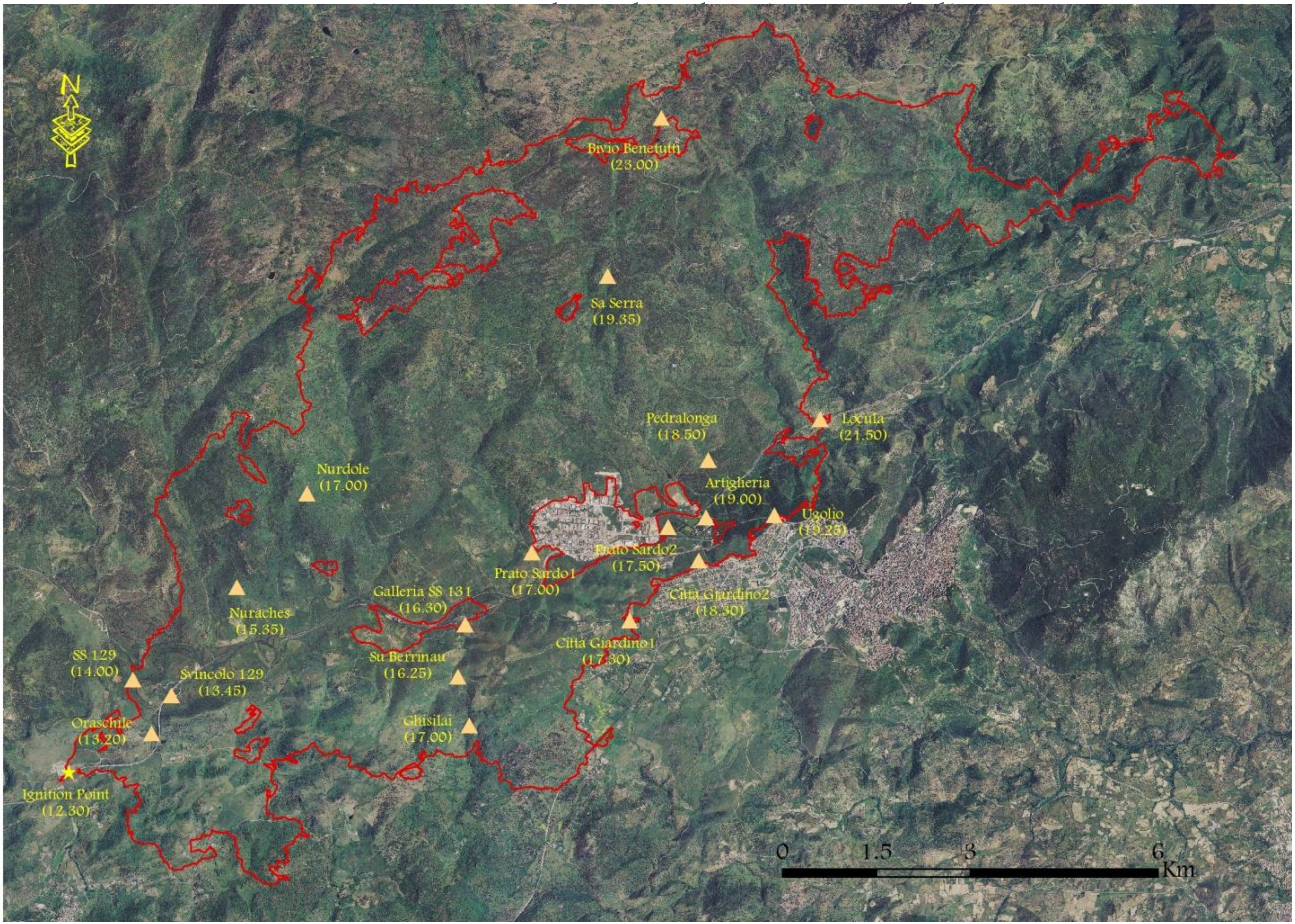


Elevation map

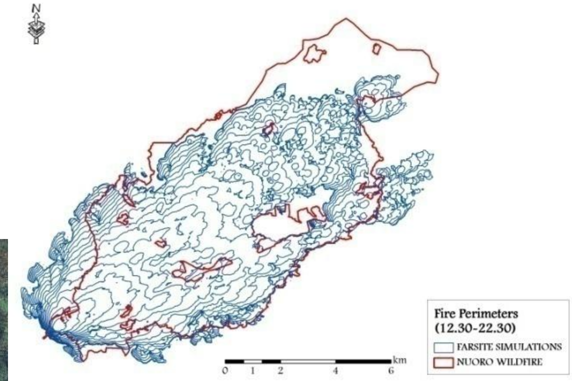
Wind field map (WindNinja)
(2.30 pm)

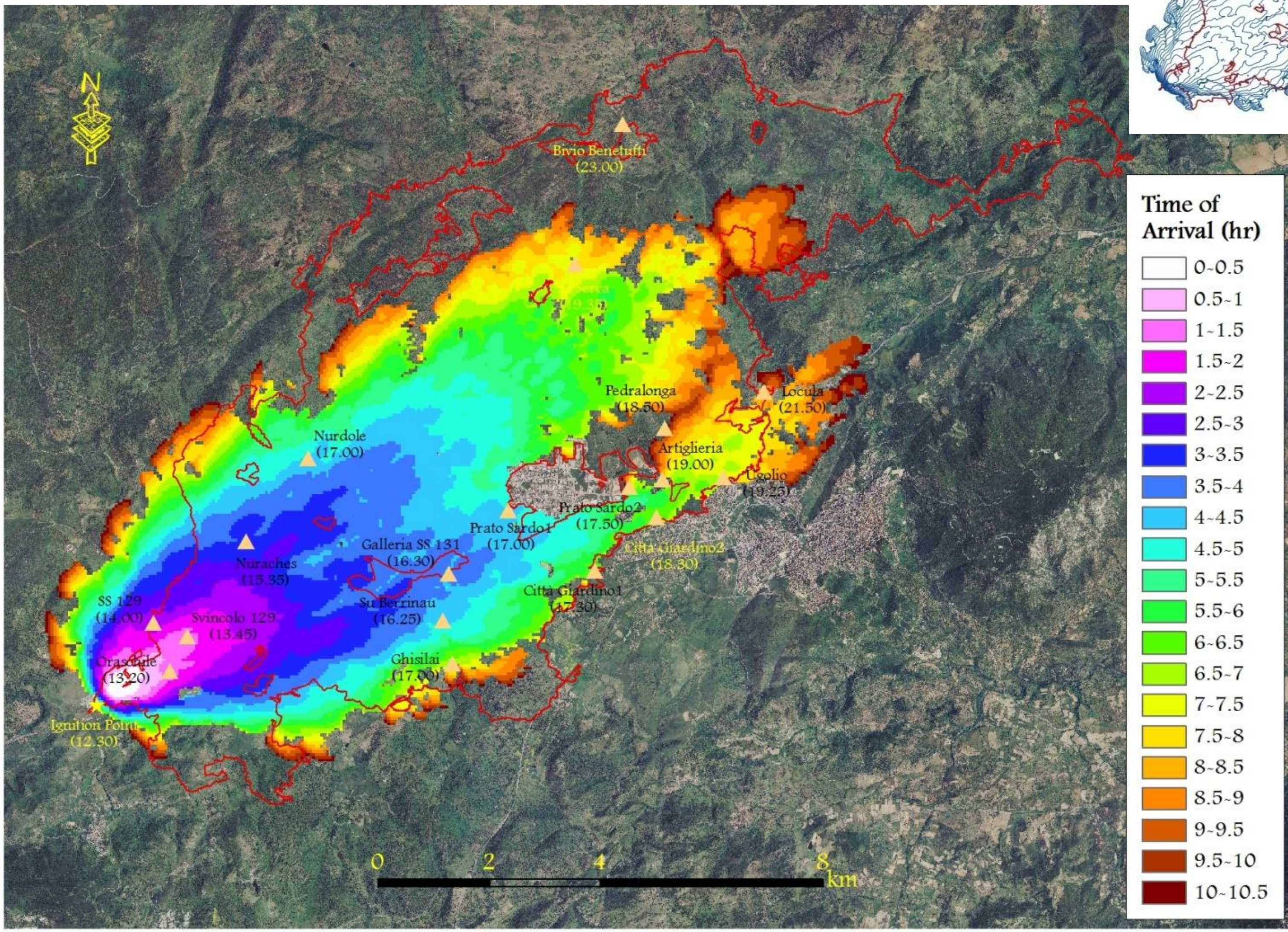


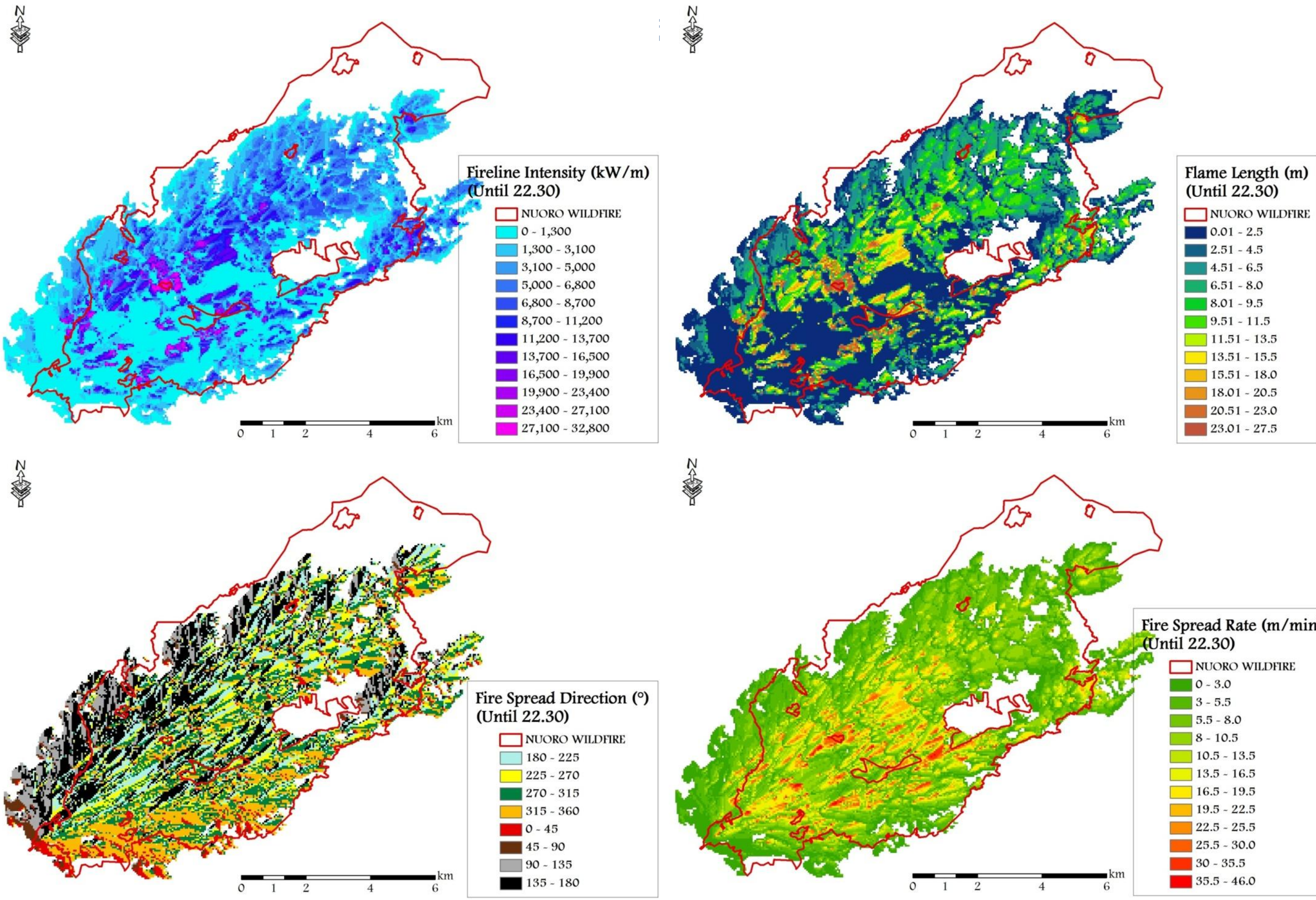
Manca, 2011


N
Bivio Benetutti
(23.00)
Sa Serra
(19.35)
Pedralonga
(18.50)
Locula
(21.50)
Nurdole
(17.00)
Artiglieria
(19.00)
Ugolio
(19.25)
Prato Sardo2
(17.50)
Prato Sardo1
(17.00)
Galleria SS 131
(16.30)
Citta Giardino2
(18.30)
Nuraches
(15.35)
Citta Giardino1
(17.30)
SS 129
(14.00)
Svincolo 129
(13.45)
Su Berrinau
(16.25)
Oraschile
(13.20)
Ghisilai
(17.00)
Ignition Point
(12.30)
0 1.5 3 6
Km

Fire Spread and Behavior Modeling

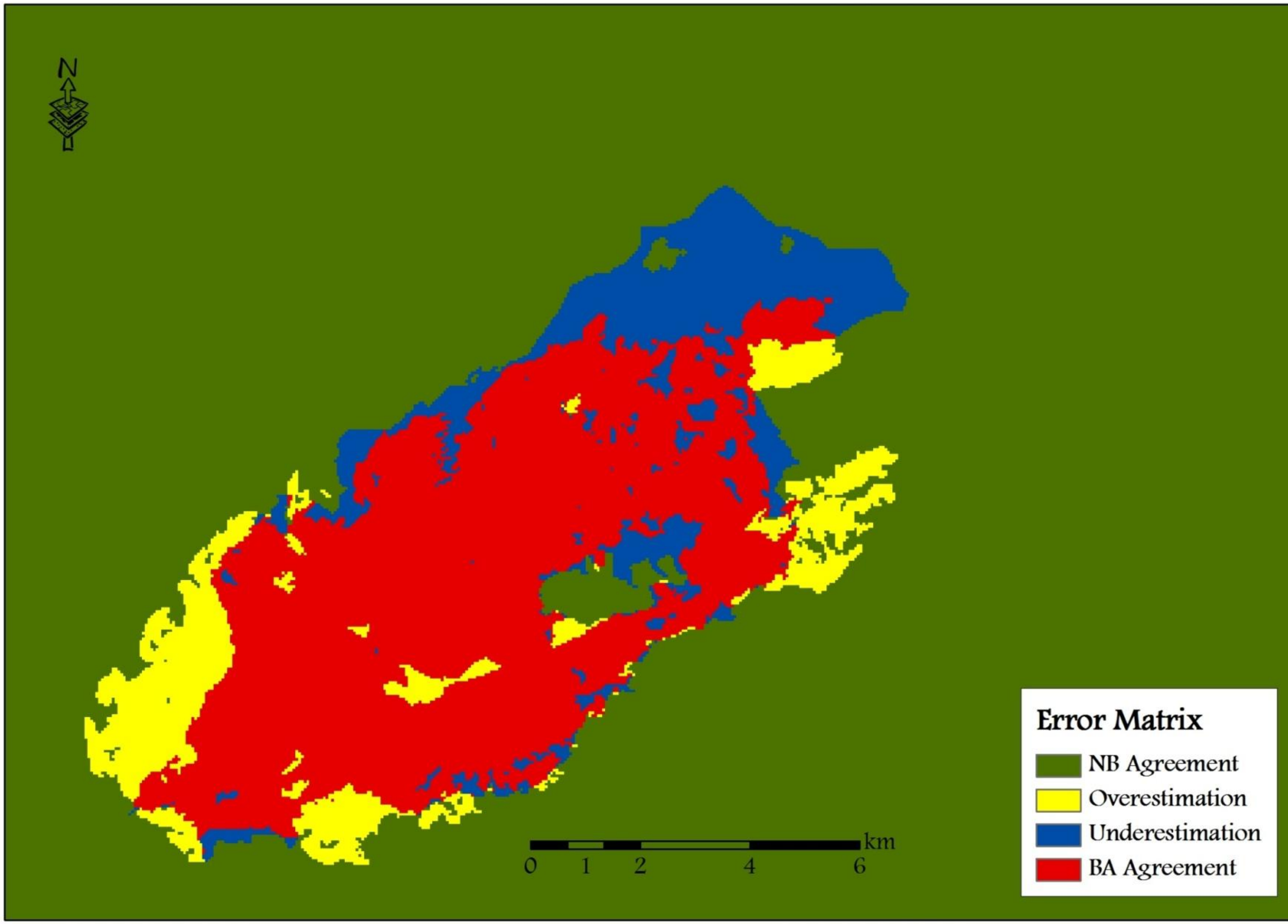





Fireline Intensity (kW/m)
(Until 22.30)
NUORO WILDFIRE
0 - 1,300
1,300 - 3,100
3,100 - 5,000
5,000 - 6,800
6,800 - 8,700
8,700 - 11,200
11,200 - 13,700
13,700 - 16,500
16,500 - 19,900
19,900 - 23,400
23,400 - 27,100
27,100 - 32,800
Flame Length (m)
(Until 22.30)
NUORO WILDFIRE
0.01 - 2.5
2.51 - 4.5
4.51 - 6.5
6.51 - 8.0
8.01 - 9.5
9.51 - 11.5
11.51 - 13.5
13.51 - 15.5
15.51 - 18.0
18.01 - 20.5
20.51 - 23.0
23.01 - 27.5
Fire Spread Direction (°)
(Until 22.30)
NUORO WILDFIRE
180 - 225
225 - 270
270 - 315
315 - 360
0 - 45
45 - 90
90 - 135
135 - 180
Fire Spread Rate (m/min)
(Until 22.30)
NUORO WILDFIRE
0 - 3.0
3 - 5.5
5.5 - 8.0
8 - 10.5
10.5 - 13.5
13.5 - 16.5
16.5 - 19.5
19.5 - 22.5
22.5 - 25.5
25.5 - 30.0
30 - 35.5
35.5 - 46.0
N
km
0 1 2 4 6

Fire Spread and Behavior Modeling

Fire simulation accuracy (Sorensen and Kappa coefficients)



Manca, 2011

Fire Spread and Behavior Modeling

Site: Lochiri
Village: Oschiri, Sardinia

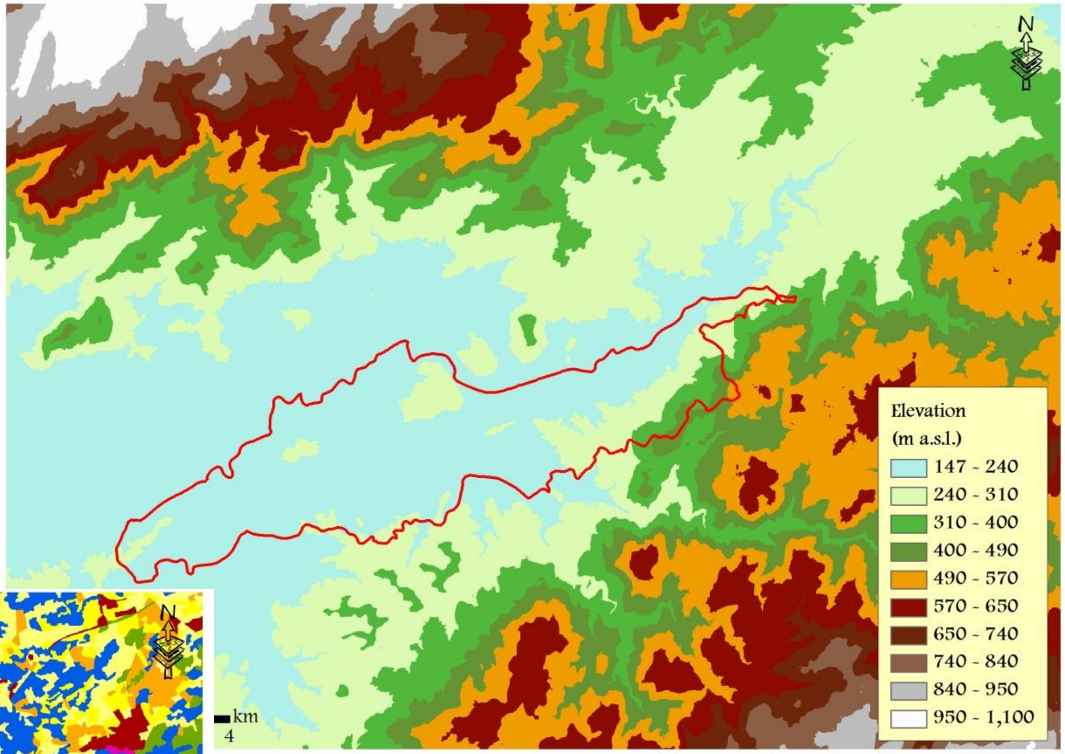
Burned Area: 2500 ha
Fire Start: 13/07/2011, 12.45 a.m. LST
Fire End: 13/07/2011, 7.15 p.m. LST

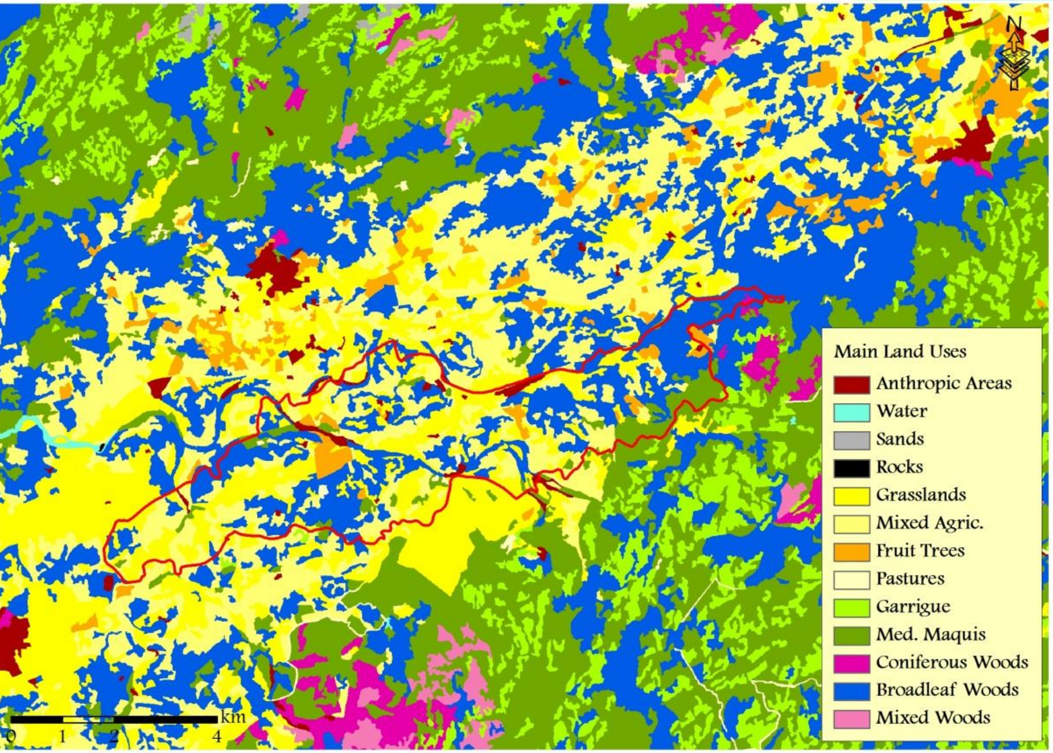
Main Vegetation: Open Pastures, Wooded Pastures, Orchards, Quercus woods, Pinus stands, Grasslands

Wind: SSW, 35 kmh^{-1}; Max Temp.: 40 °C

Mavuli et al. 2011; Salis et al. 2012

Fire Spread and Behavior Modeling





Mavuli et al. 2011; Salis et al. 2012



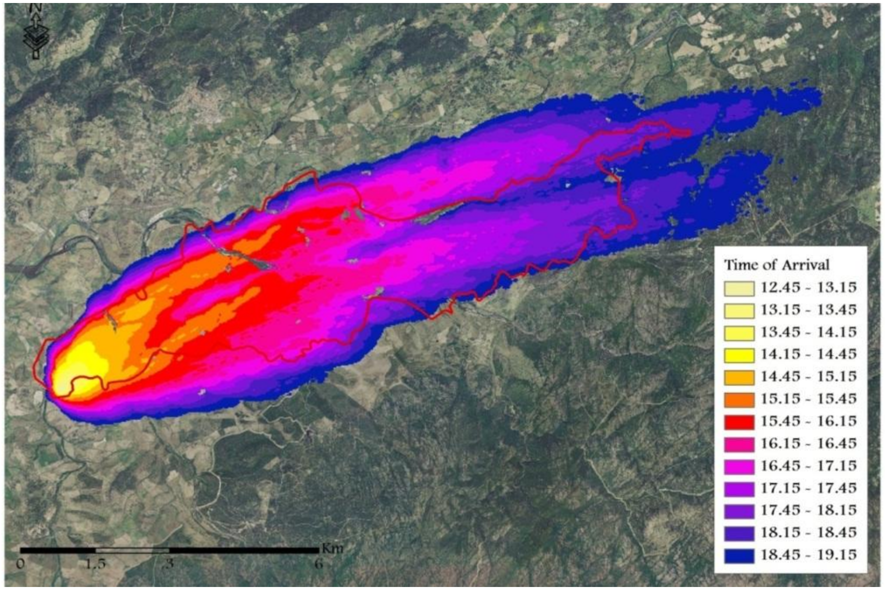


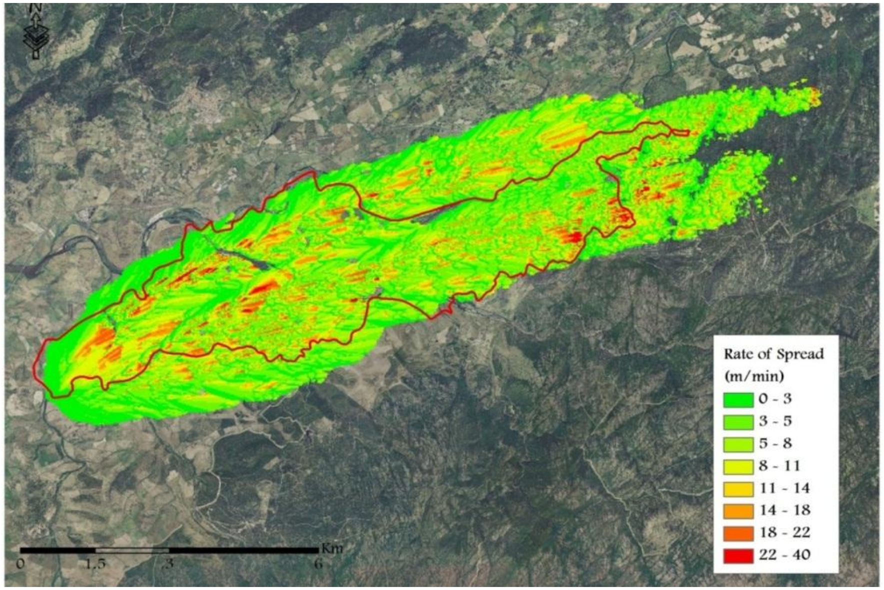


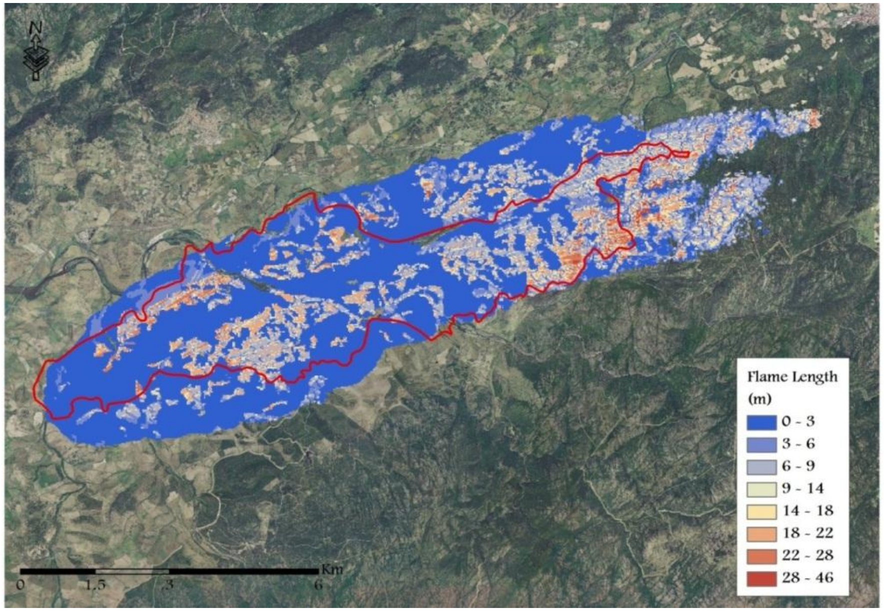


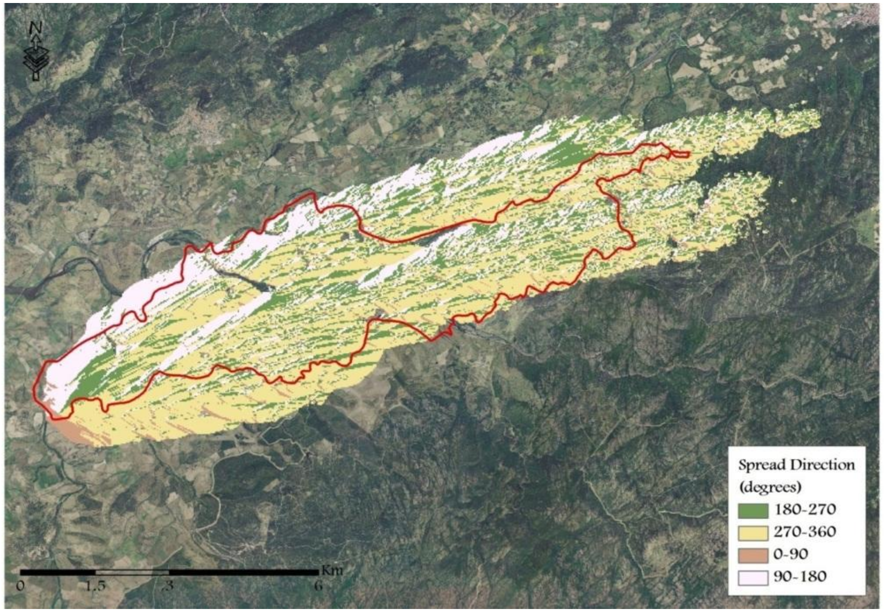
Mavuli et al. 2011; Salis et al. 2012

Fire Spread and Behavior Modeling



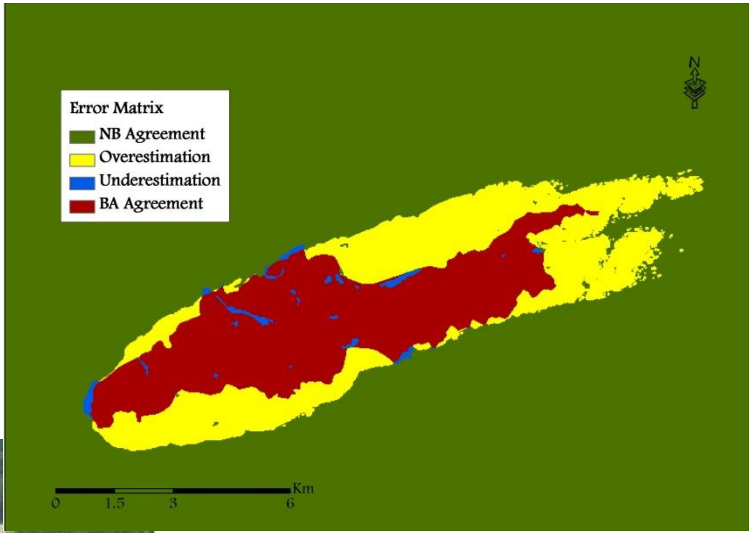


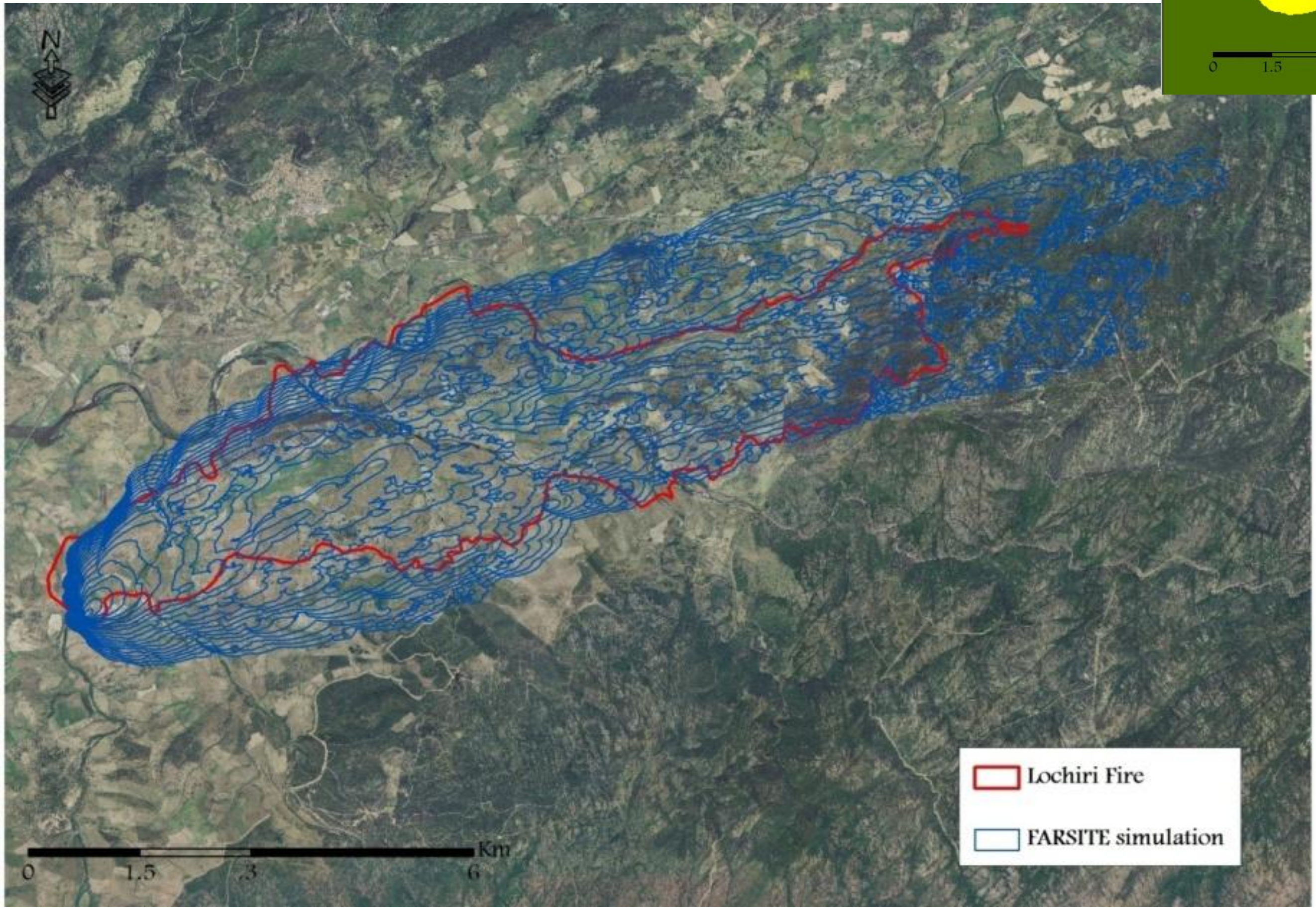




Fire Spread and Behavior Modeling

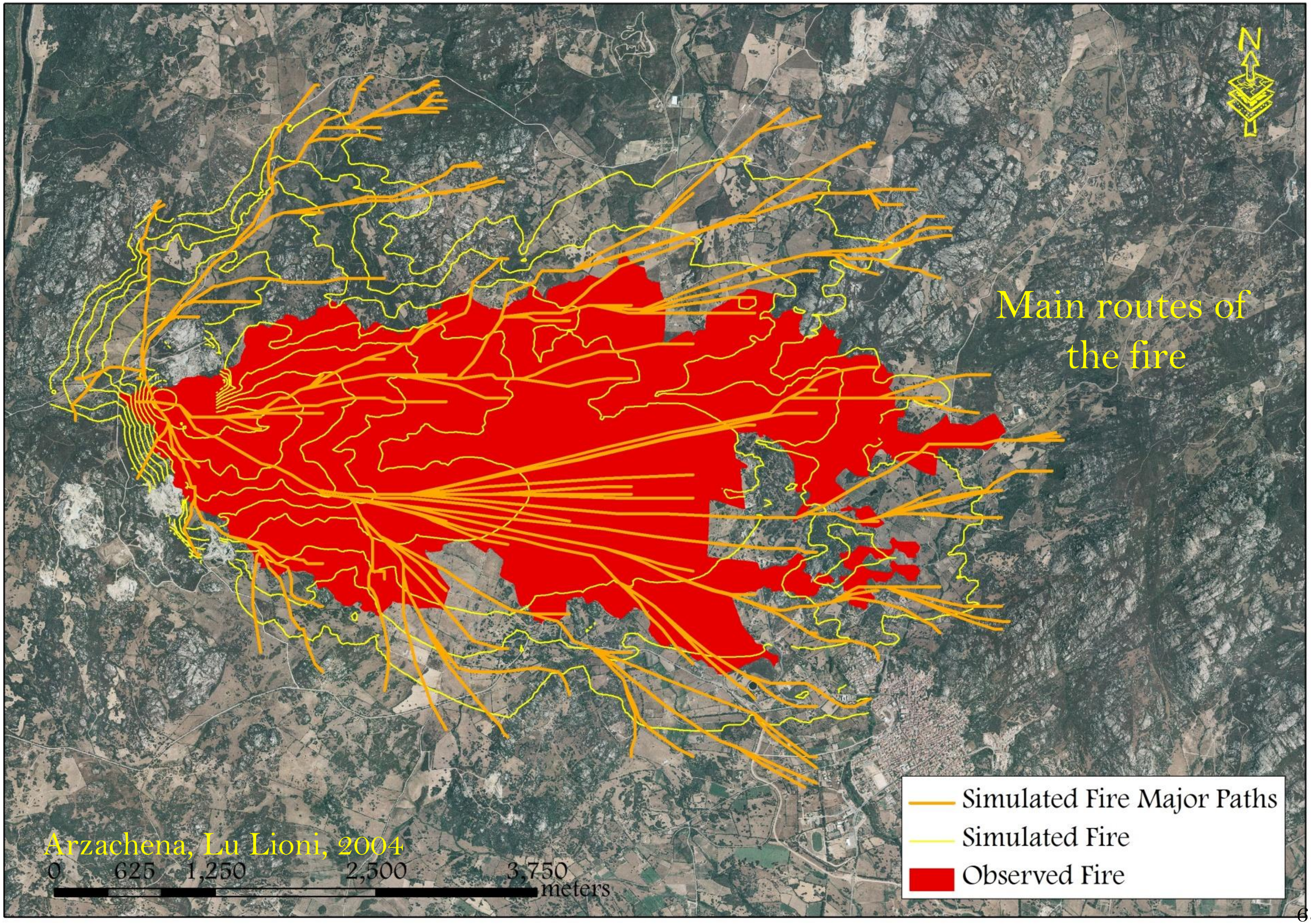
Accuracy of the simulation: about 65%



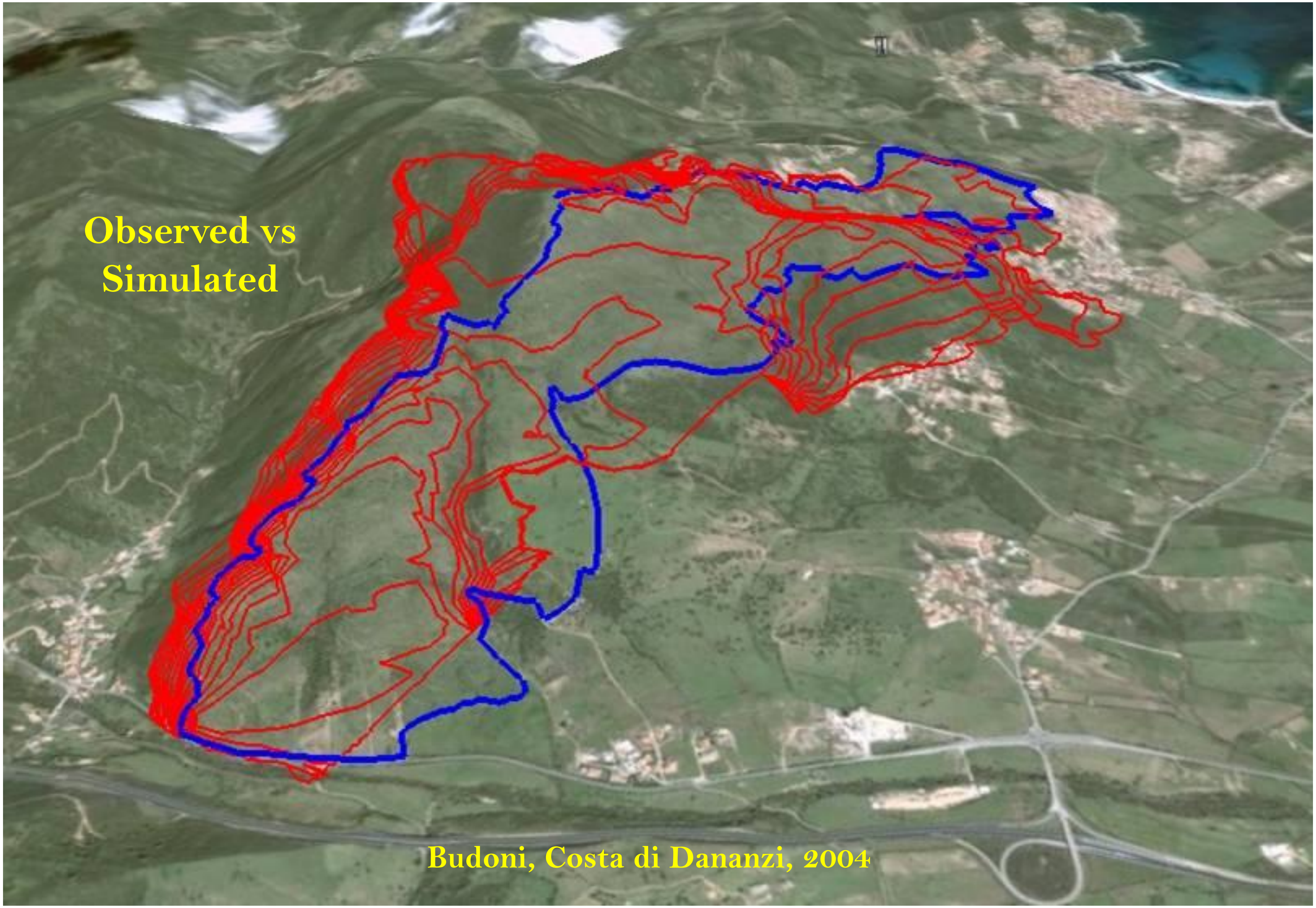


Mavuli et al. 2011; Salis et al. 2012

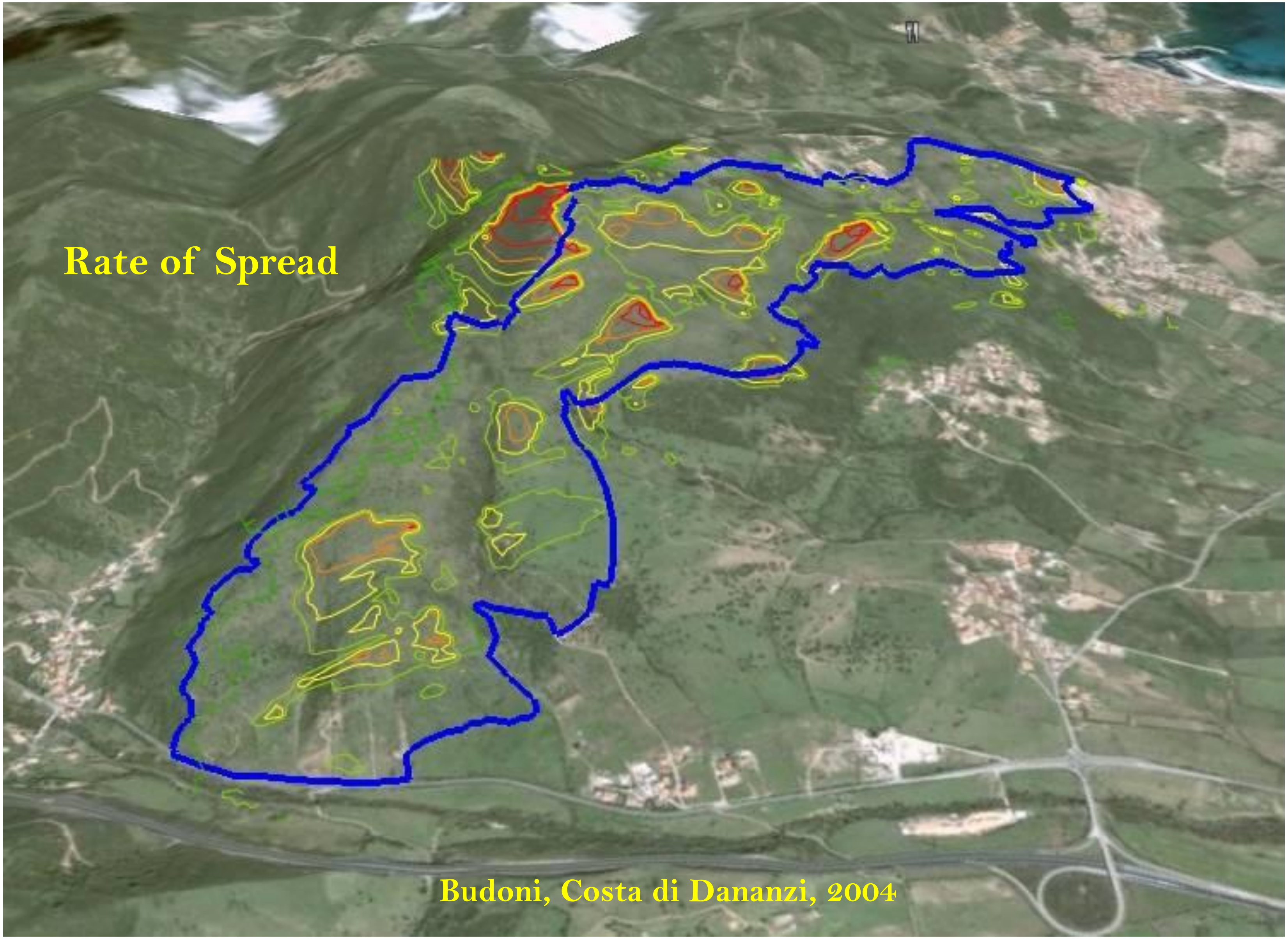
Fire Spread and Behavior Modeling



Fire Spread and Behavior Modeling



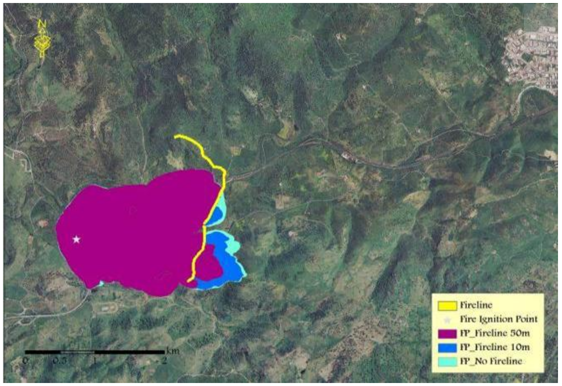
Fire Spread and Behavior Modeling

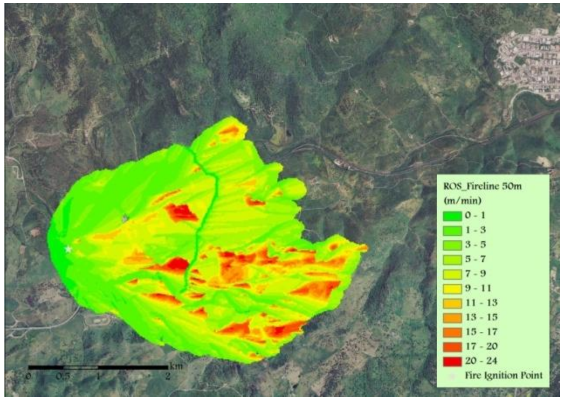


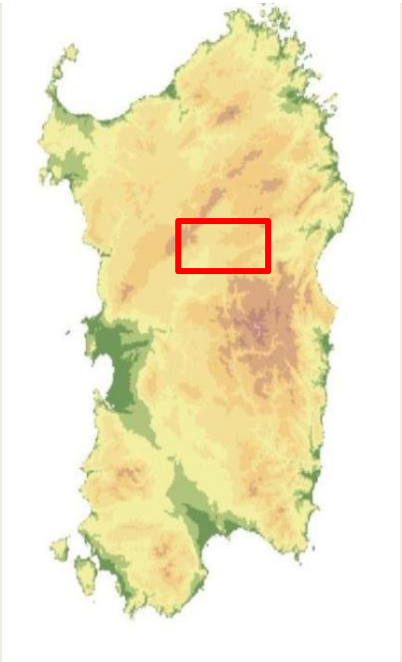
Fire Spread and Behavior Modeling

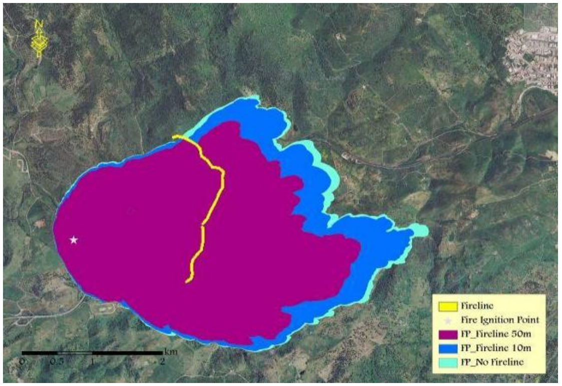
Diana et al. 2011; Salis et al. 2012

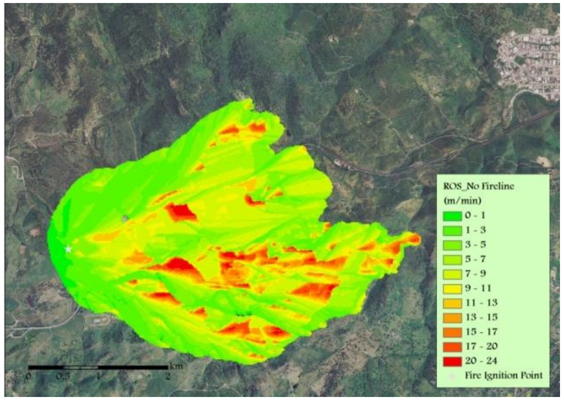
Fire Spread and Behavior Modeling











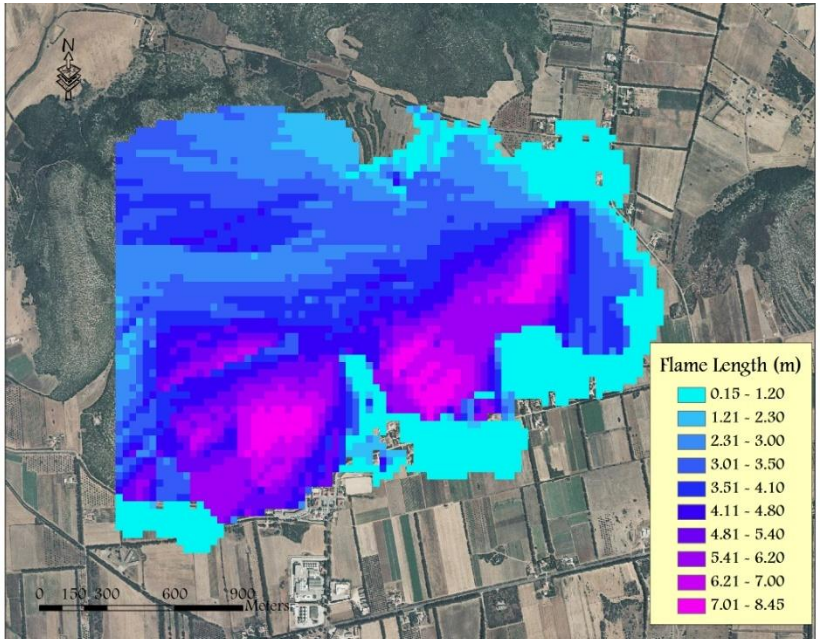
Effects of firelines of different width (0 m, 10 m, 50 m).

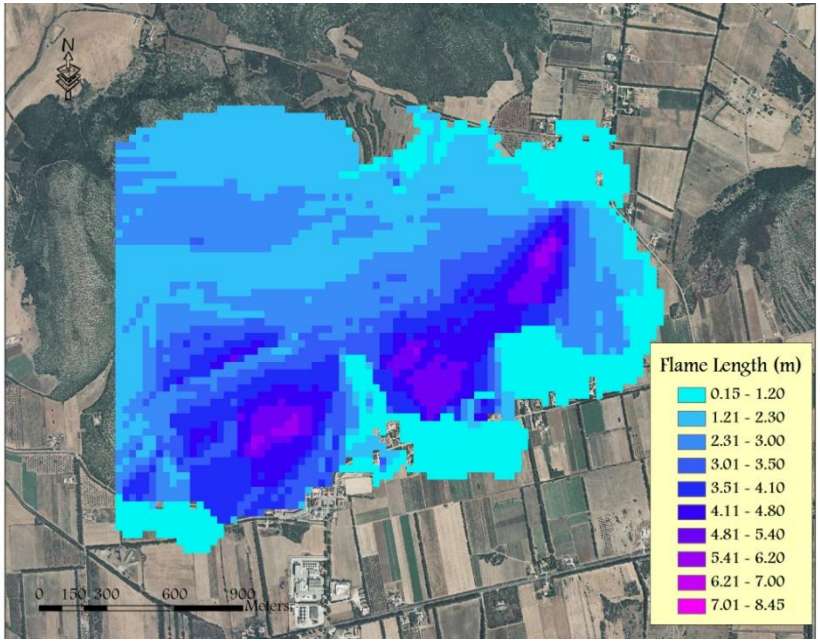
Comparison of fire ROS values in different situation: 50 m width fireline, no fireline

Diana et al. 2011; Salis et al. 2012

Fire Spread and Behavior Modeling

Evaluation of fire mitigation strategies

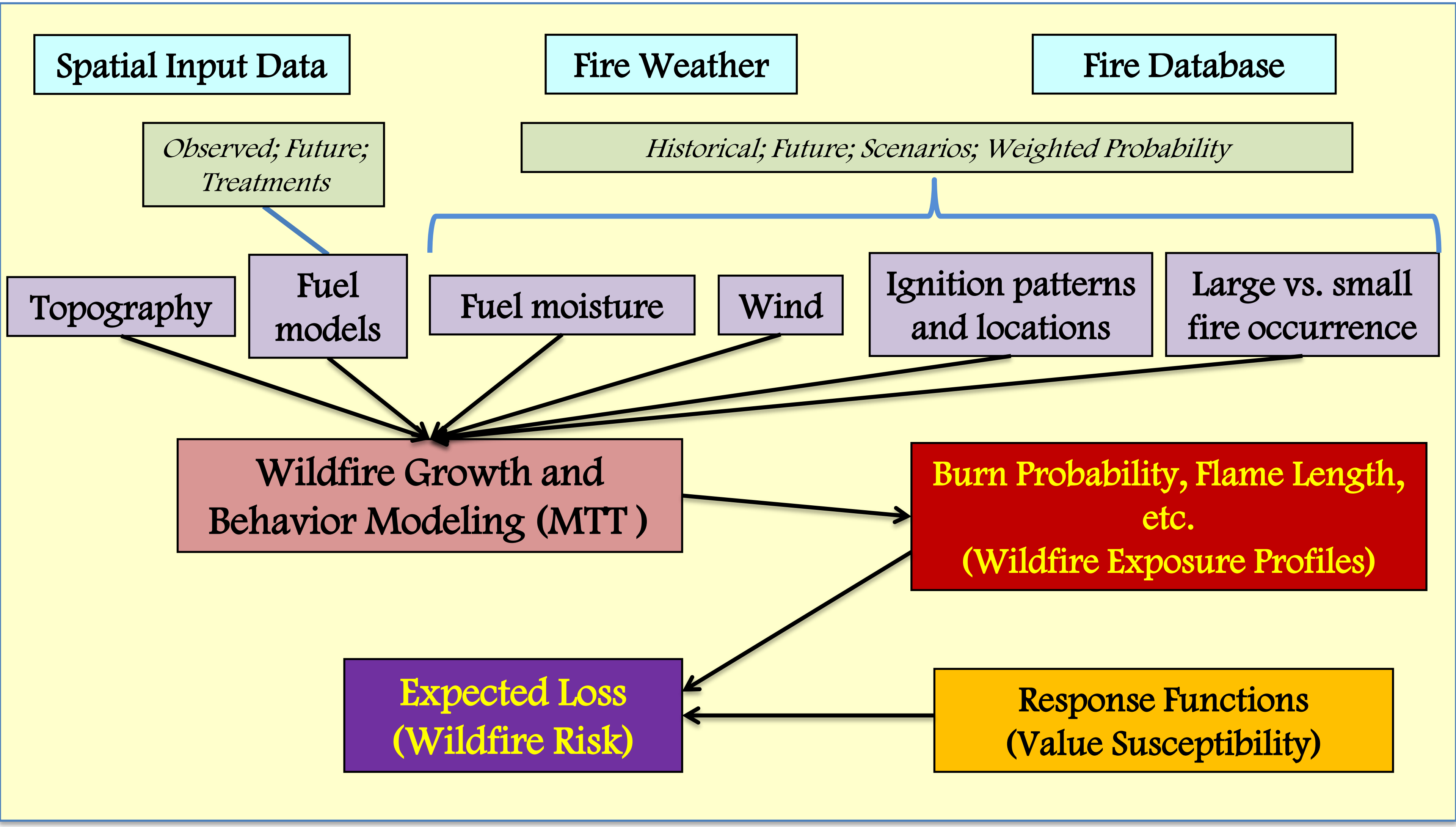




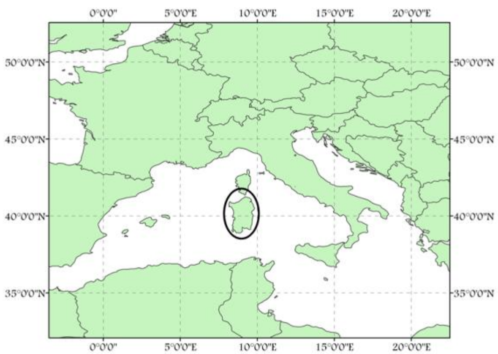
Diana et al. 2011; Salis et al. 2012

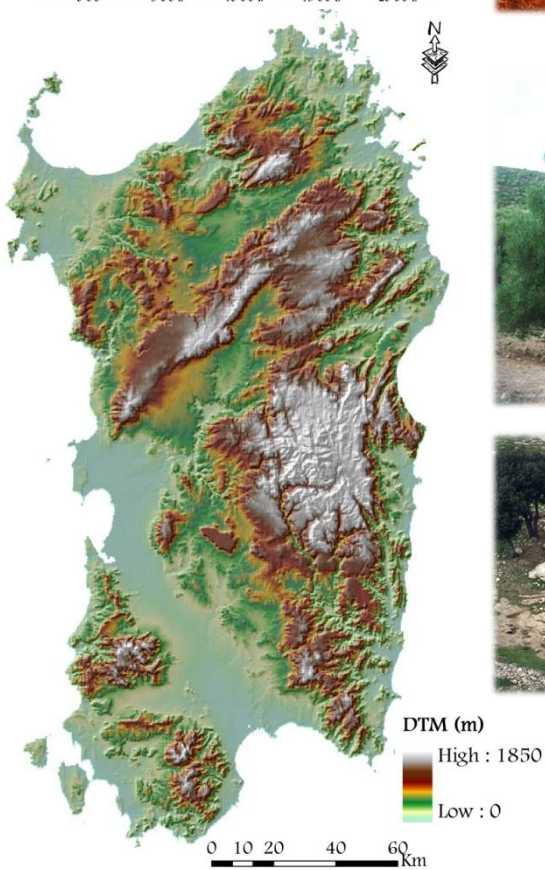
Fire Exposure Assessment in Sardinia

Methodological Framework

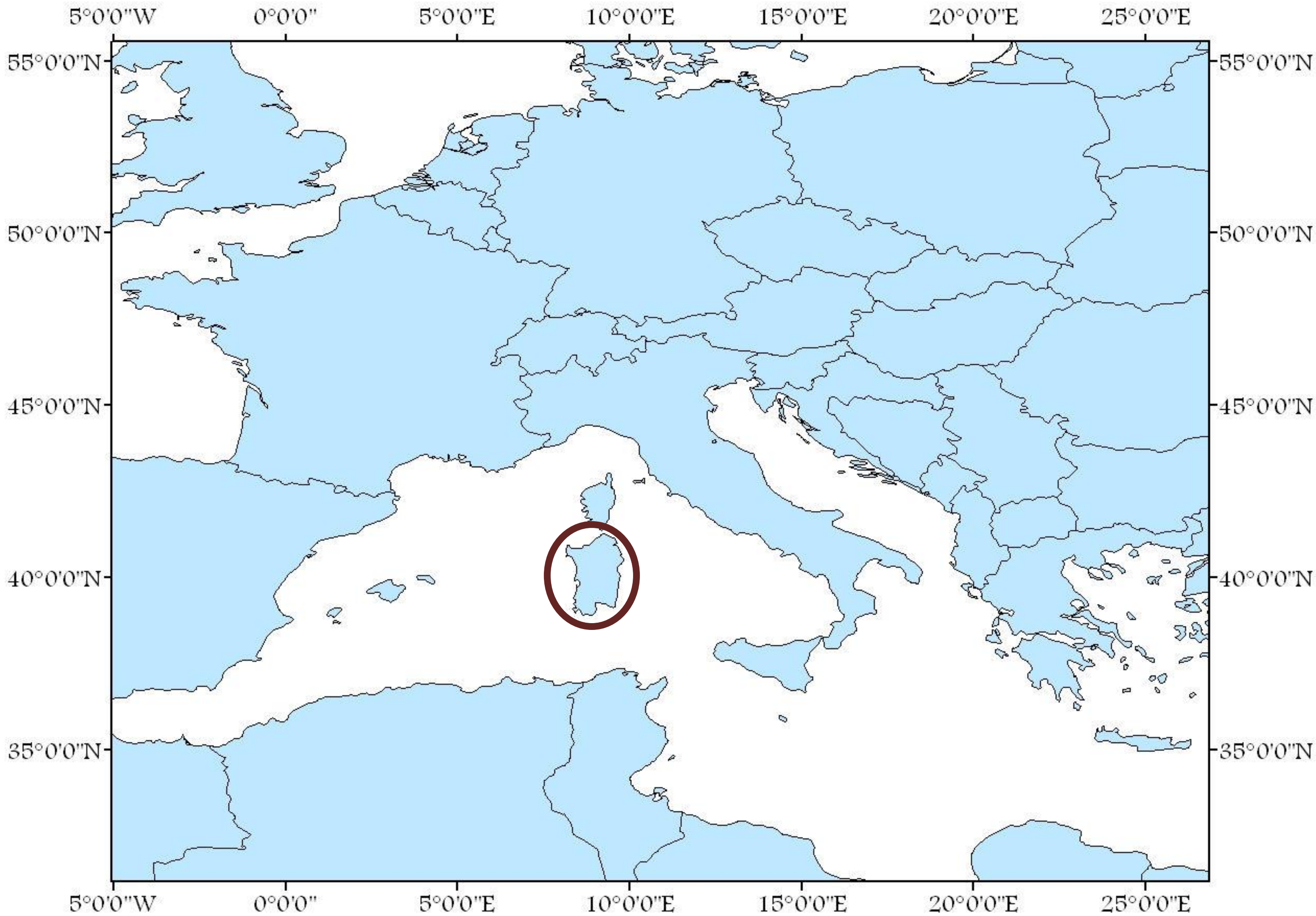


Fire Exposure Assessment in Sardinia

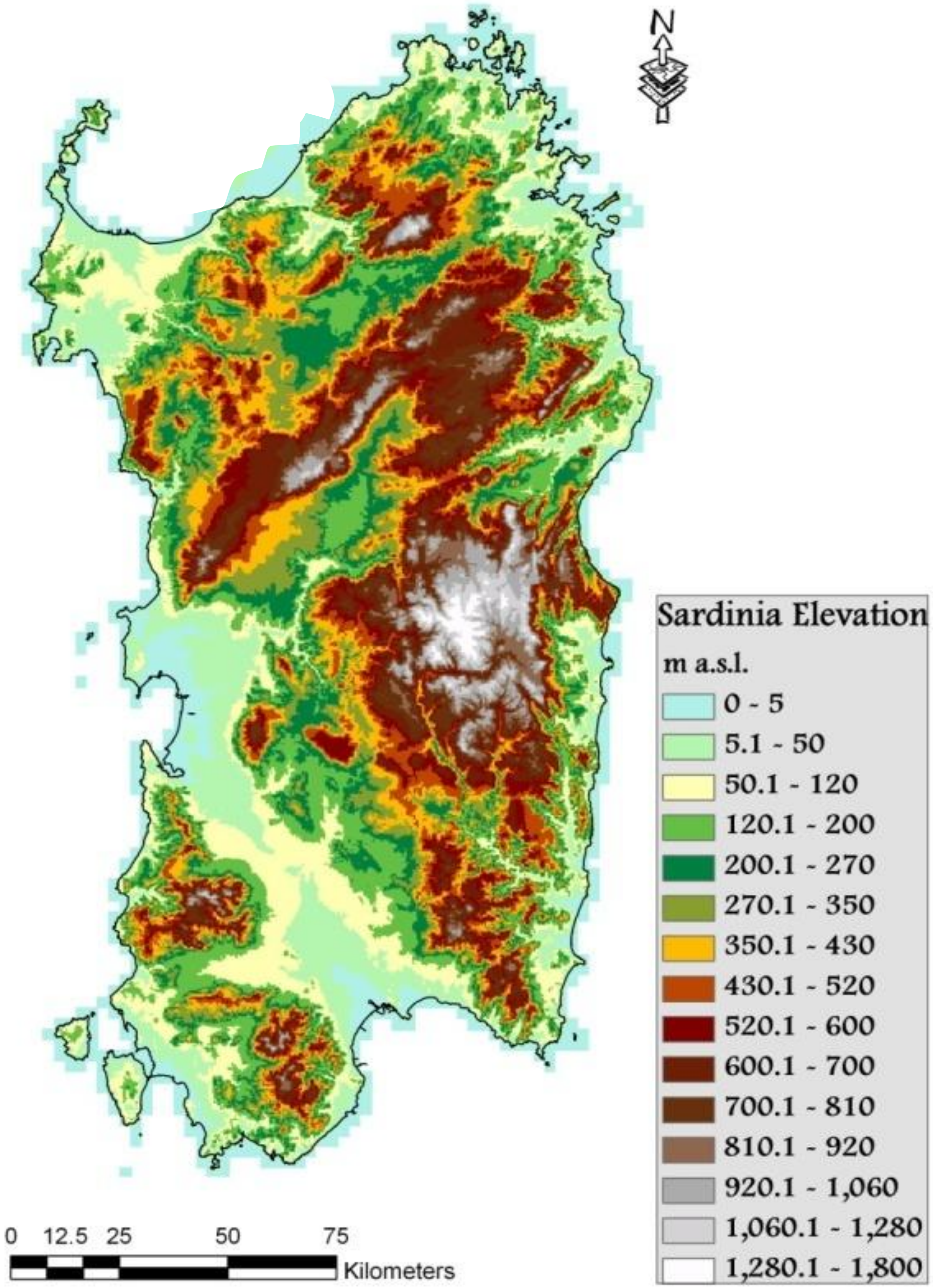




Many diverse values at risk!



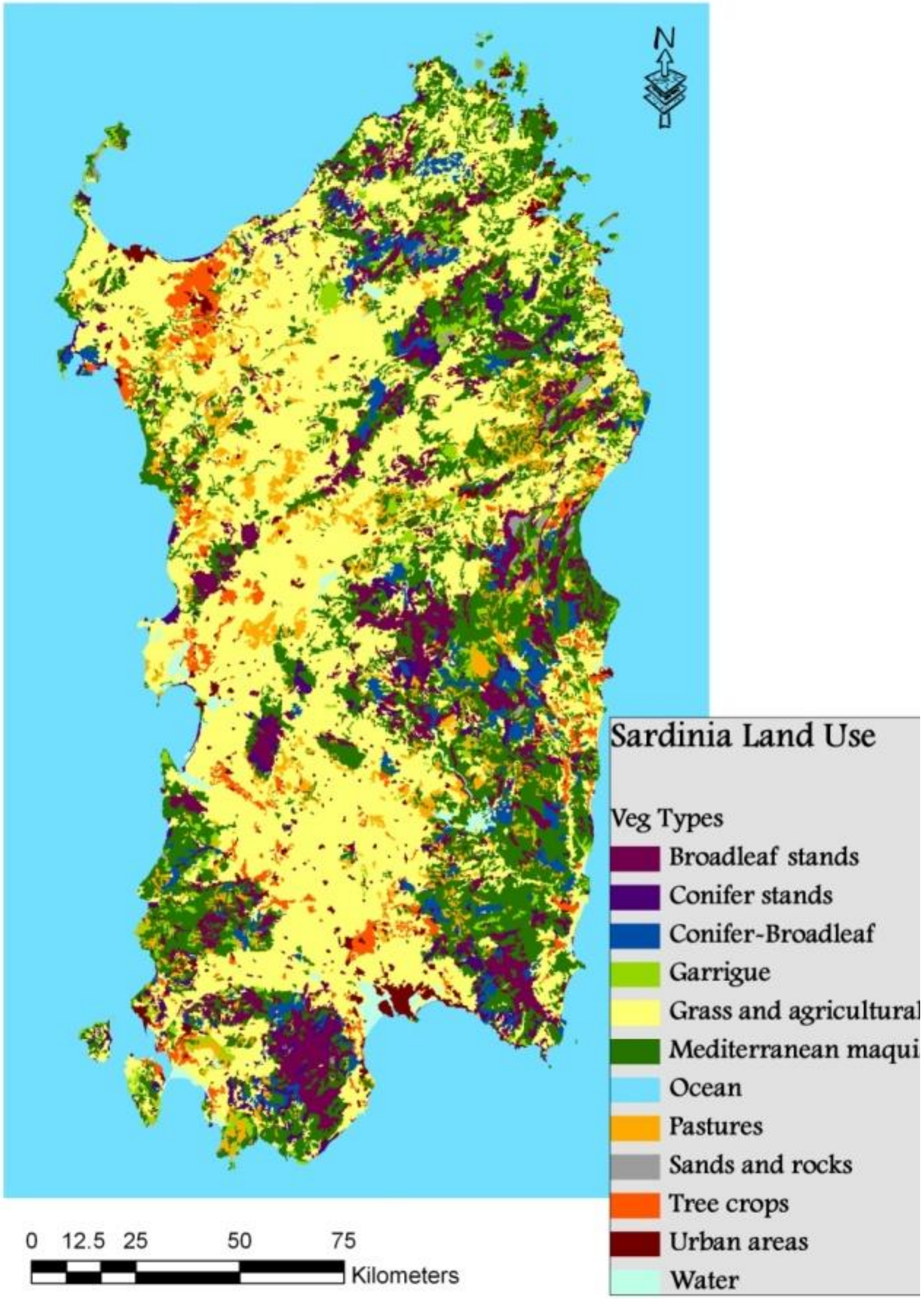
With a surface of about 24,000 km^2, Sardinia is located in the western part of the Mediterranean Basin and is the second largest island in the Mediterranean Sea



Sardinian Orography

The orography is generally hilly, with the highest point being 1834 m a.s.l. (Gennargentu) in the center of the island.

The largest plains are located in the western parts of the island



Sardinian Vegetation

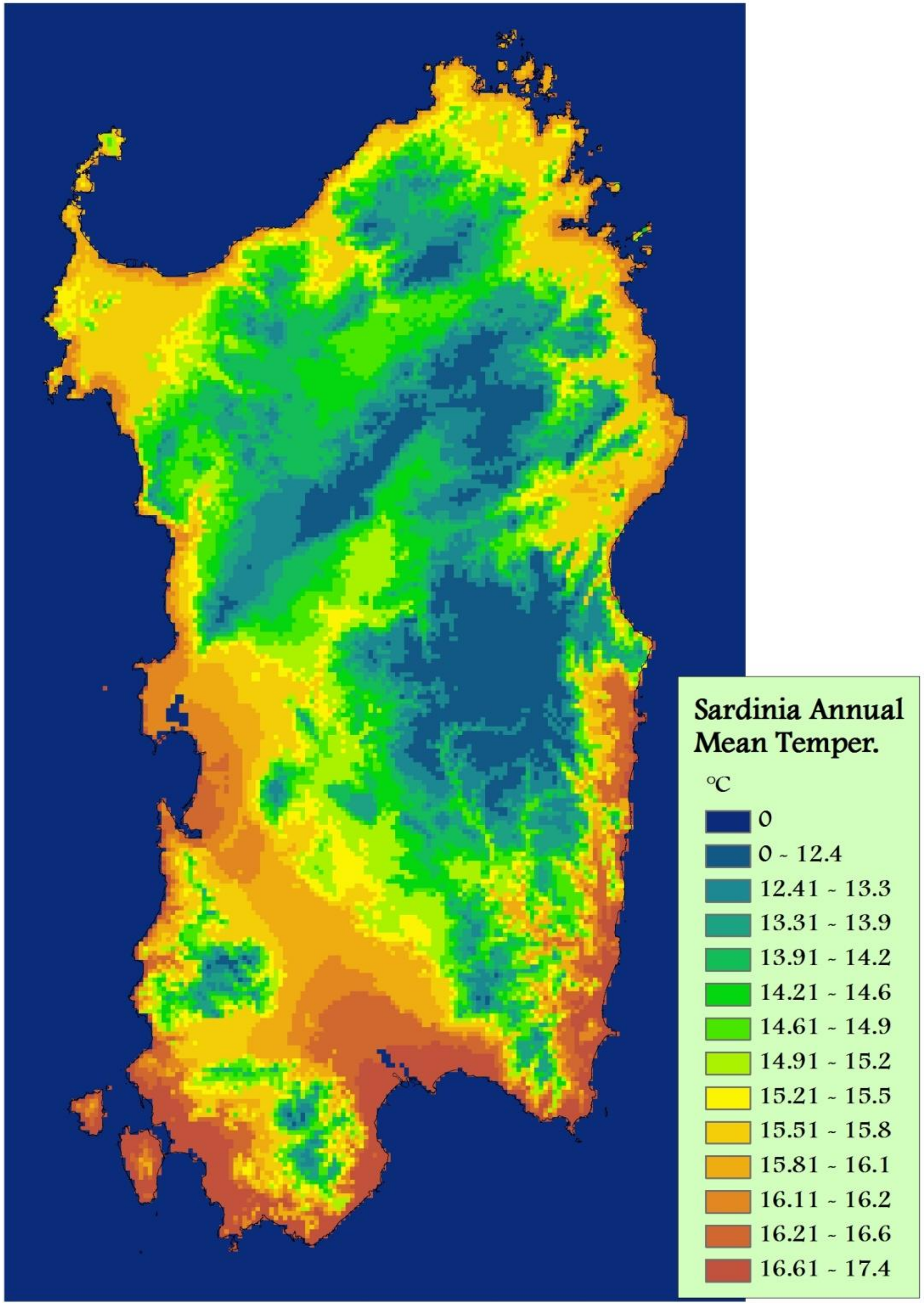
Wood and forest represent approximately 16% (year 2000) of the Sardinian vegetation, and are mainly represented by *Quercus ilex*, *Quercus suber*, *Quercus pubescens*. At higher elevation the oak formation mainly merges with *Castanea sativa*.

The coniferous stands (represented by Pinus spp.) are limited (3%).

The most important forest vegetation type (28%) is represented by Mediterranean maquis and garrigue.

Urban and anthropic areas cover about 3% of Sardinian landscape.

The remaining fraction is represented by pastures and agricultural areas (49%), and by other land uses.



Sardinian Climate

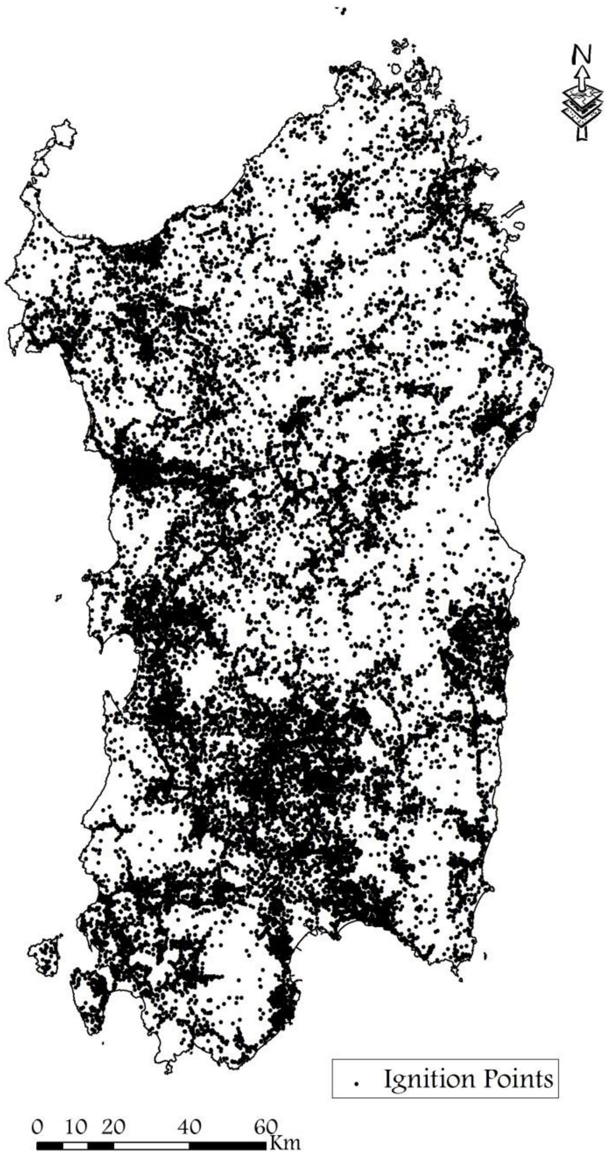
The climate is Mediterranean sub-arid, with a remarkable water deficit from half May until half September.

The most of annual rainfall amounts (approximately 700 mm on average) occur in fall and winter.

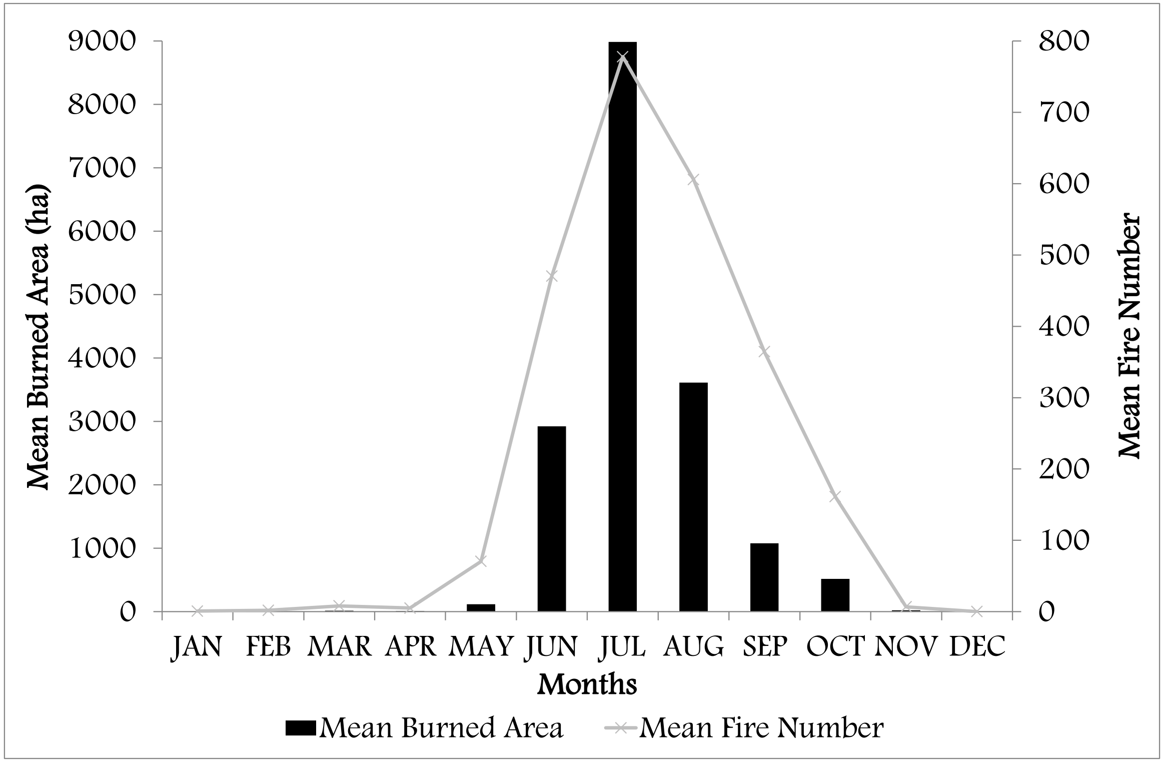
The Sardinia mean annual temperature along the coast line is approximately 17 °C, mostly in the southern part of the island.

During the summer season, Sardinia experiences peaks of temperature higher than 30 °C.

Sardinian fires



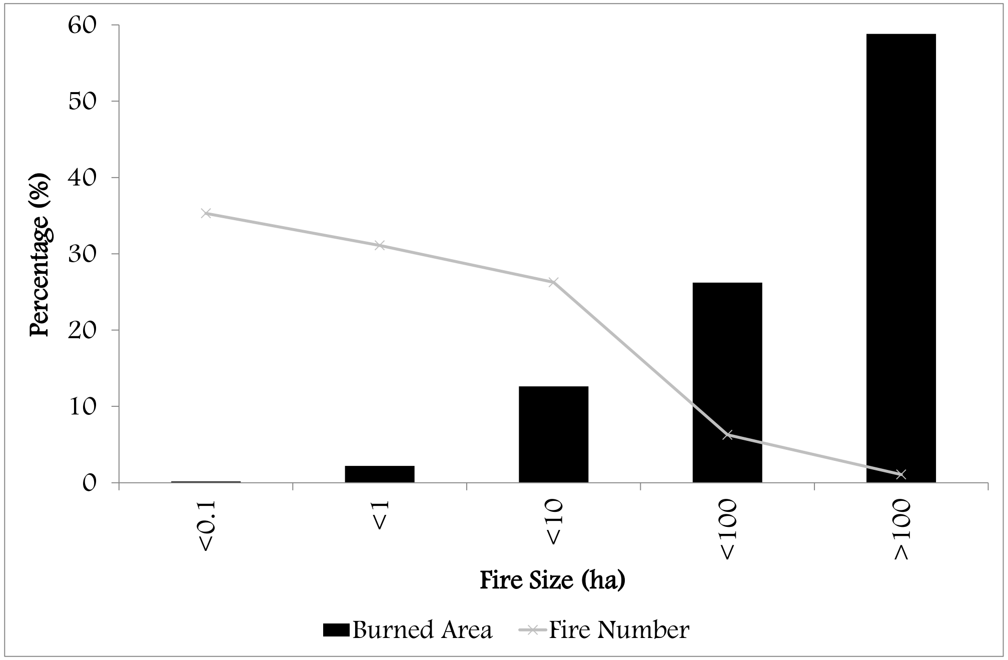
Fire ignitions (1995-2009)



The wildfire issue is commonly concentrated in the period June-September

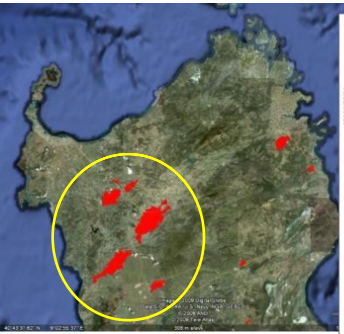
On average, in recent years Sardinia experienced about 2,500 wildfires per year, with an area burned close to 18,000 ha

Sardinian fires

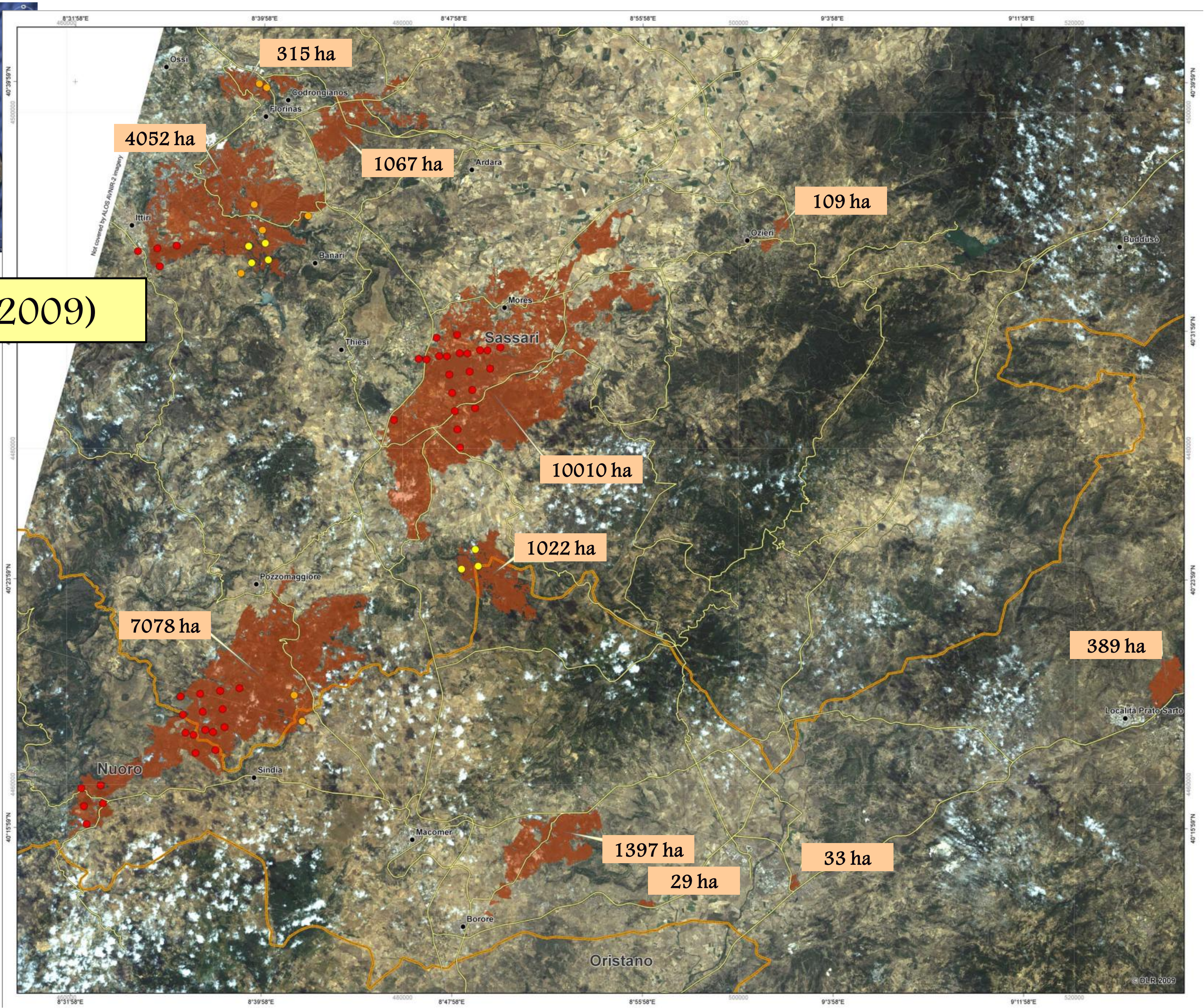


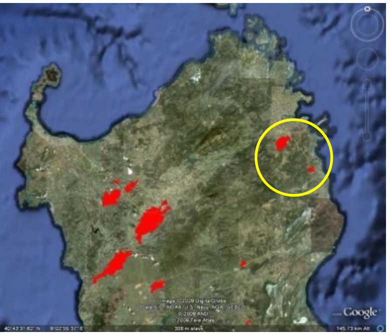
Wildfires with size > 100 ha account for only 2% of fires, but for about 60% of the total area burned in the island

Such large events are very often driven by strong winds and severe environmental conditions (high temperatures, low RH, etc.)

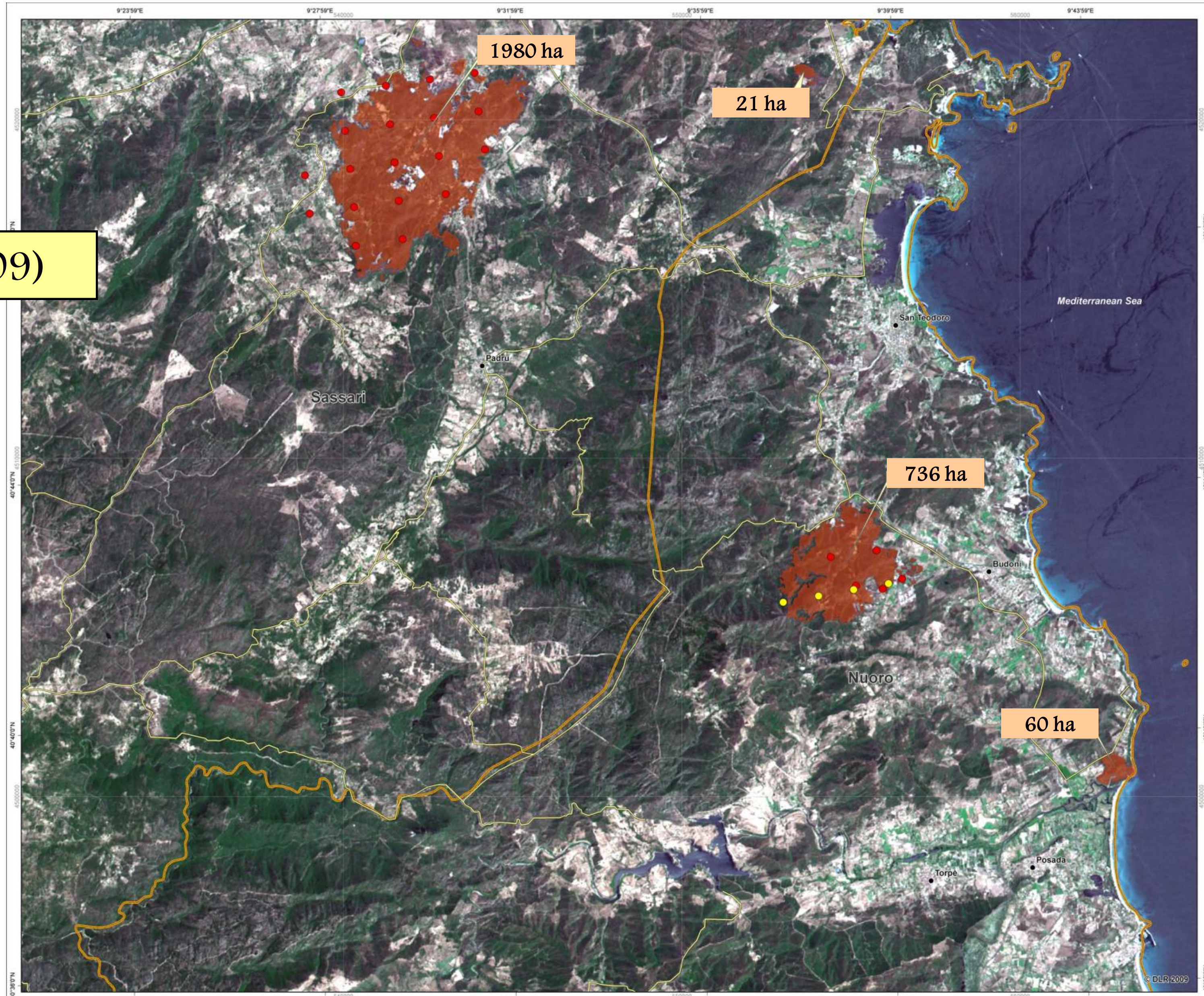


(23-24 July 2009)





(23-24 July 2009)



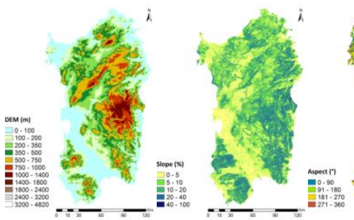
(23-24 July 2009)

2 persons died and several injured; 25,000 ha burned in 30-36 hours by 9 wildfires > 1,000 ha; huge damages to flora, fauna, urban areas, anthropic values, and farms

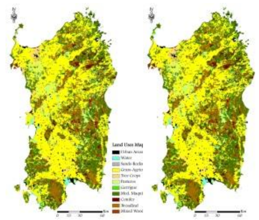
Spatial Input Data | **Historical Fire Database** | **Weather**

INPUTS

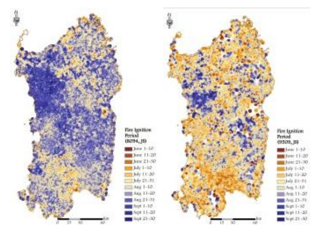
Topography | **Fuels** | **Ignition patterns and locations** | **Burn period** | **Wind** | **Fuel moisture**



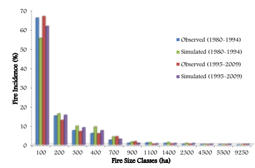
Elevation Slope Aspect



1980-1994 1995-2009



1980-1994 1995-2009



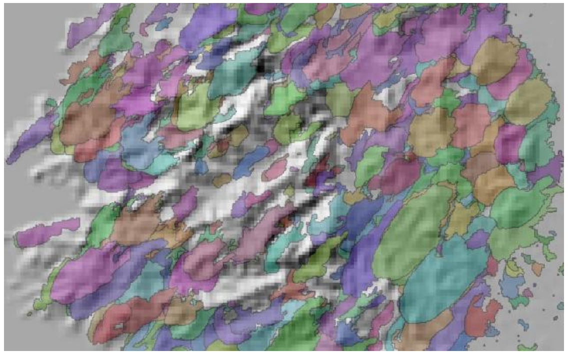
Study period	(1980-1994)	(1995-2009)
Wind Speed (km h^{-1})	29.0	29.0
Temperature (°C)	36.0	36.5
Rain (mm)	0	0
1 hr dead FM (%)	7	7
10 hr dead FM (%)	9	9
100 hr dead FM (%)	11	11
Wind Direction (°)	315 (35%); 225 (22%); 270 (19%); other (24%)	315 (40%); 225 (24%); 270 (14%); other (22%)

SIMULATIONS

Randig, MTT algorithm (Finney 2002)

Simulation of 100,000 fires, randomly sampling from historical weather, fuel moisture, ignition patterns, burn periods (study period 1995-2009)

Data resolution: 250 m (100 m) over 24,000 km2



OUTPUTS

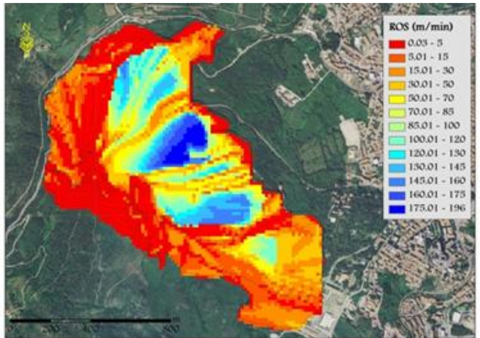
Burn Probability (BP)

Conditional Flame Length (CFL)

Fire Size (FS)

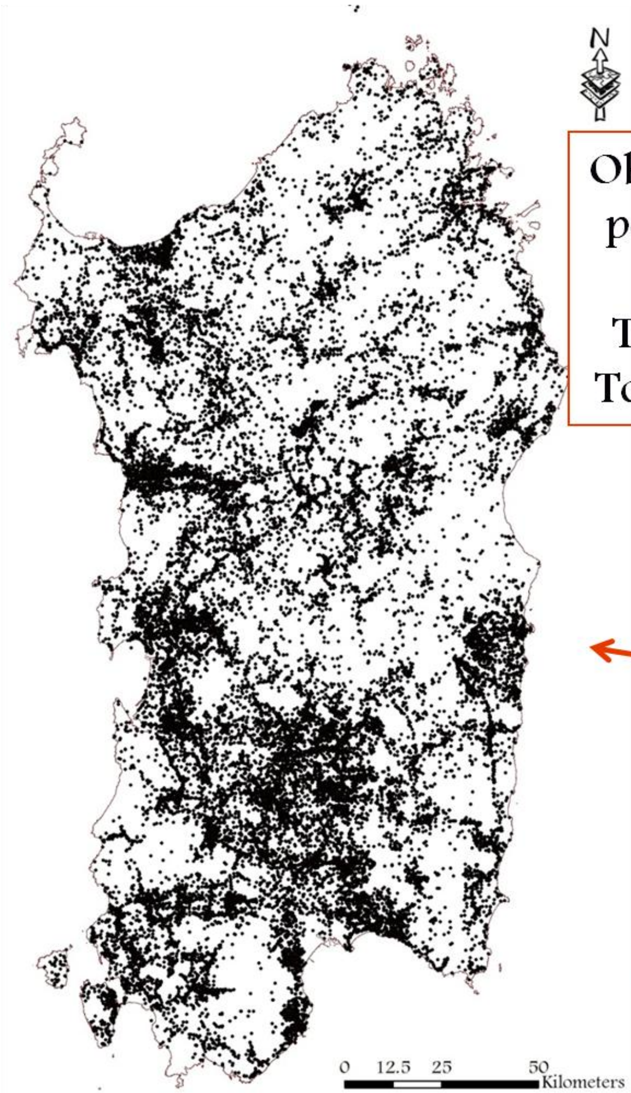
Fire Potential Index (FPI) and more…

(Salis et al. 2013 - IJWF)



Fire Exposure Assessment in Sardinia

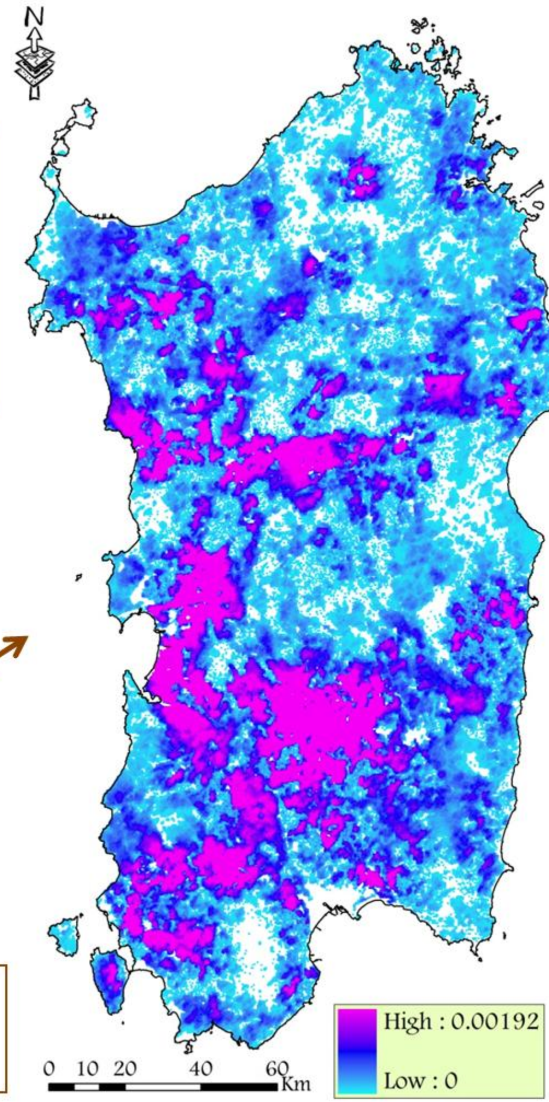
Identification of areas characterized by high burn probability



Observed fire ignition points (1995-2009)

Total Fires : 33,000
Total BA: 250,000 ha

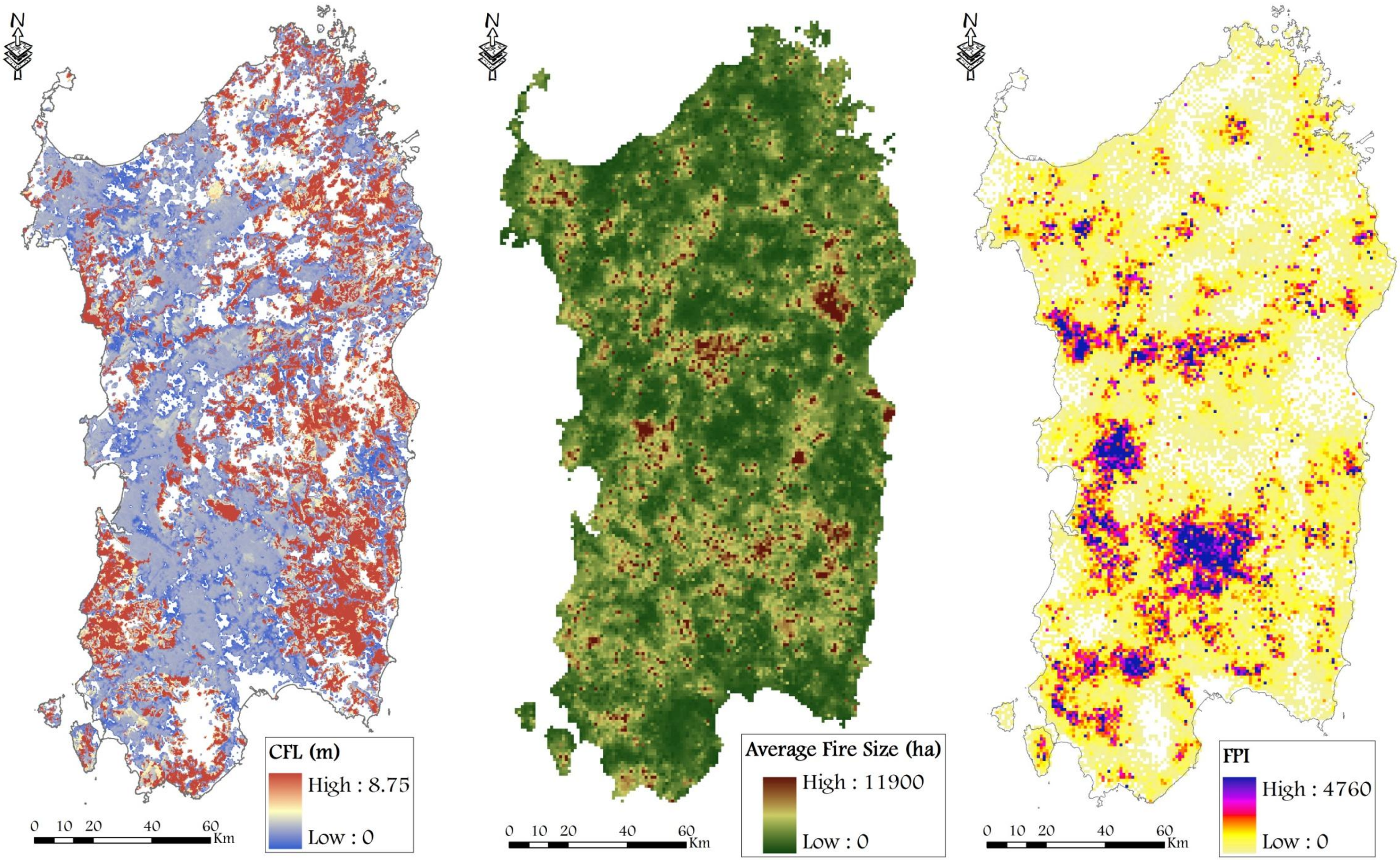
Historical Burn Prob. (1995-2009)



(Salis et al. 2013 ~ IJWF)

Fire Exposure Assessment in Sardinia

Identification of areas characterized by high fire exposure



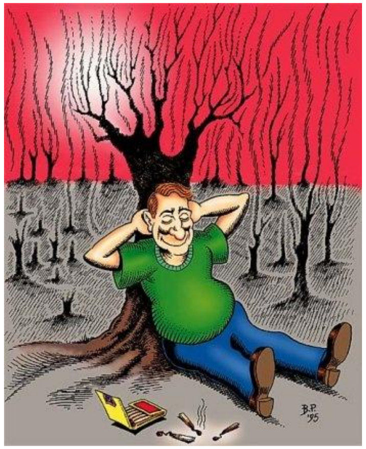
(Salis et al. 2013 ~ IJWF)

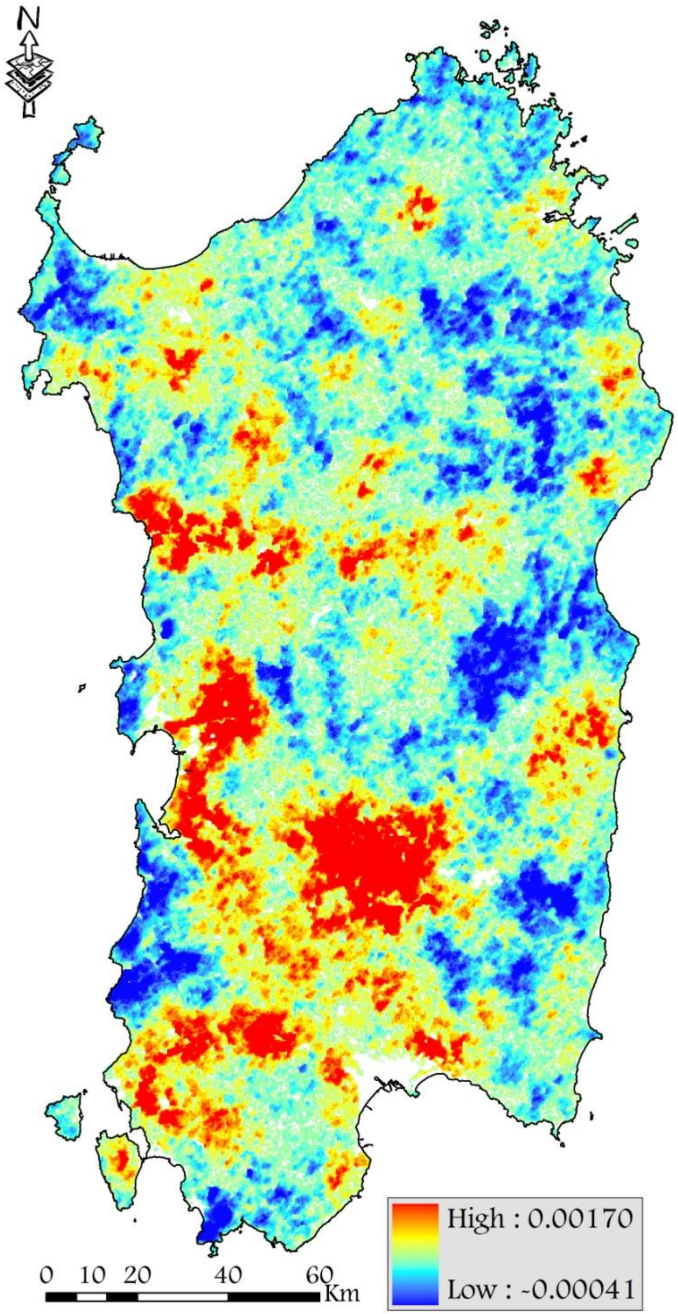
Fire Exposure Assessment in Sardinia

Causes of Wildfires

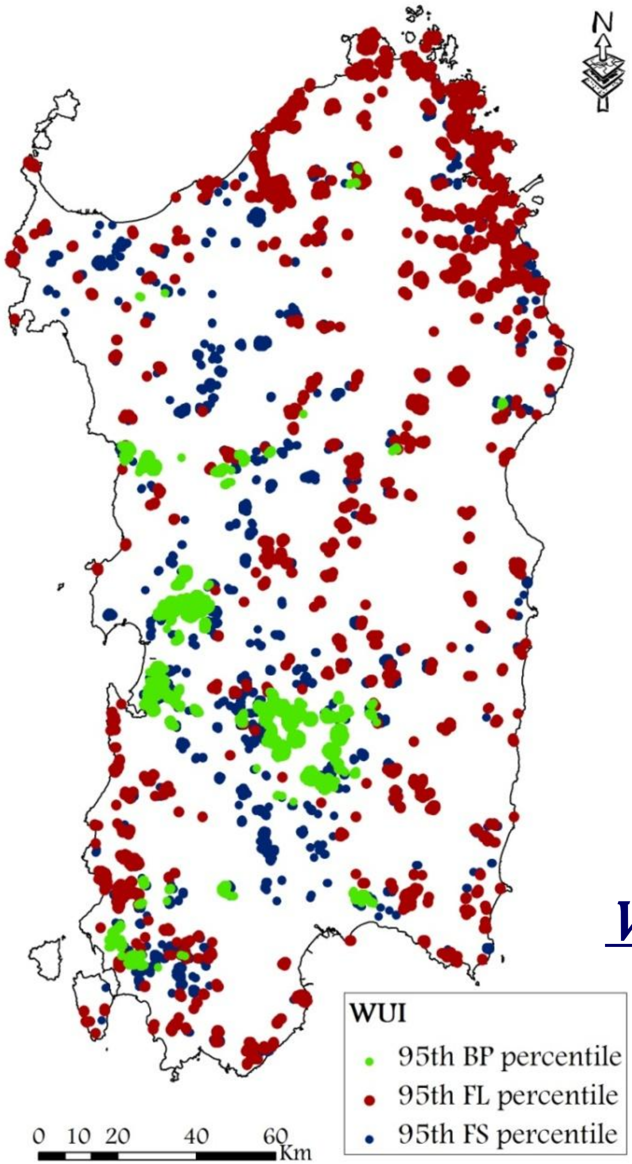
Strong role played by humans in igniting fires

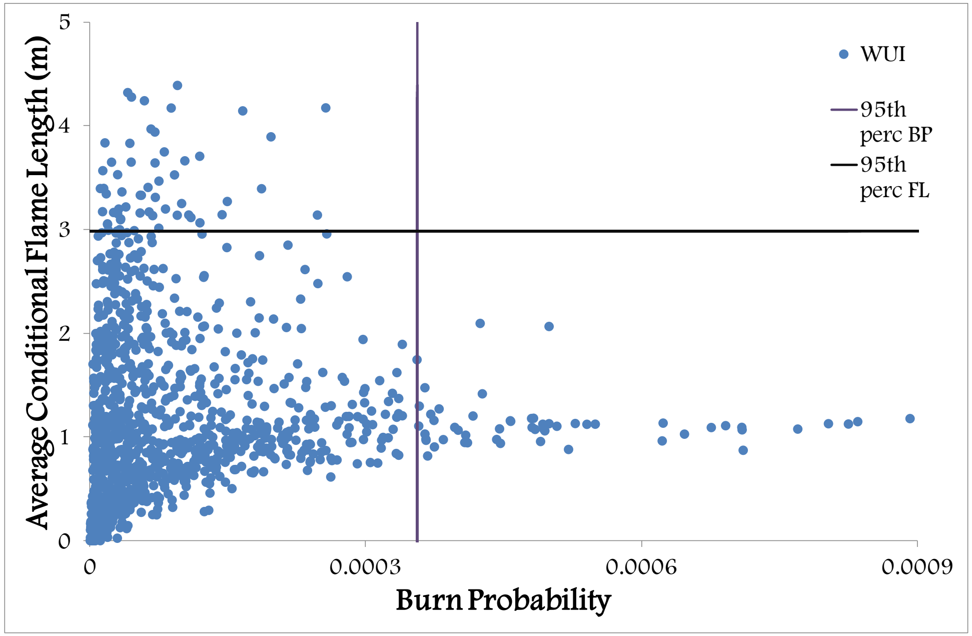
Difference between "historical" and random fire ignitions occurrence obtained with RANDIG

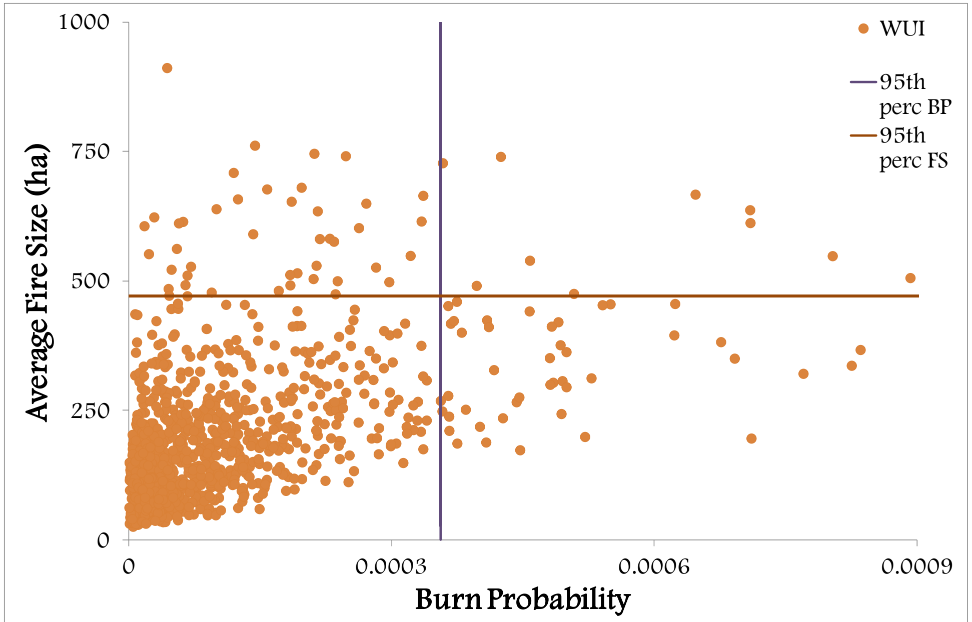




Fire Exposure Assessment in Sardinia





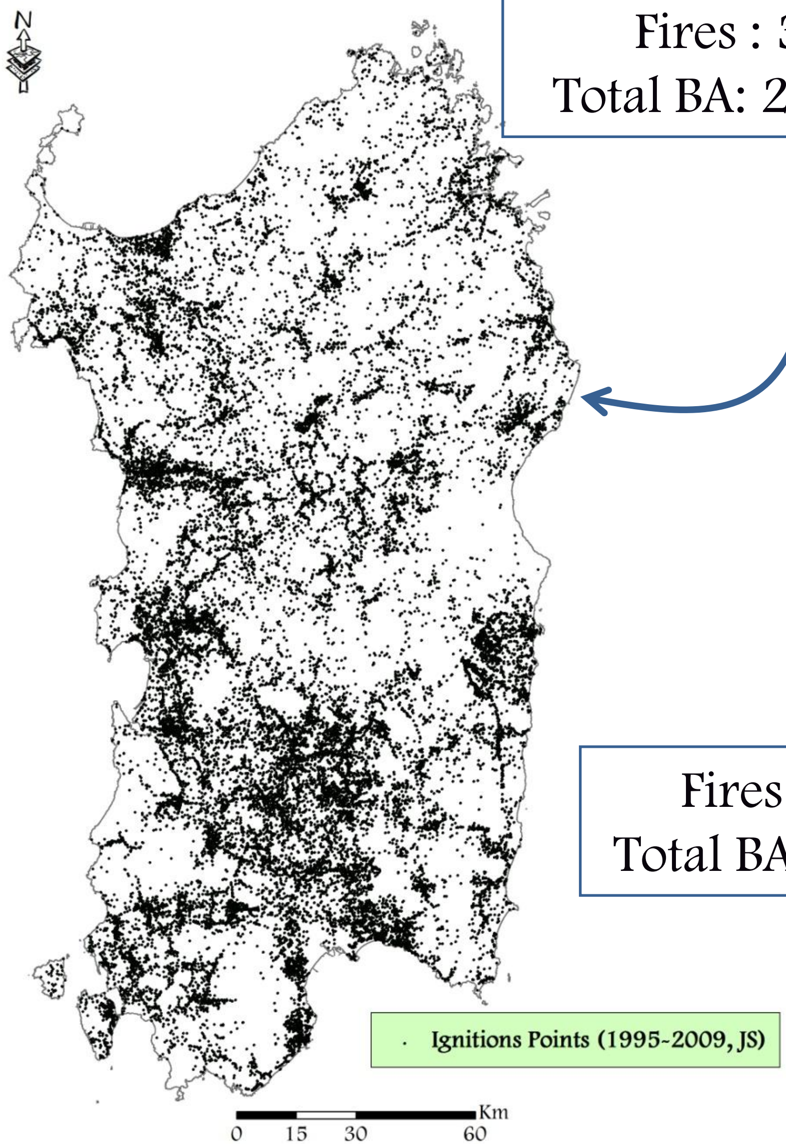


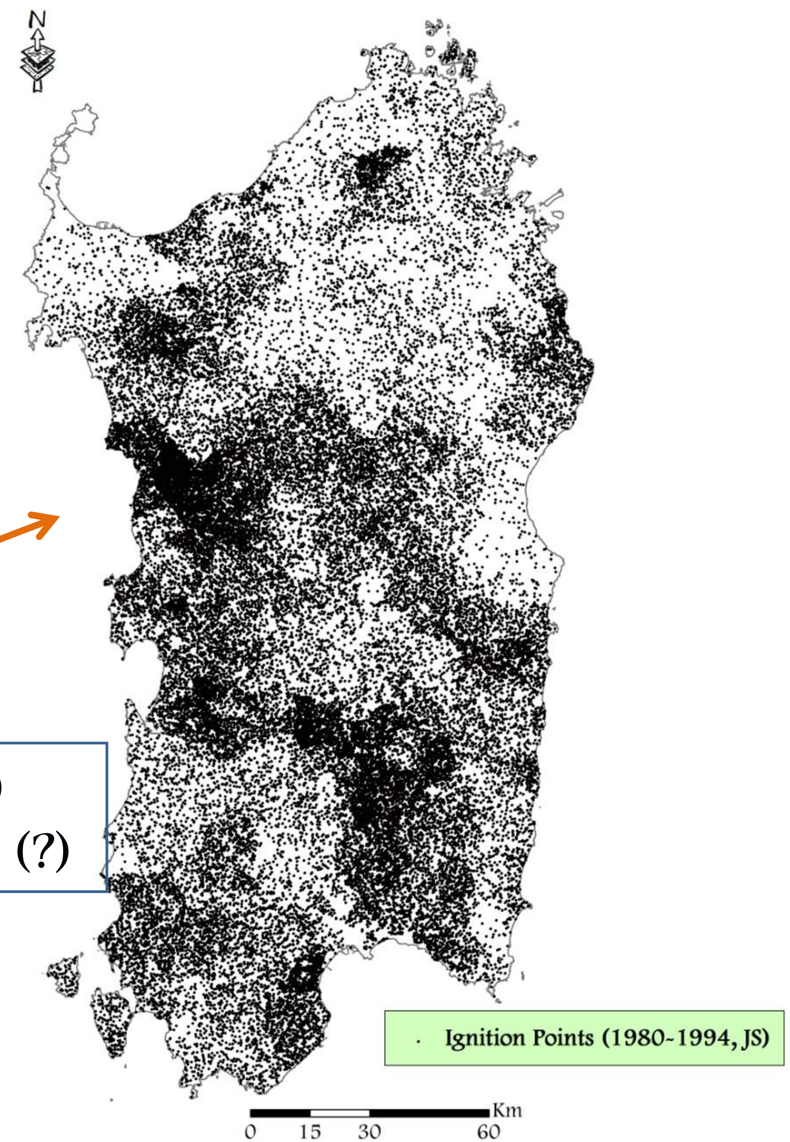
WUIs

(Salis et al. 2013 - IJWF)

Fire Exposure Assessment in Sardinia

Fires : 33,000
Total BA: 250,000 ha

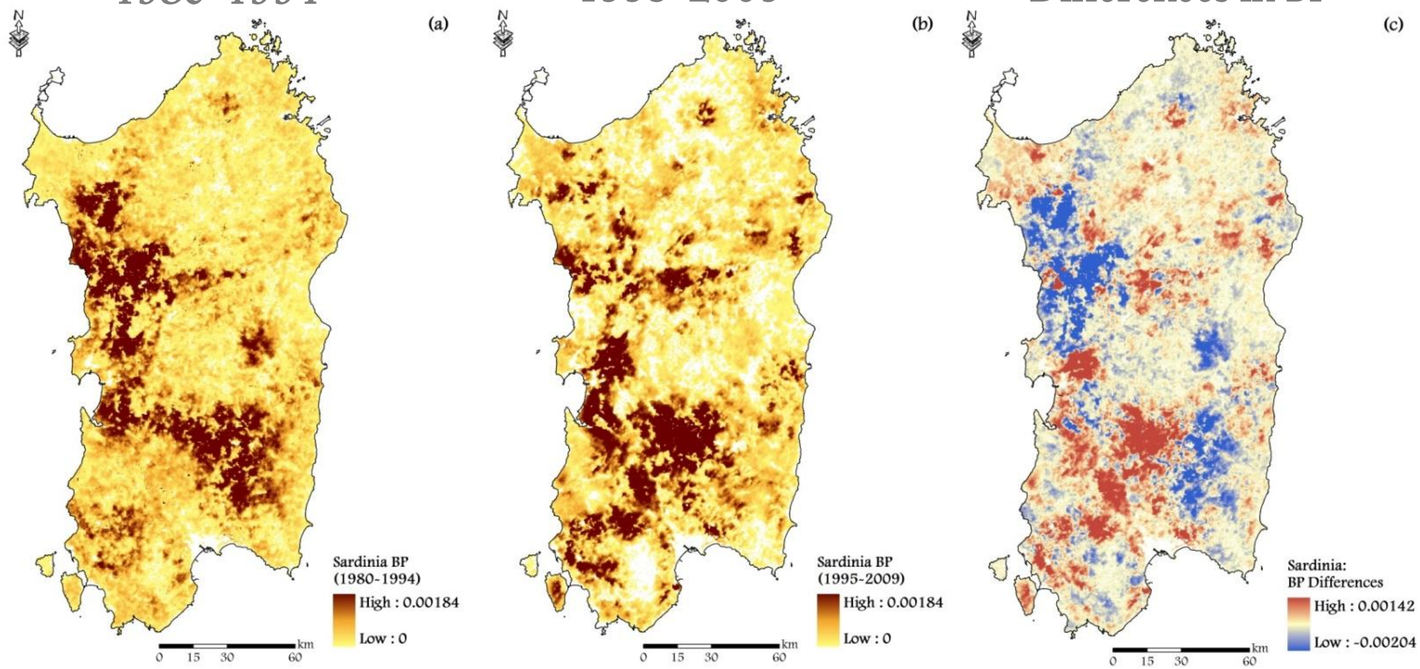




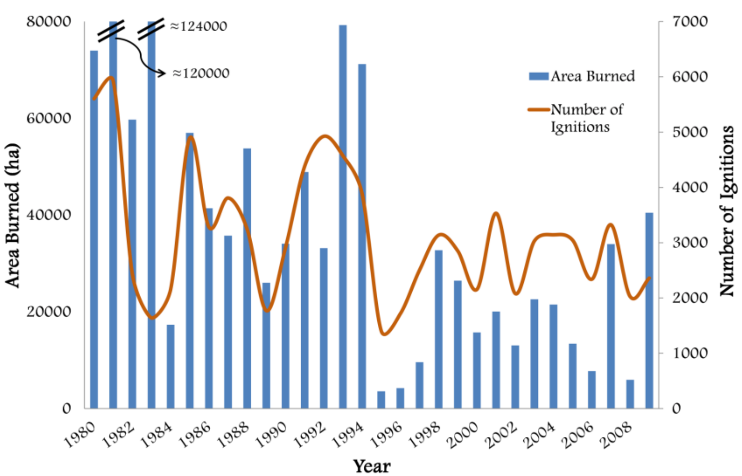
Fires : 127,000 (?)
Total BA: 875,000 ha (?)

Fire Exposure Assessment in Sardinia

1980~1994 | 1995~2009 | Differences in BP



Fire exposure varies depending on the study period

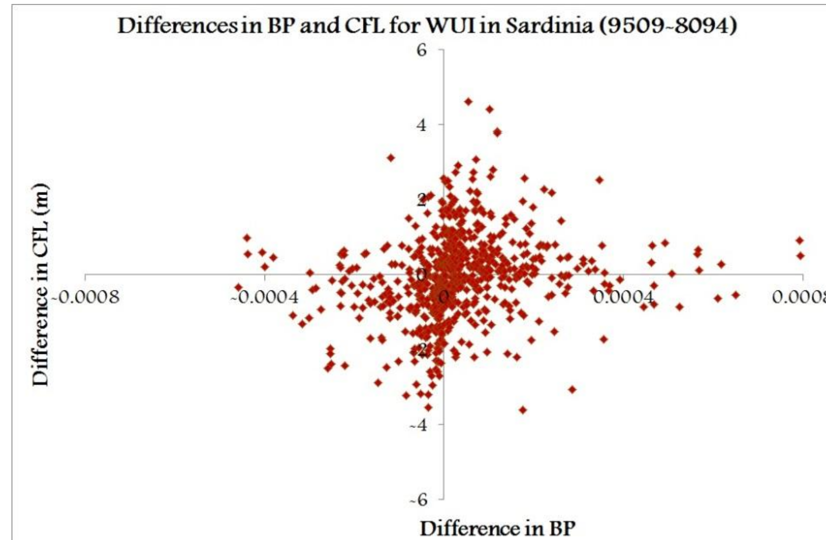


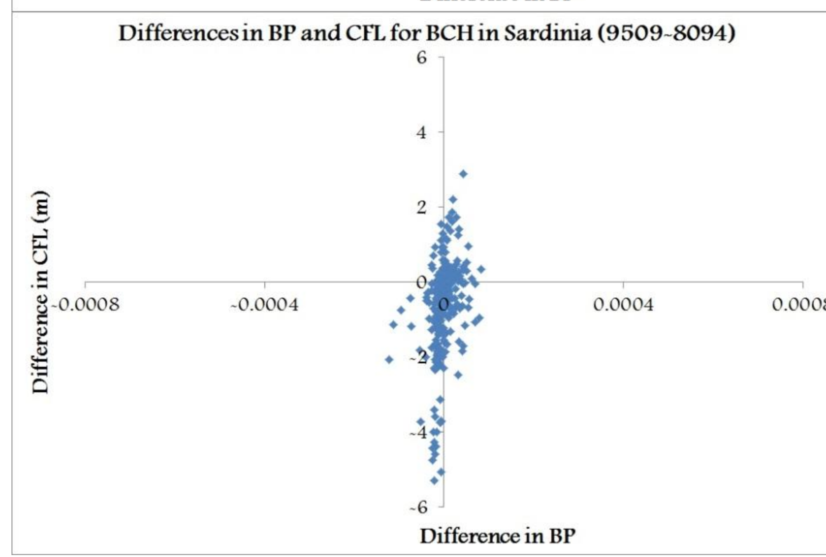
- Strong reduction in FN and AB
- Increase of fire ignitions nearby urban interfaces and agricultural areas
- Anticipation of the fire seasons of about 15 days
- Improvements in fire suppression capacity

(Salis et al. 2014 - NHAZ)

Fire Exposure Assessment in Sardinia

Anthropic Areas (WUIs, beaches) observed an overall increase in BP in recent years



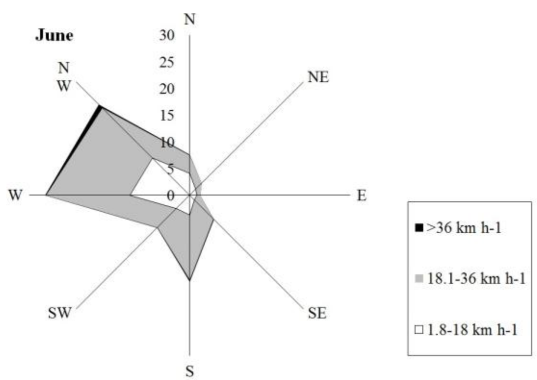


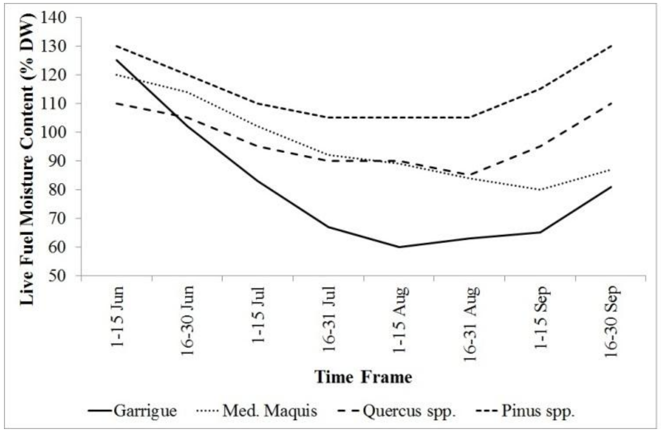
(Salis et al. 2014 - NHAZ)

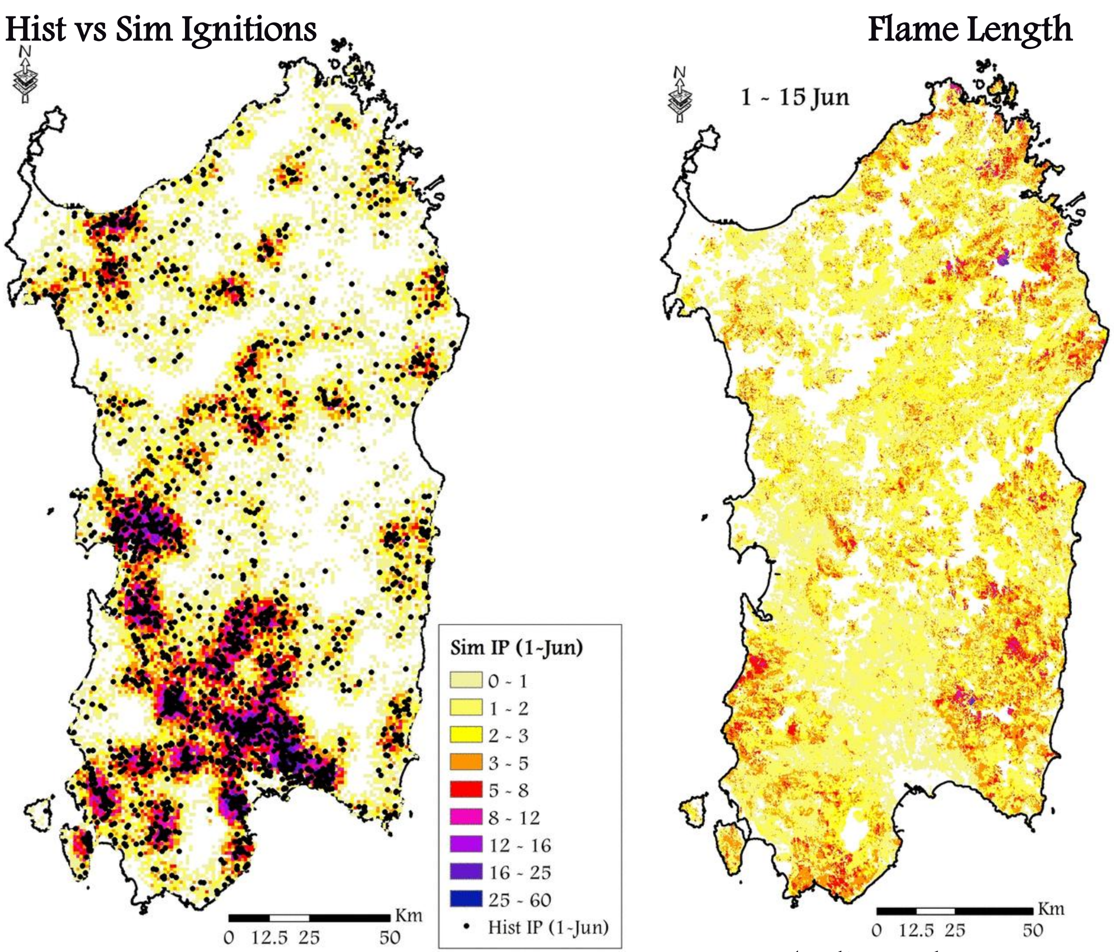
Fire Exposure Assessment in Sardinia

Fire exposure varies depending on the time of the year

(variation in fire-related factors (fuel moisture, fuel load, weather, ignitions, etc.))





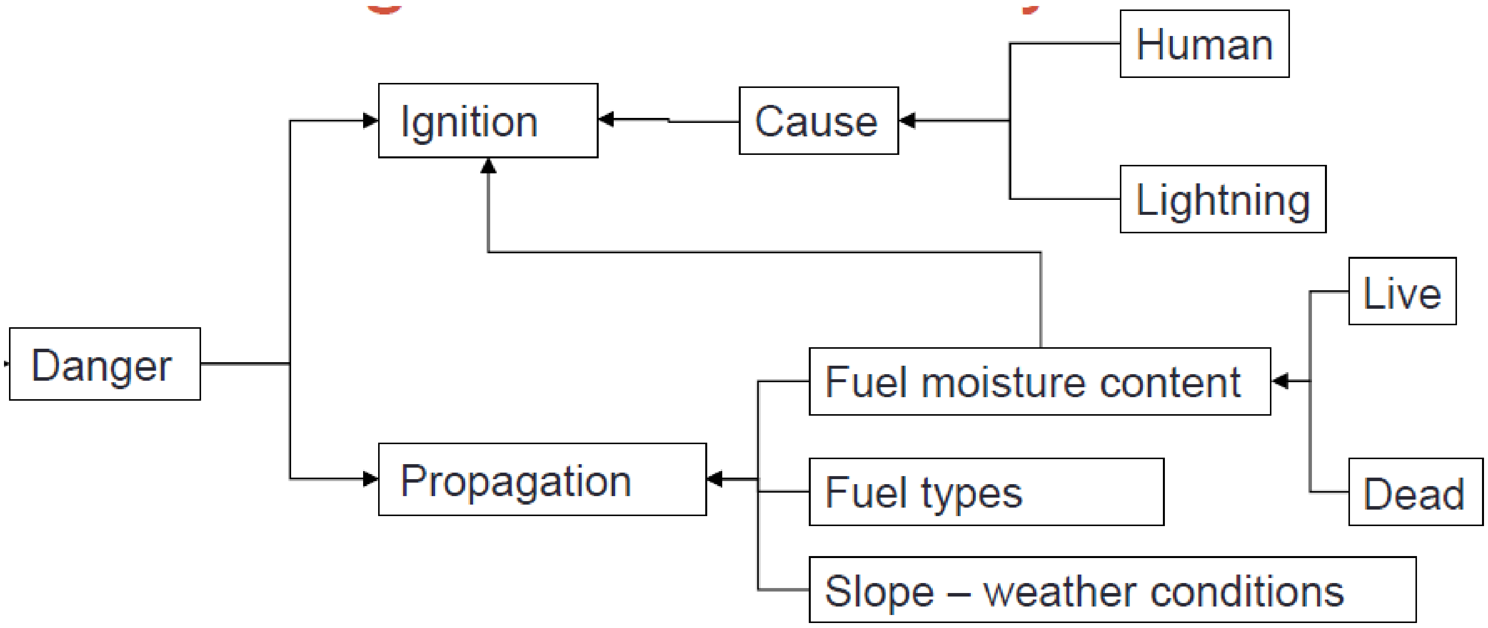


(Salis et al. 2015 - EMAS)

Tools to assess wildfire issues

Main Goal		Main Applications
Fire spread and behaviour modeling	→	~ fire spread and behaviour projections using future scenarios ~ assessing fire mitigation strategies (prescribed fires, fuel reduction, etc.) ~ quantifyng fire exposure and risk ~ identification of hot-spots
Fire danger modeling	→	~ daily/seasonal fire danger forecast ~ fire danger projections with future scenarios ~etc

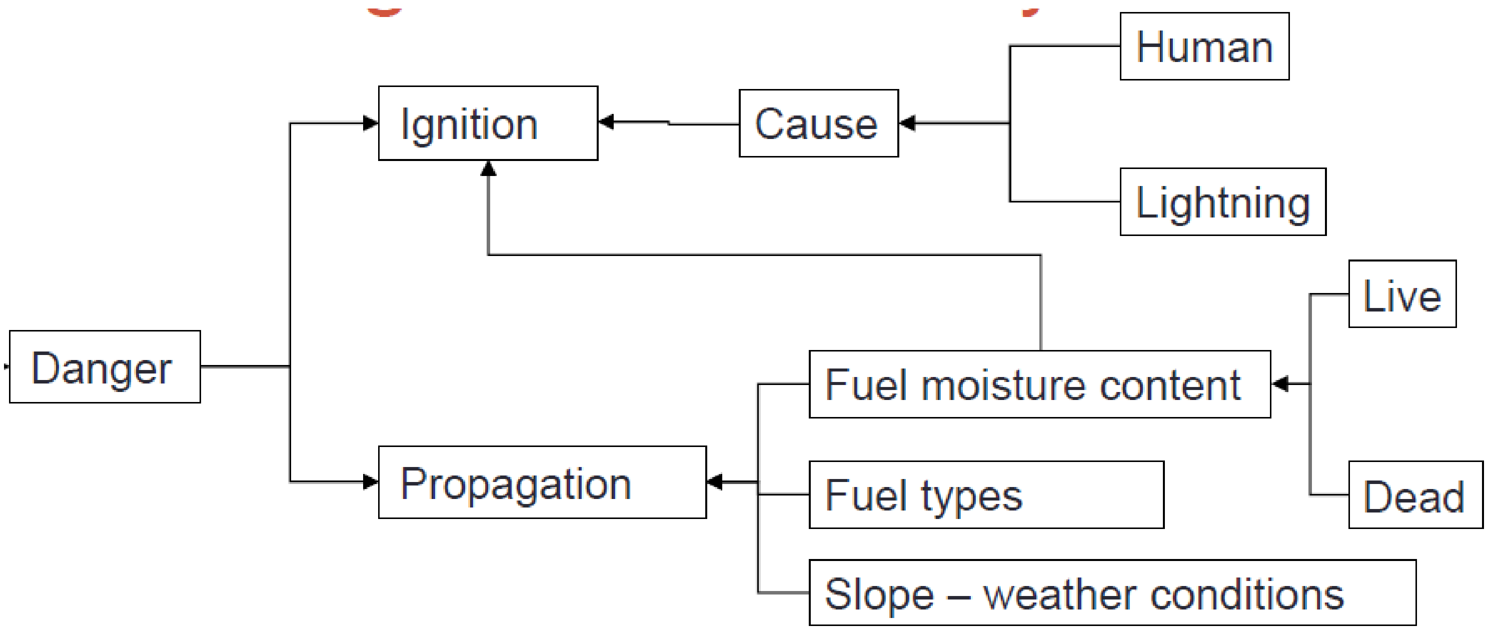
Fire Danger



Fire danger aims to assess the ease of ignition, the rate of spread, and the difficulty of fire suppression considering as input a set of fixed and variable factors of the fire environment for a given area

Fireglobe project
Chuvieco et al., 2013, IJWF (adapted)

Fire Danger



- Fire Ignition Danger - due to the combination of factors that can lead to the occurrence of a fire (e.g.: fuel moisture; lightning)
- Fire Propagation Danger - due to the combined presence of factors that favor the fire spread (e.g.: wind speed; fuel load)

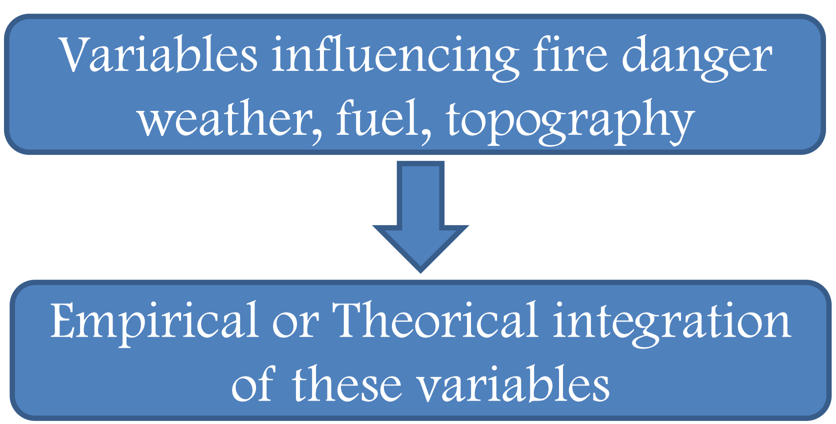
Fire Danger

What is Fire Danger Index?

i) A quantitative indicator of one or more facets of fire danger, expressed in classes, in relative or absolute value

i) Estimating fire danger involves identifying the potentially contributing variables (i.e., weather) and integrating them into a mathematical expression

Fire danger rating



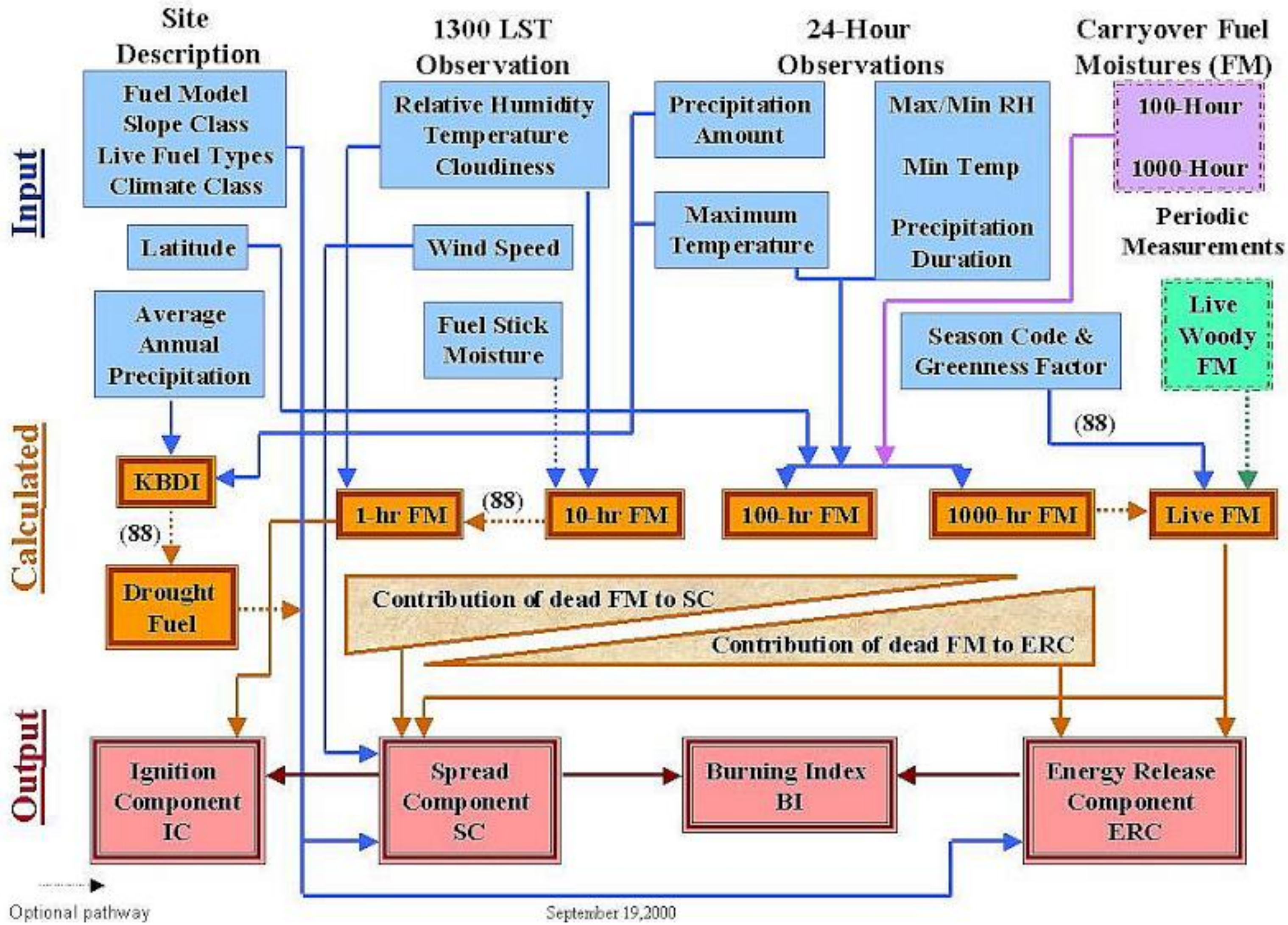
The process of systematically evaluating and integrating the factors influencing fire danger, represented in the form of fire danger indices

Fire Danger

Input	Aims/applications	Time windows	Input data reliability
Historical data	•Retrospective analysis •Calibration/validation •Weather – FD - fire occurrence relationship	From hour ly to yearly	****
Short term forecast	•Active fire-fighting •Near real time simulations •Day-to-day strategies •Prescribed fires	from hourly up to 7 days	***
Seasonal forecast	•Medium term fire management strategies at local-regional scale •Fuel management plans	From monthly to season	**
Climate projections	•Long term fire regime and fire impacts estimation •Regional-global policies	10 up to 100 years	*

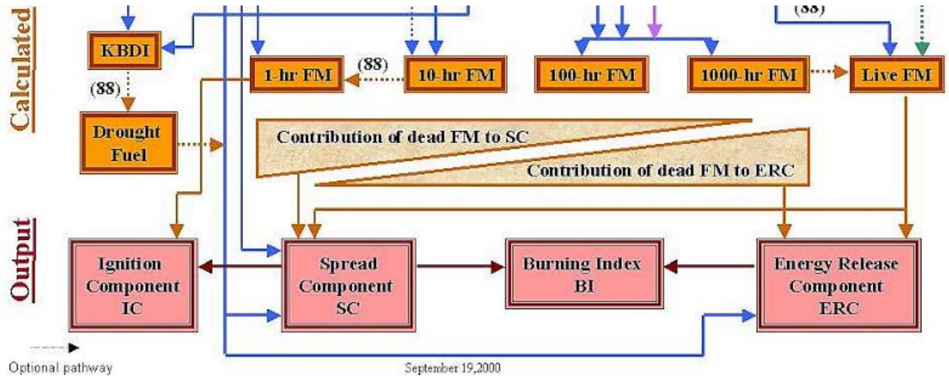
Fire Danger

USA National Fire Danger Rating System



Fire Danger

USA National Fire Danger Rating System

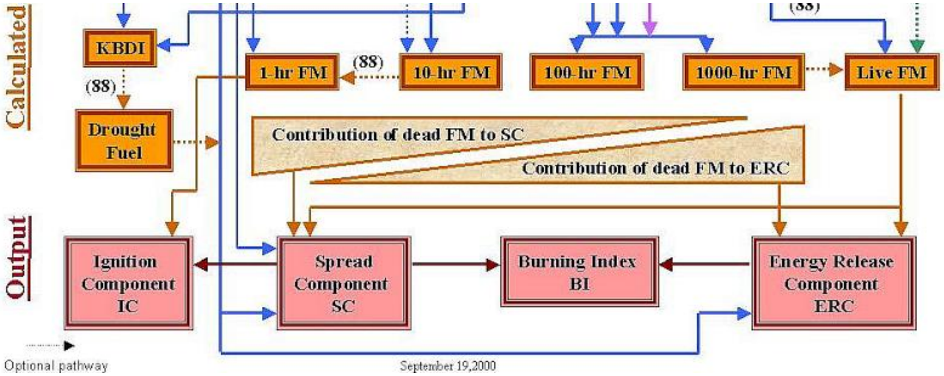


Keetch-Byram Drought Index (KBDI)

- Not an output of the National Fire Danger Rating System, but often used;
- Stand-alone index that measures the effects of seasonal drought on fire potential;
- The actual numeric value is an estimate of the amount of precipitation needed to bring the soil back to saturation (a value of 0 is complete saturation of the soil);
- The KBDI relationship to fire danger is that as the index value increases, the vegetation is subjected to increased stress due to moisture deficiency; at higher values desiccation occurs and live plant material is added to the dead fuel loading on the site

Fire Danger

USA National Fire Danger Rating System

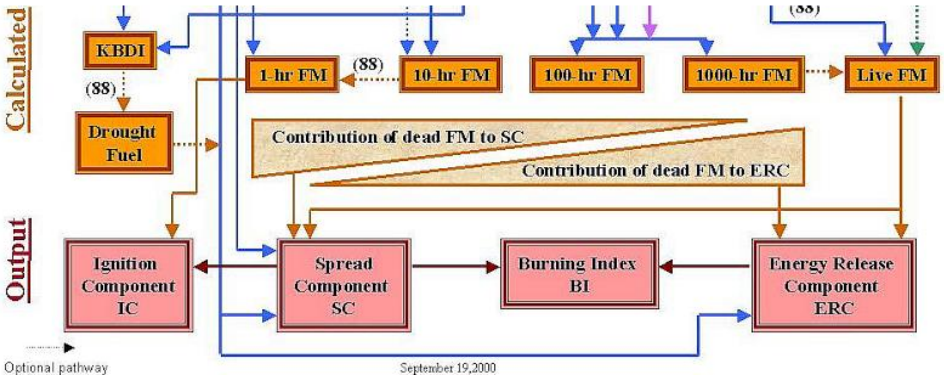


Ignition Component (IC)

- A rating of the probability that a firebrand will cause a fire requiring suppression action;
- Expressed as a probability, it ranges on a scale of 0 to 100;
- An IC of100 means that every firebrand will cause an "actionable" fire if it contacts a receptive fuel. Likewise an IC of 0 would mean that no firebrand would cause an actionable fire under those conditions

Fire Danger

USA National Fire Danger Rating System

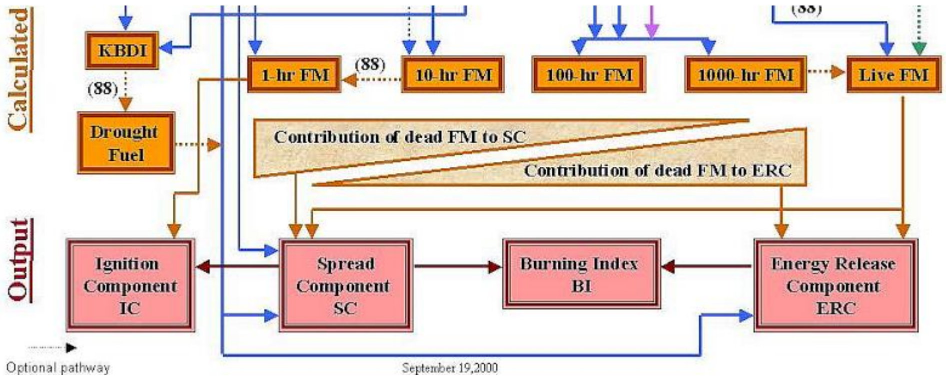


Spread Component (SC)

- A rating of the forward rate of spread of a headfire;
- Is numerically equal to the theoretical ideal rate of spread expressed in feet-per-minute

Fire Danger

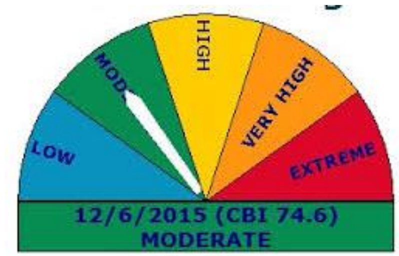
USA National Fire Danger Rating System



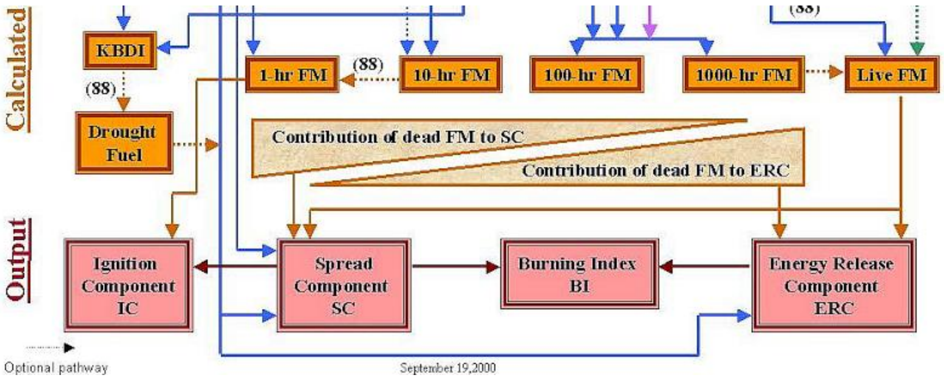
Energy Release Component (ERC)

- A number related to the available energy per unit area within the flaming front at the fire head: it represents the potential "heat release" per unit area;
- Daily variations in ERC are due to changes in moisture content of the various fuels present, both live and dead;
- It may be considered a composite fuel moisture value as it reflects the contribution that live and dead fuels have to potential fire intensity;
- Is a cumulative or "build-up" type of index. As live fuels cure and dead fuels dry, the ERC values get higher thus providing a good reflection of drought conditions.

Fire Danger



USA National Fire Danger Rating System



Burning Index (BI)

- A number related to the contribution of fire behavior to the effort of containing a fire;
- Derived from a combination of SC and ERC;
- Is expressed as a numeric value closely related to the flame length and fireline intensity

Fire Danger

USA National Fire Danger Rating System

USFS - WFAS
Wildland Fire Assessment System

Rocky Mountain Research Station

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- Growing Season Index
- AVHRR NDVI
- Keetch-Byram Index
- Palmer Index
- National Fuel Moisture

Fire Danger Rating

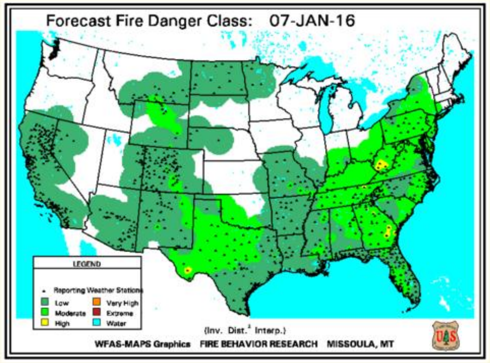
Fire Potential / Fire Danger Maps	Current Conditions	Forecast	Image Archive	Data Archive
Fire Danger Rating	US48 | AK US48 Regional Subsets KML | KMZ	US48	US48	

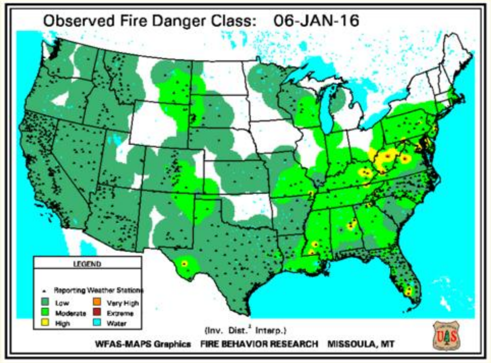
A Fire Danger Rating level takes into account current and antecedent weather, fuel types, and both live and dead fuel moisture (Deeming and others 1977, Bradshaw and others 1984).

The adjective class rating is a method of normalizing rating classes across different fuel models, indexes, and station locations. It is based on the primary fuel model cataloged for the station, the fire danger index selected to reflect staffing levels, and climatological class breakpoints. This information is provided by local station managers. About 90% use the Burning Index (BI); others use Energy Release Component (ERC). Staffing class breakpoints are set by local managers from historical fire weather climatology.

Only reporting station locations are indicated with a marker on the maps. Values between stations are estimated with an inverse distance-squared technique on a 10-km grid. This works pretty well in areas of relatively high station density, but has obvious shortcomings in other areas.

< Prev Next >

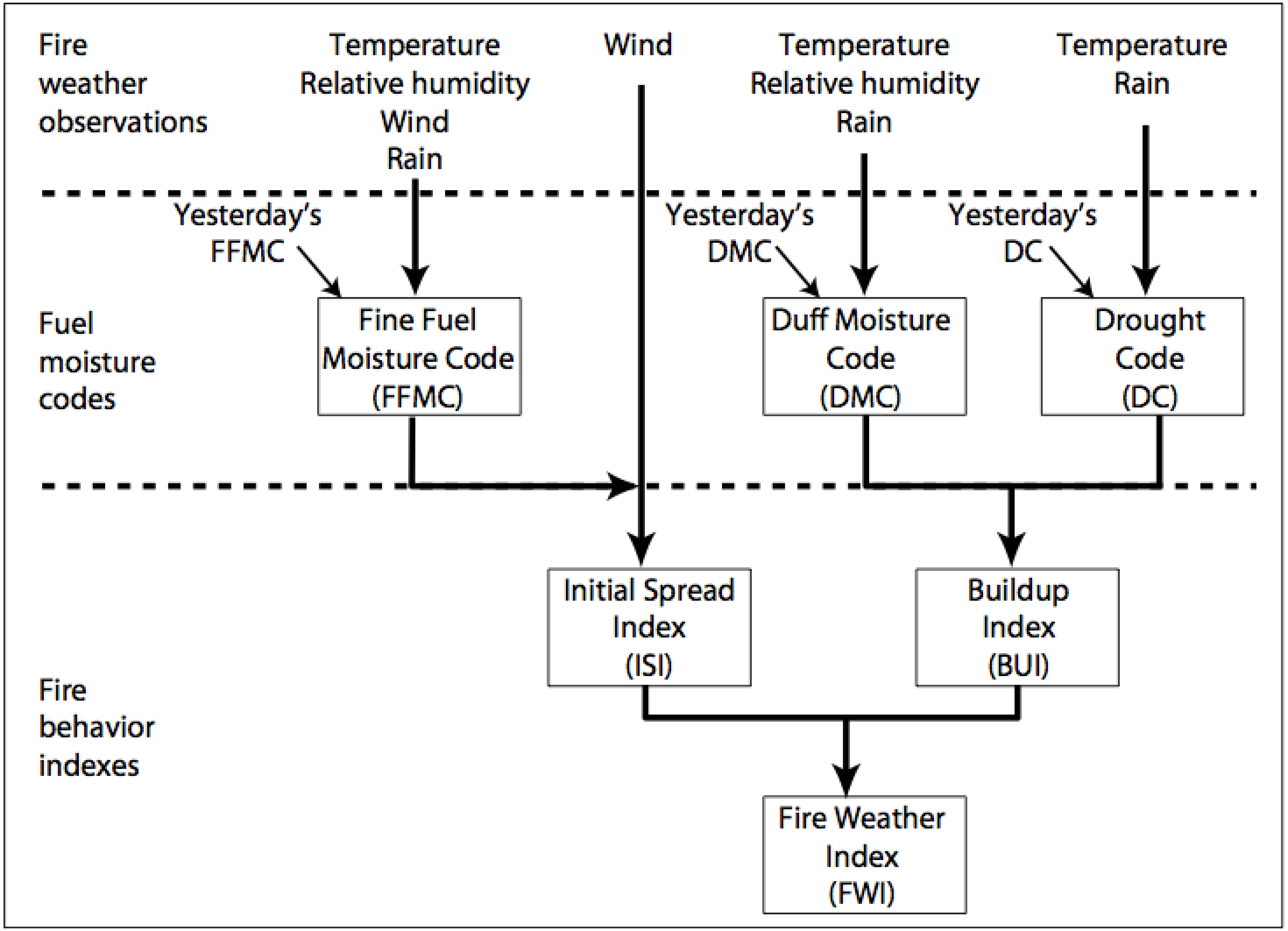




http://www.wfas.net

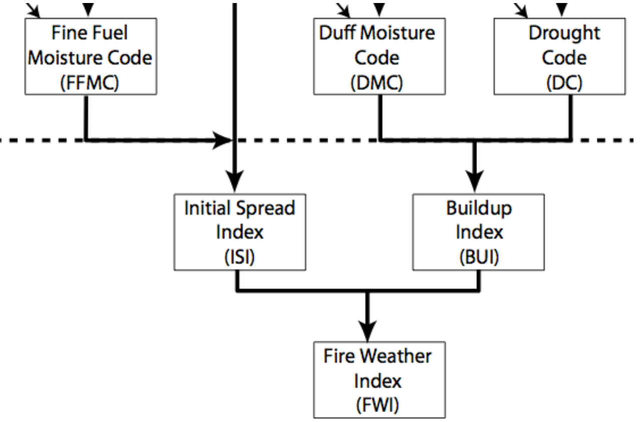
Fire Danger

Canadian Fire Weather Index



Fire Danger

Canadian Fire Weather Index

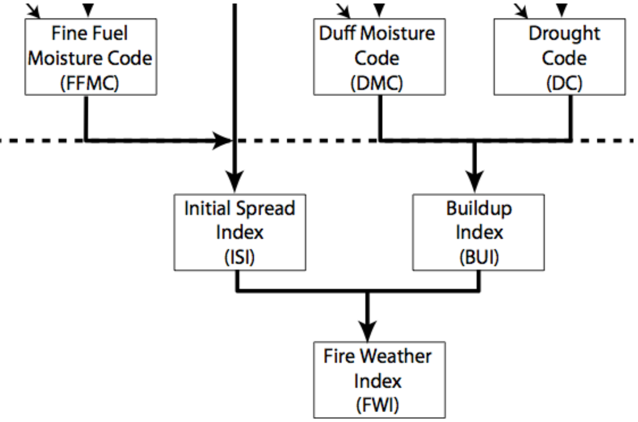


Fine Fuel Moisture Code (FFMC)

- Represents the fuel moisture of forest litter fuels under the shade of a forest canopy;
- It is intended to represent moisture conditions for the equivalent of16-hour timelag fuels;
- It ranges from 0 to 101.

Fire Danger

Canadian Fire Weather Index

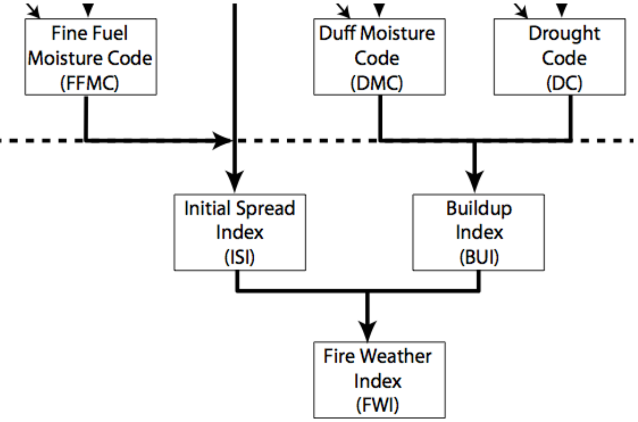


Duff Moisture Code (DMC)

- Represents the fuel moisture of decomposed organic material underneath the litter;
- Represents moisture conditions for the equivalent of 15-day (or 360 hr) timelag fuels;
- Is unitless and open ended;
- It may provide insight to live fuel moisture stress.

Fire Danger

Canadian Fire Weather Index

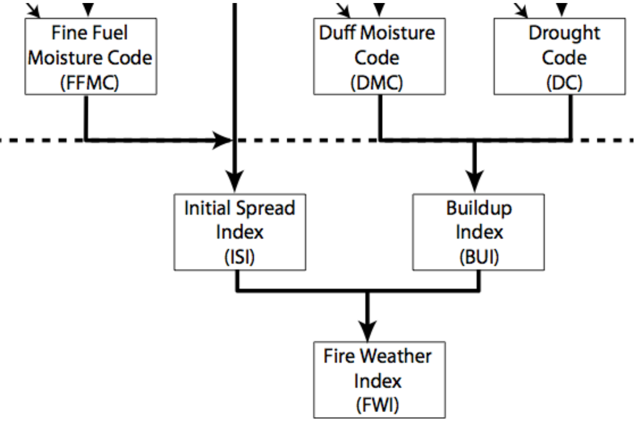


Drought Code (DC)

- Like the KBDI, represents drying deep into the soil
- It approximates moisture conditions for the equivalent of 53-day (1272 hour) timelag fuels
- It is unitless, with a maximum value of 1000

Fire Danger

Canadian Fire Weather Index

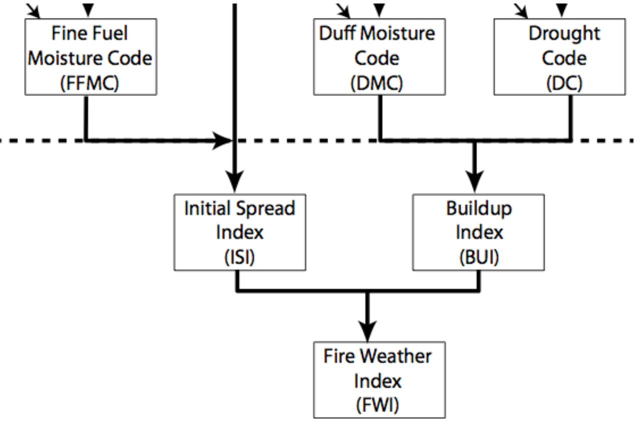


Initial Spread Index (ISI)

- ❖ Is analogous to the NFDRS Spread Component (SC);
- ❖ Integrates fuel moisture for fine dead fuels and surface windspeed to estimate a spread potential;
- ❖ Is unitless

Fire Danger

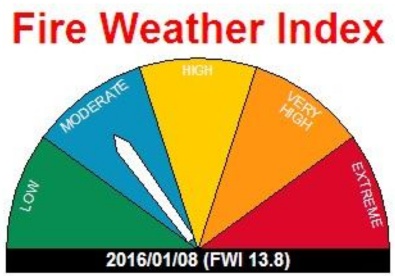
Canadian Fire Weather Index



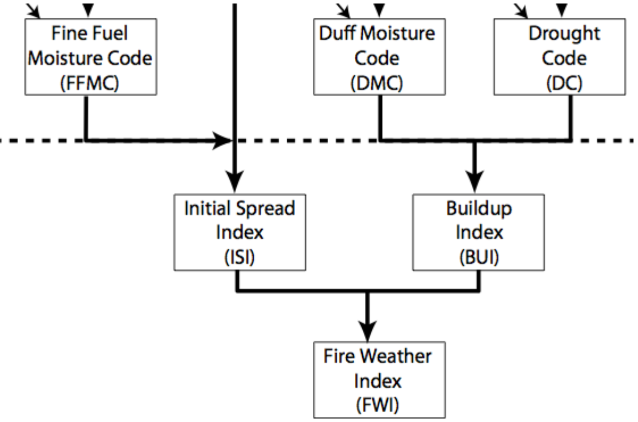
Buildup Index (BUI)

- ❖ Is analogous to the NFDRS Energy Release Component (ERC);
- ❖ Combines the current DMC and DC to produce an estimate of potential heat release in heavier fuels;
- ❖ Is unitless

Fire Danger



Canadian Fire Weather Index



Fire Weather Index (FWI)

- Integrates current ISI and BUI to produce a unitless index of general fire intensity potential

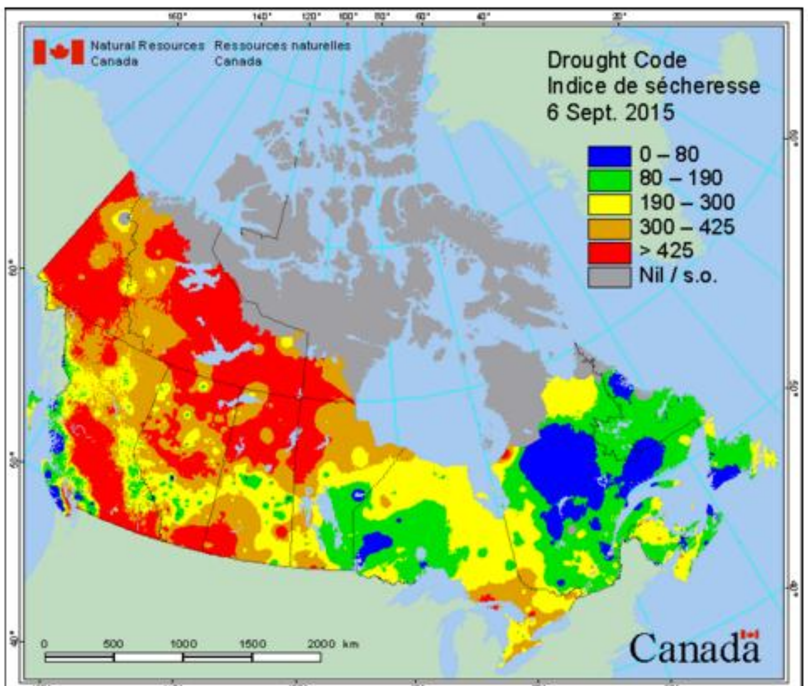
Fire Danger

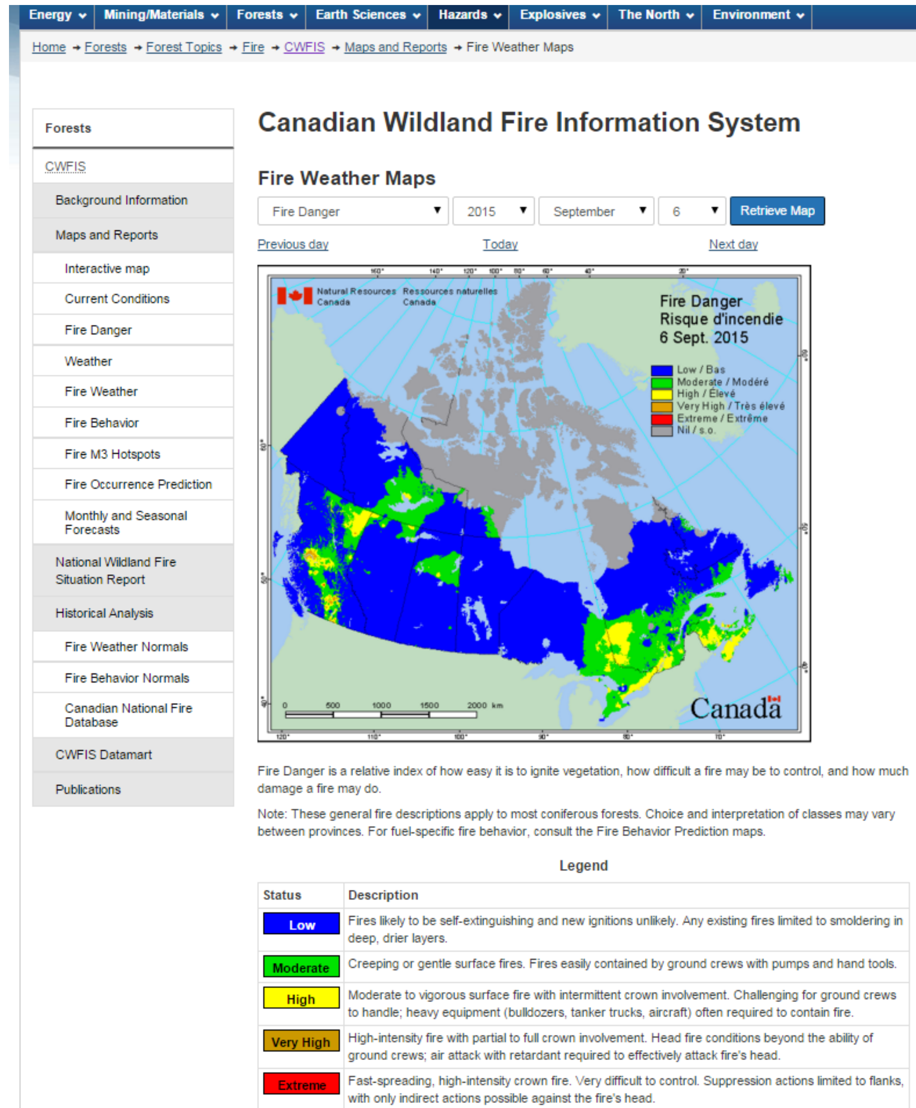
Canadian Fire Weather Index

Fire Weather Maps

Drought Code ▼ 2015 ▼ September ▼ 6 ▼ Retrieve Map

Previous day Today Next day





http://cwfis.cfs.nrcan.gc.ca/maps

Fire Danger

European Forest Fire Information System (EFFIS)

Definition and scope of EFFIS

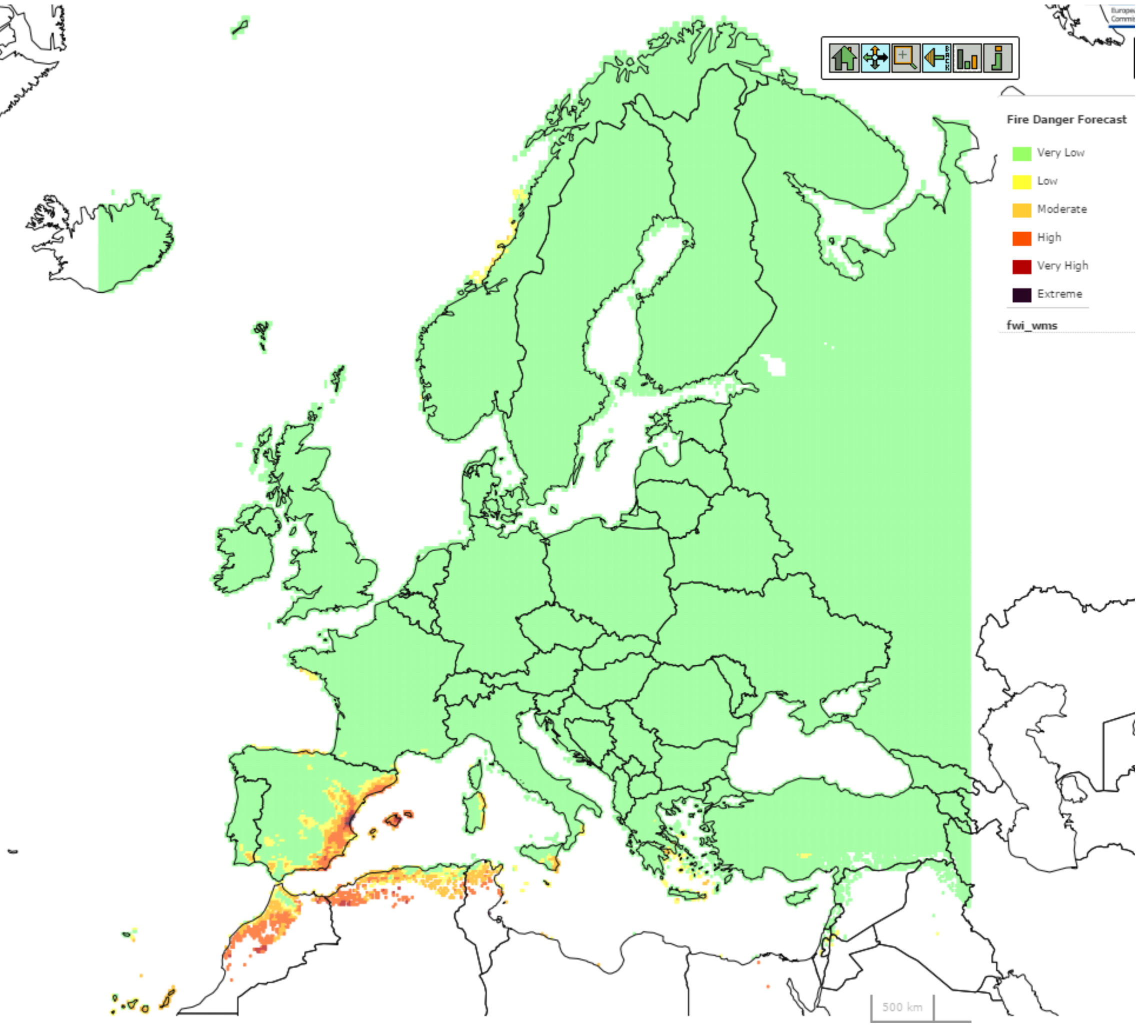
- System established by the Joint Research Centre (JRC) and DG Environment (ENV) as focal point for information on forest fires in Europe (1998)
- Provides EU level assessments during both pre-fire and post-fire phases, thus supporting fire prevention, preparedness, fire fighting and post-fire operations
- Complements national fire information systems through the provision of harmonised data, methods and standards

Users

- EC Services, European Parliament, national/regional forest fires and civil protection services of EU and non-EU countries
- FAO, United Nations Economic Commission for Europe, FAO *Silva Mediterranea*

Fire Danger

European Forest Fire Information System (EFFIS)

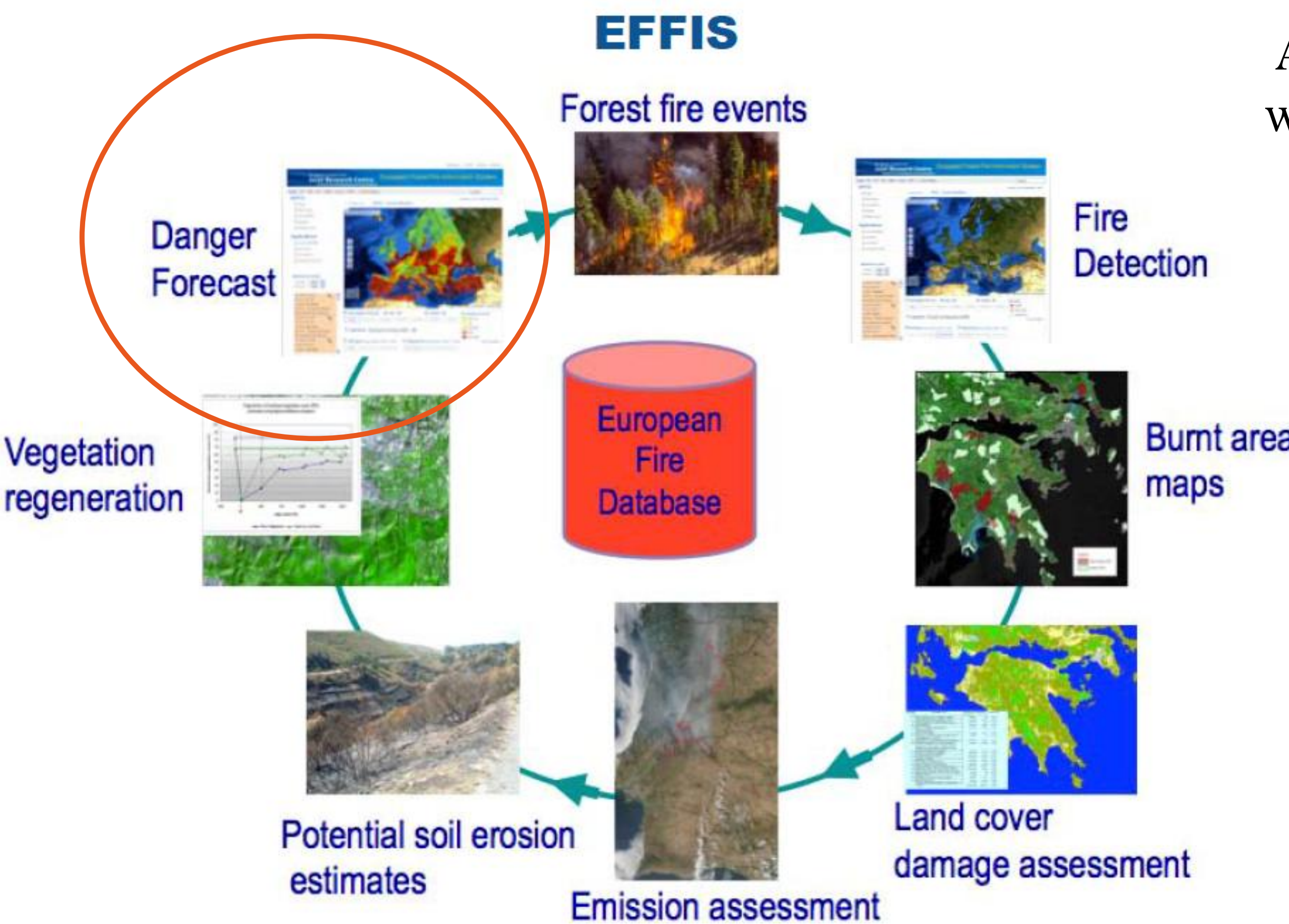


There are currently **38 countries** involved in the EFFIS network: Albania, Algeria, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Former Yugoslavian Republic of Macedonia, Germany, Greece, Hungary, Ireland, Italy, Kosovo, Latvia, Lebanon, Lithuania, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey and the United Kingdom.

www.effis.jrc.it

Fire Danger

European Forest Fire Information System (EFFIS)



A web based platform with different modules (www.effis.jrc.it)

San Miguel Ayanz, 2014

Fire Danger

European Forest Fire Information System (EFFIS)

- In EU there is a relative young tradition in FDR and many different approaches
- The fire danger rating module of EFFIS has been established as unified platform for implementing at the EU scale selected national indices
- The main motivation was having a common system to support preparedness and cooperation among EU countries
- The Canadian FWI has been adopted since 2007

San Miguel Ayanz, 2014

Fire Danger

European Forest Fire Information System (EFFIS)

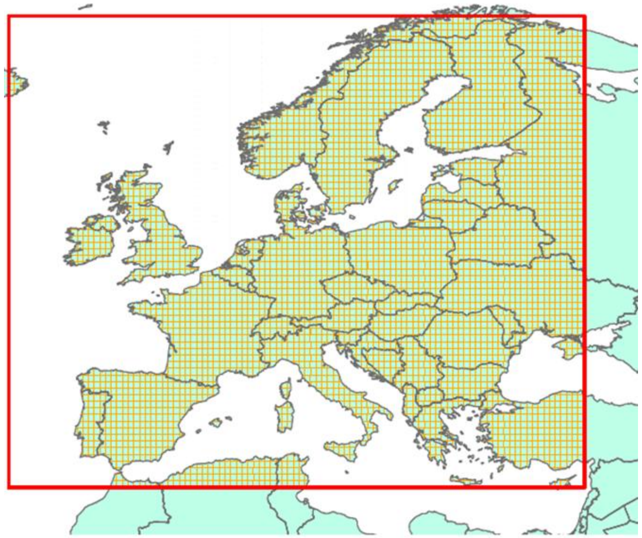
The fire danger forecast module of EFFIS generates daily maps of 1 to 6 days projected fire danger in EU using weather forecast data.

PERIOD: from 16th of February to 31st of October
DATA: meteorological forecasted data received daily

From Meteo-France
- Spatial resolution of 10km
- Forecast up to 4 days

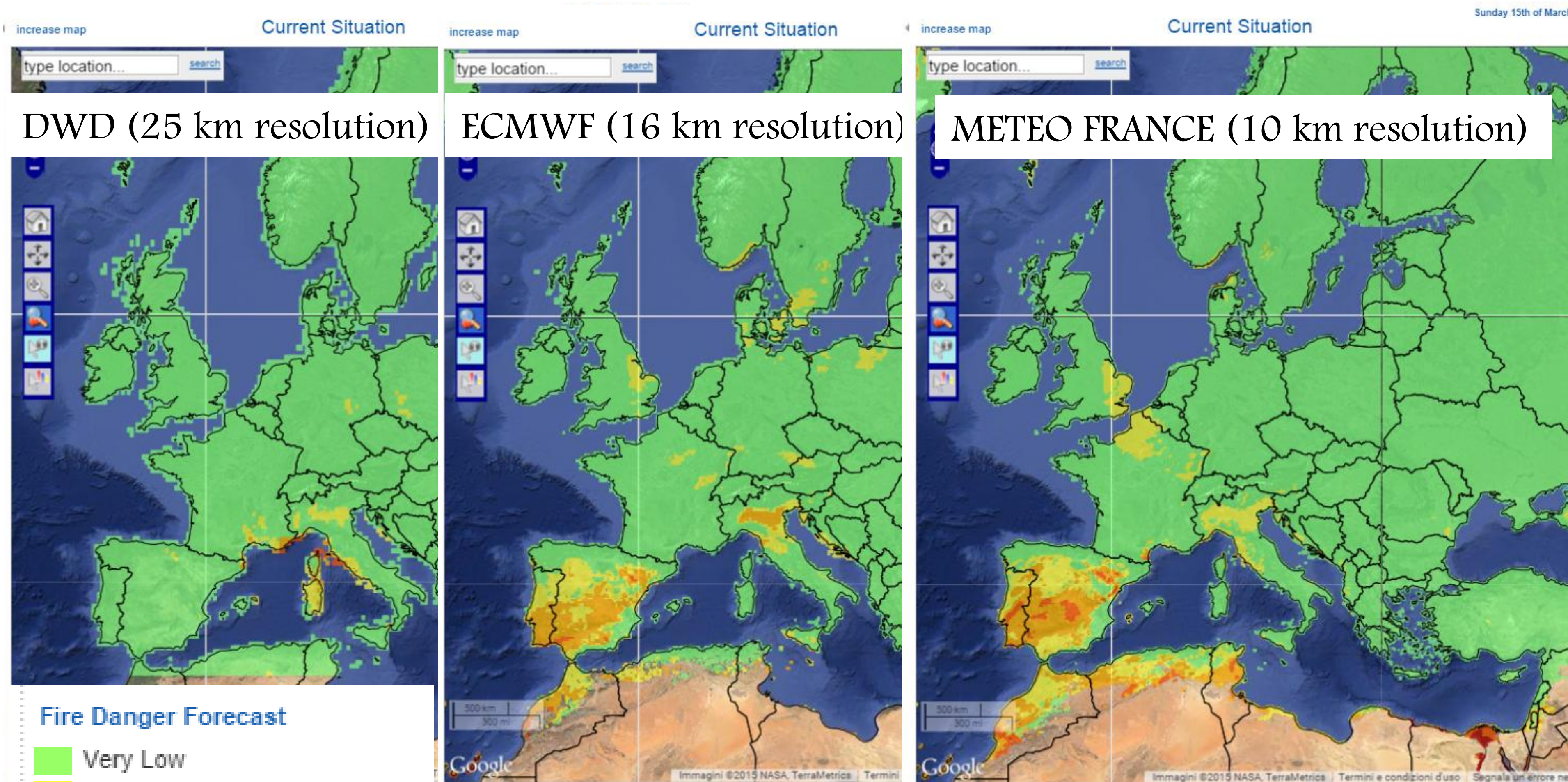
From DWD (Deutscher Wetterdienst)
- Spatial resolution of 25km
- Forecast up to 7 days

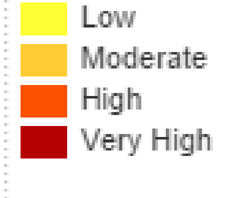
From ECMWF
- Spatial resolution of 16km
- Forecats up to 8 days



San Miguel Ayanz, 2014

Fire Danger



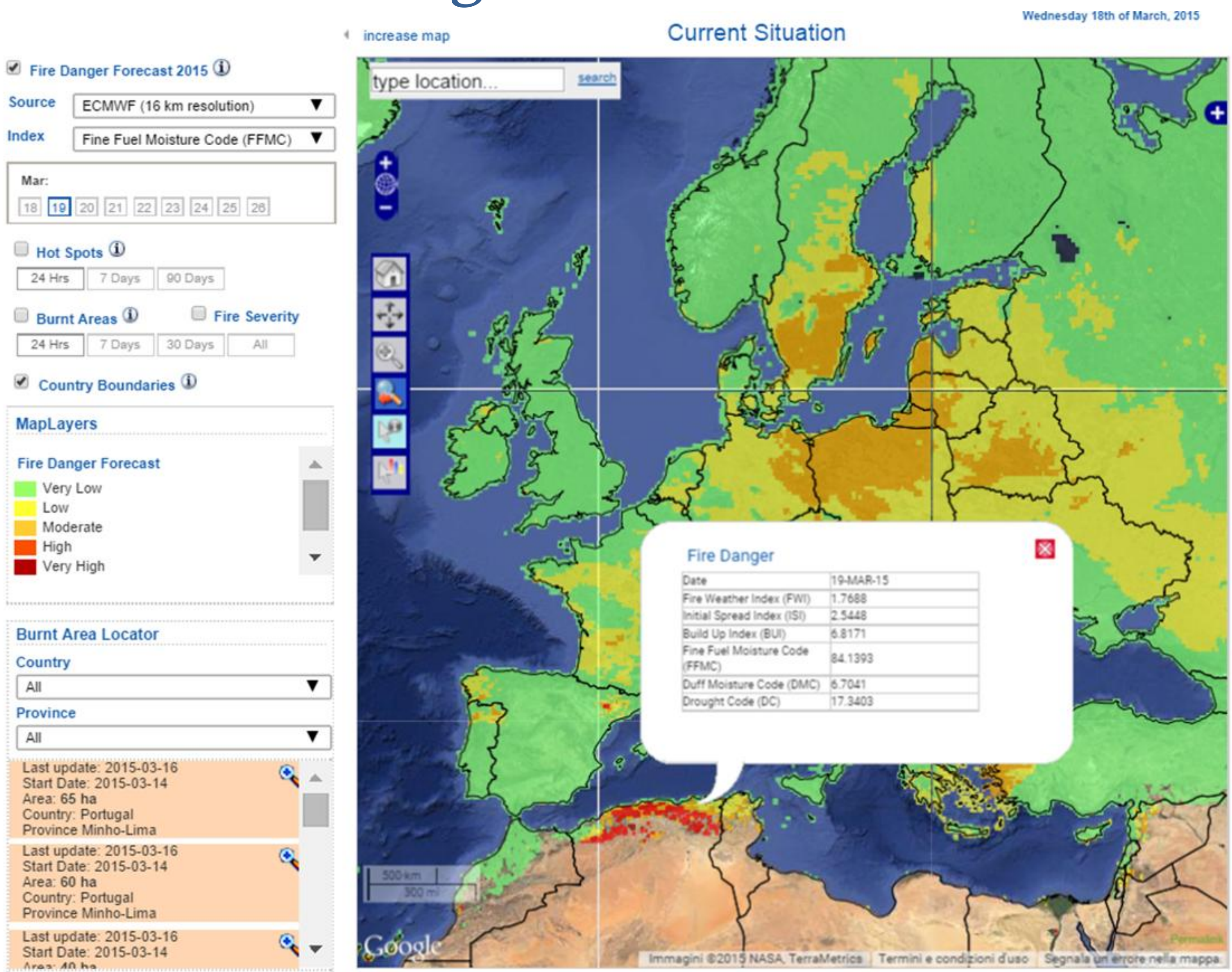


http://forest.jrc.ec.europa.eu/effis/applications/current-situation/

Bacciu, 2015

Fire Danger

European Forest Fire Information System (EFFIS)



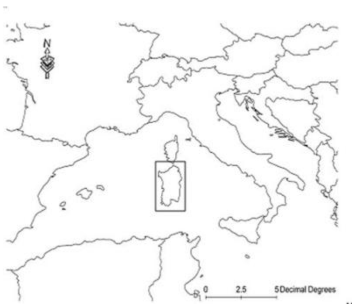
http://forest.jrc.ec.europa.eu/effis/applications/current-situation/

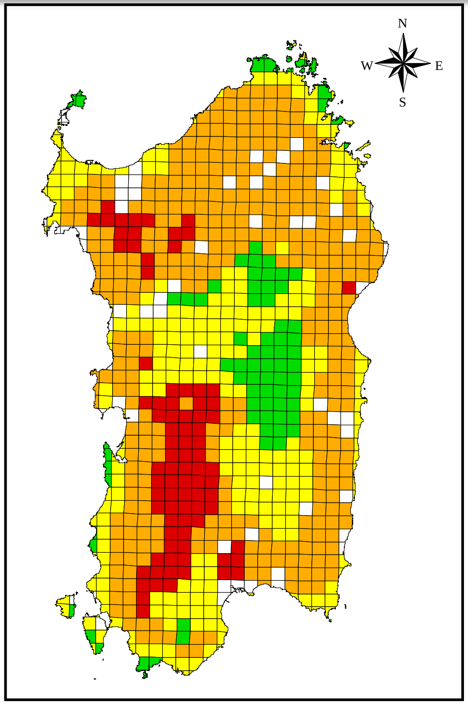
Bacciu, 2015

Fire Danger

Integrated Fire Danger Index (IFI)

- Developed in Sardinia (Italy) by the University of Sassari
- Daily fire danger outputs used in an operative version by the Civil Protection of Sardinia for fire monitoring and alerts
- Fire danger is a unitless value ranging from 0 to 18. High values indicate high fire danger
- Fire danger is commonly espressed in classes ranging from 1 (very low) to 5 (extreme)

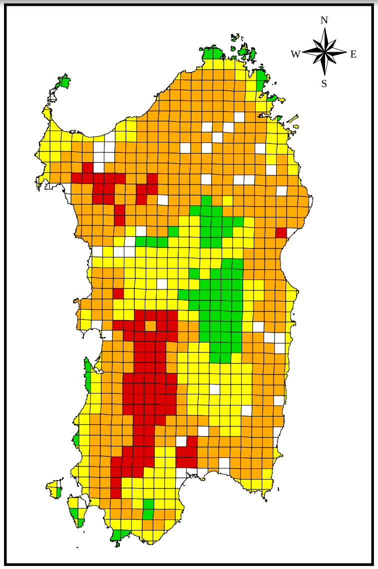




IFI danger classes

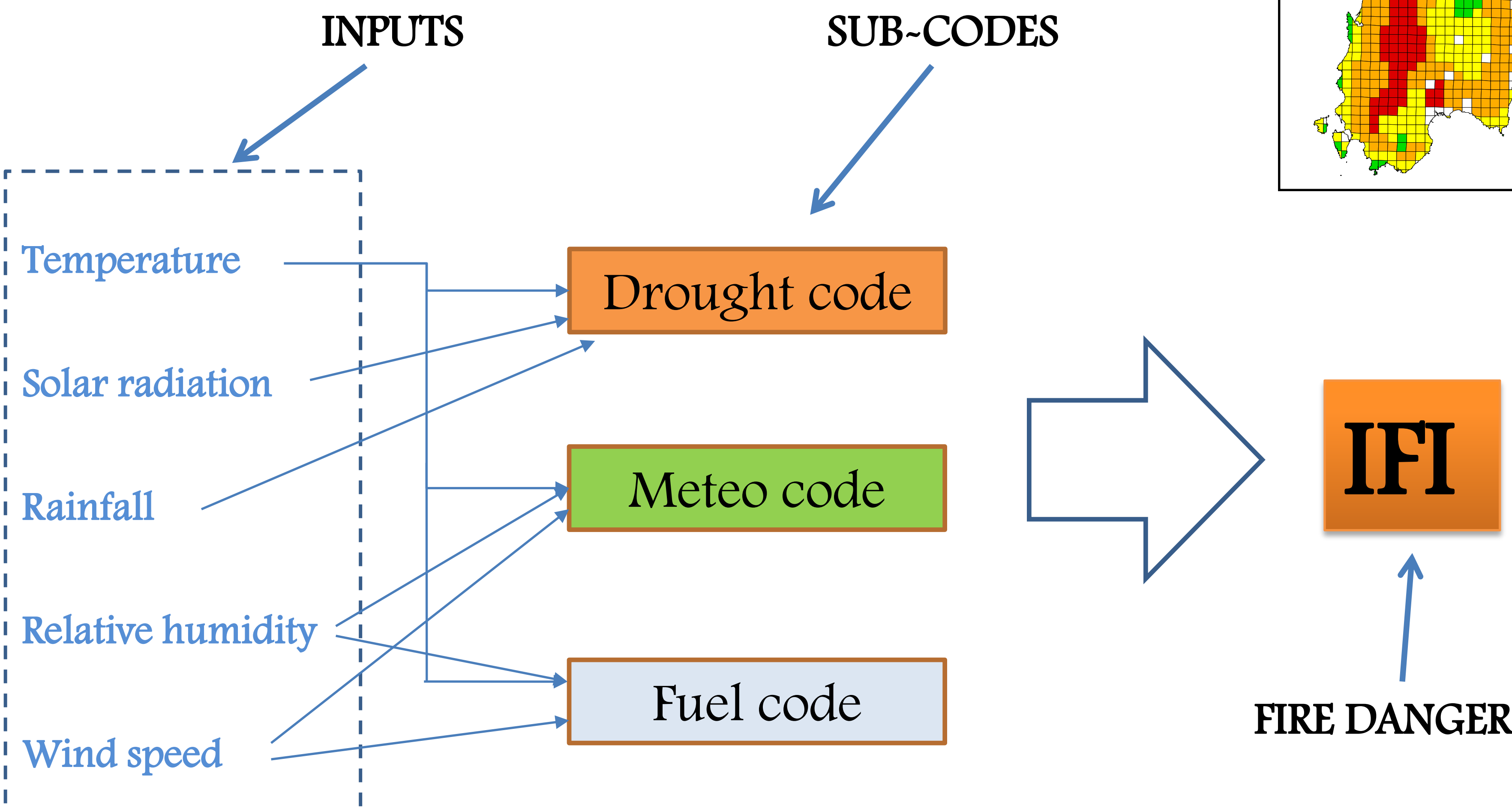
- n. a.
- very low
- low
- medium
- high
- extreme

Sirca, 2014

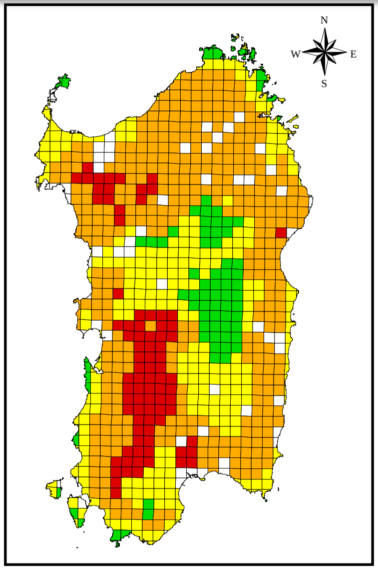


Fire Danger

Integrated Fire Danger Index (IFI)



Sirca, 2014



Fire Danger

Integrated Fire Danger Index (IFI)

Indicator of the soil dryness

Drought code

Meteo code

Indicator of the fire weather severity

Indicator of the fuel moisture conditions

Fuel code

Sirca, 2014

Thank you for your attention!

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