Wildfire Risk Assessment and Management: Insights, Challenges and Future Perspectives for Mediterranean Areas

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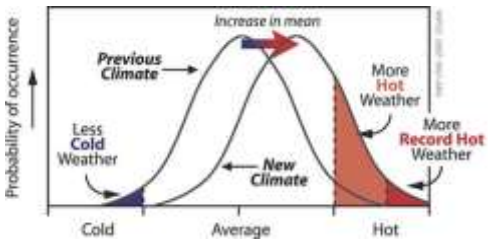
cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

uniss UNIVERSITÀ DEGLI STUDI DI SASSARI

ICTP The Abdus Salam International Centre for Theoretical Physics

Increased frequency of extreme weather



Lengthening of fire seasons

Increment of fire suppression budgets

Loss of confidence in using agricultural fires

MEDITERRANEAN AREAS: INCREASE IN FIRE RISK AND MEGA-FIRE FREQUENCY

Land use / land cover changes

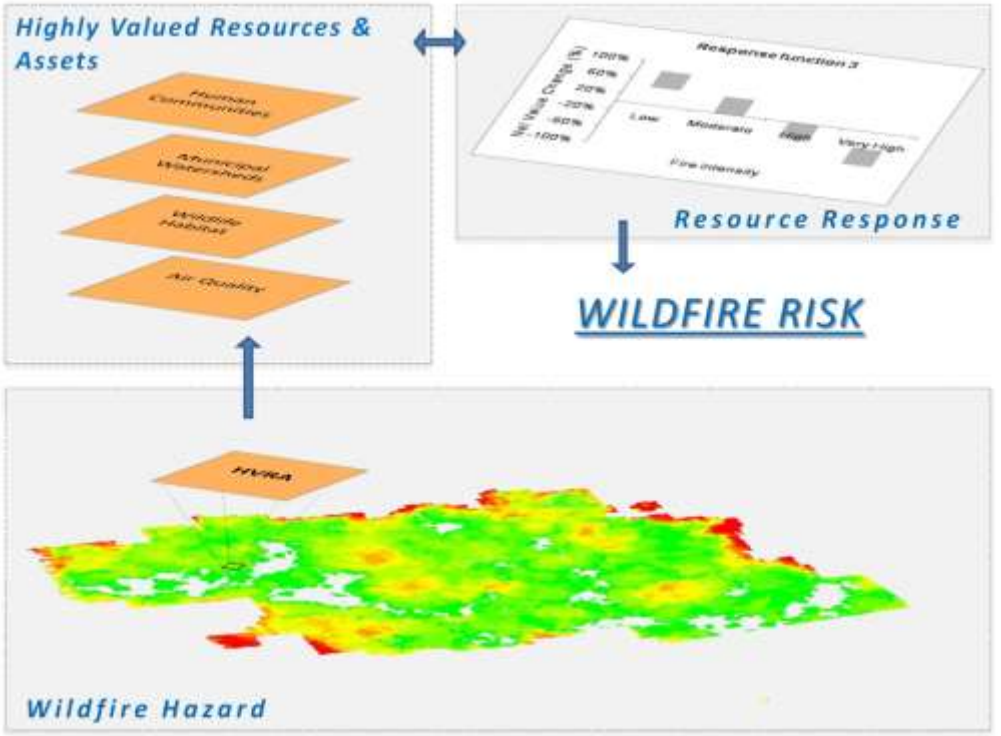
Ageing population in forest/rural areas

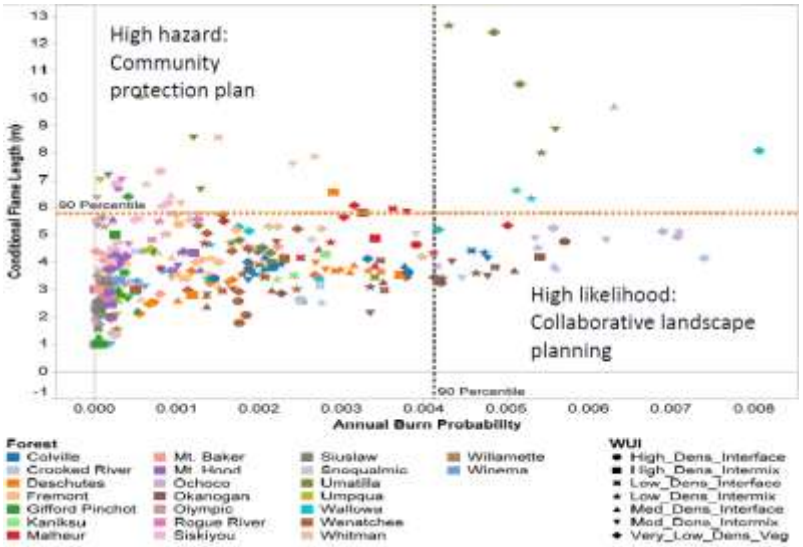
Lacking land management and build-up of unmanaged fuelbeds

Increased pressure in coastal and urban areas

Foreword

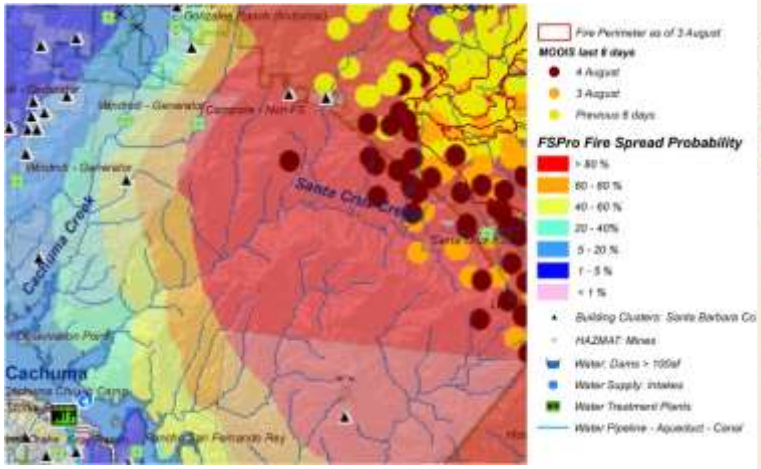
The growing incidence of large fires impacting forests and urban interfaces over the past decades has led to extensive research on wildfire risk

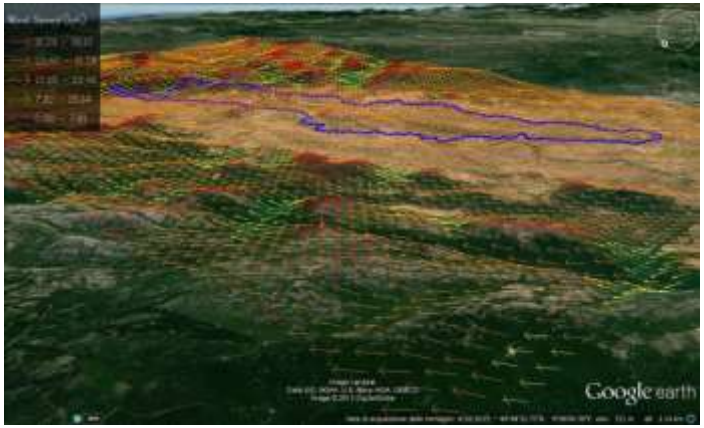




Foreword

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





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.)

(Finney 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

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

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

$E(L) =$ Expected loss — "Risk"

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

(Finney 2013)

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

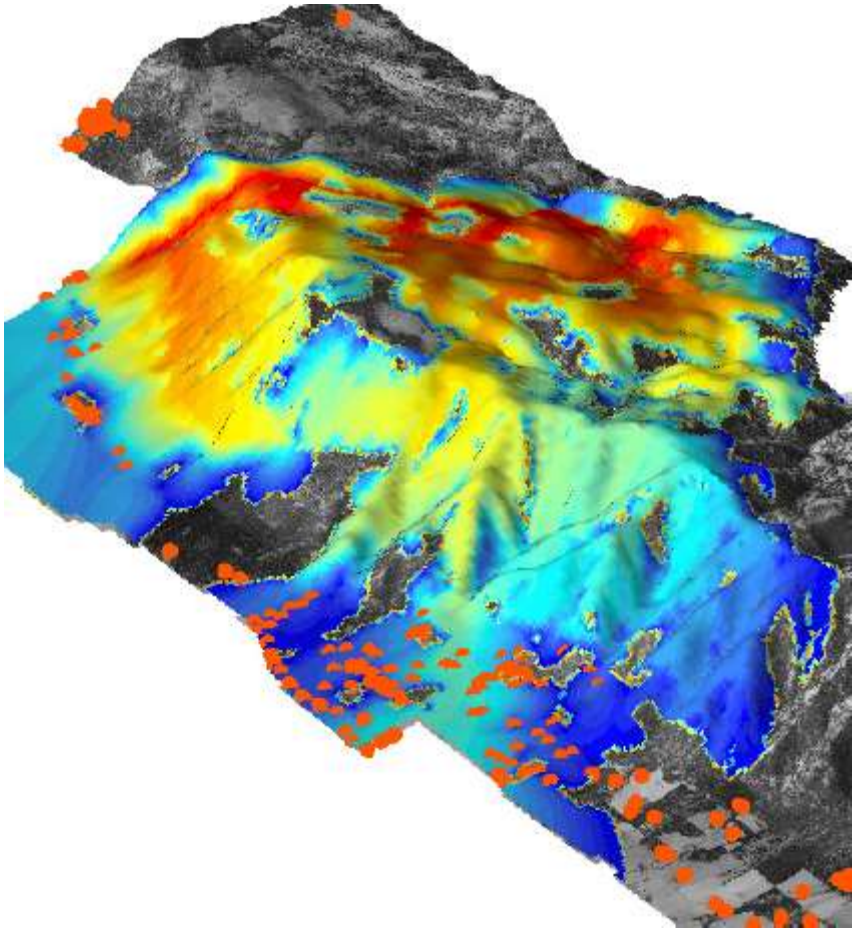
Landscape Fire Simulation Models

How do we estimate burn probability and fire intensity?

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

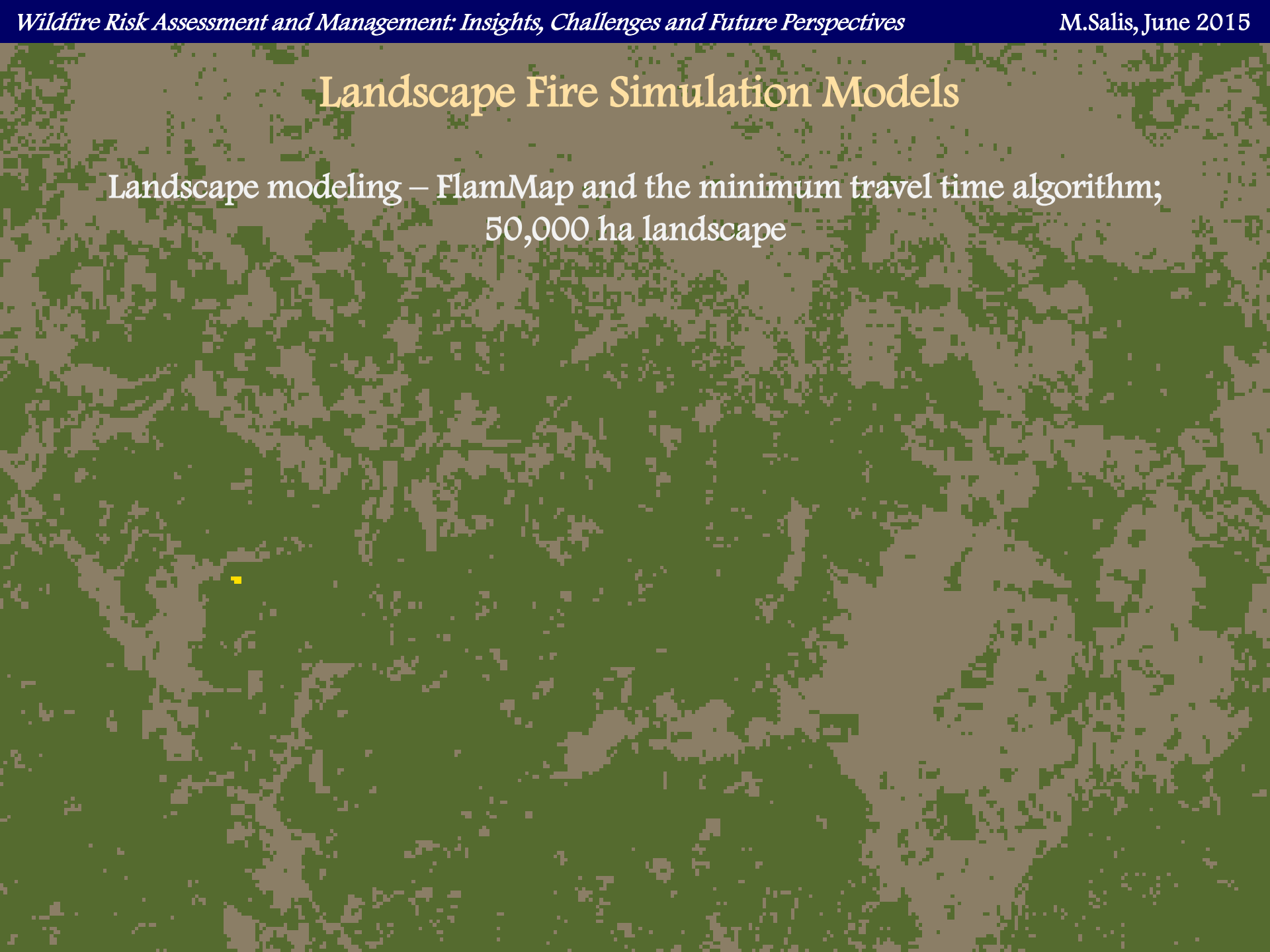
Historical wildfire data and reports are generally insufficient to map burn probability and intensity at fine scales

In recent years, several studies have used landscape fire simulation models



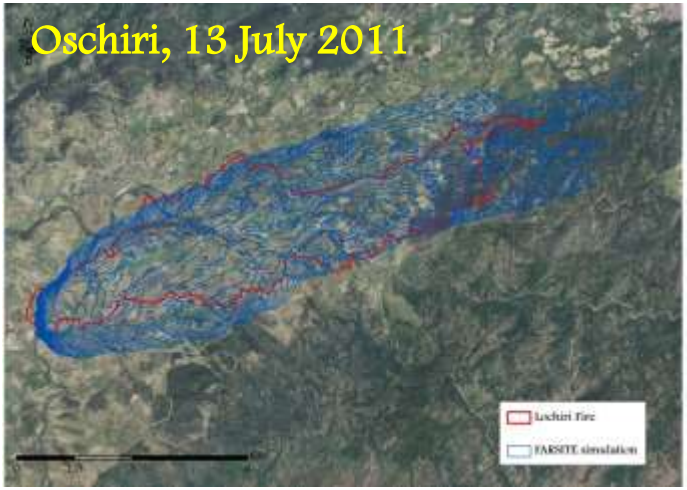
Landscape Fire Simulation Models

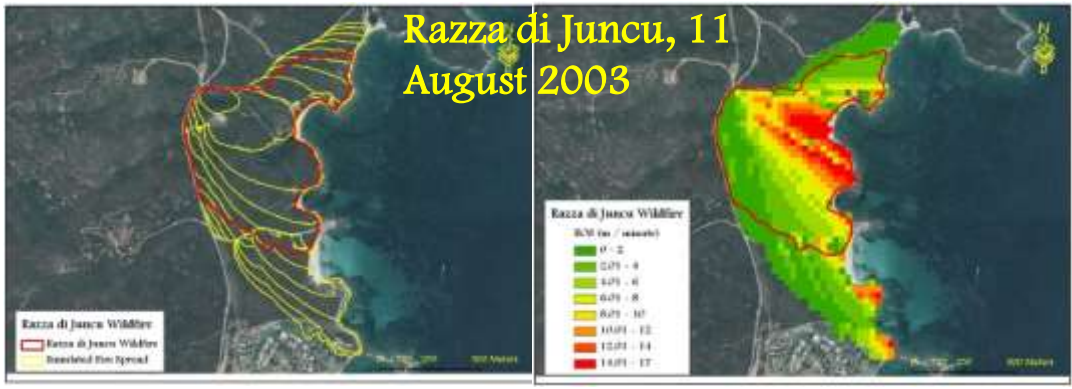
Landscape modeling – FlamMap and the minimum travel time algorithm; 50,000 ha landscape

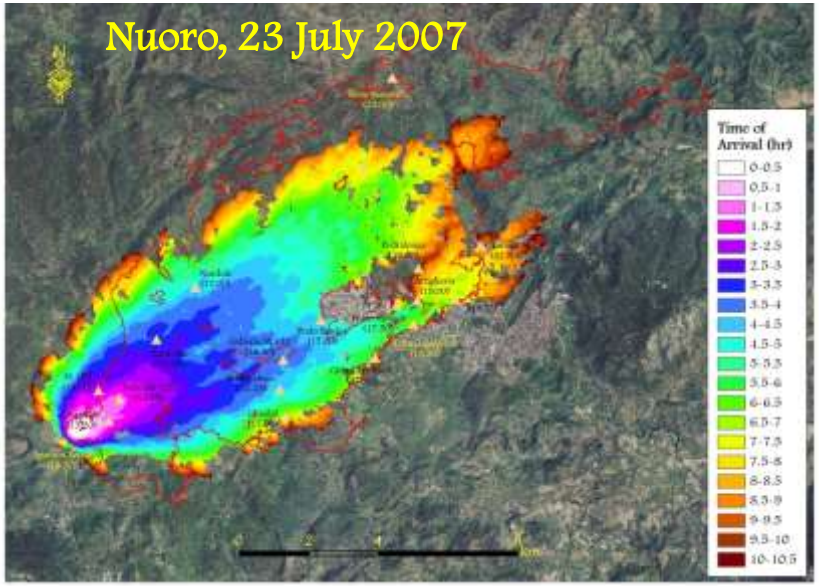


Landscape Fire Simulation Models

Need to calibrate and validate the fire spread models



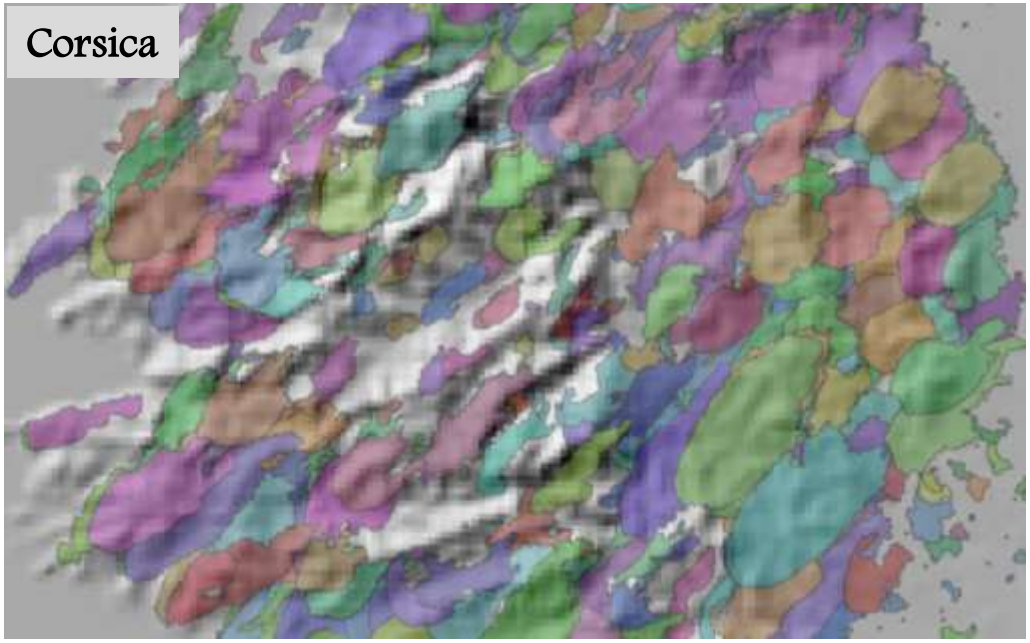


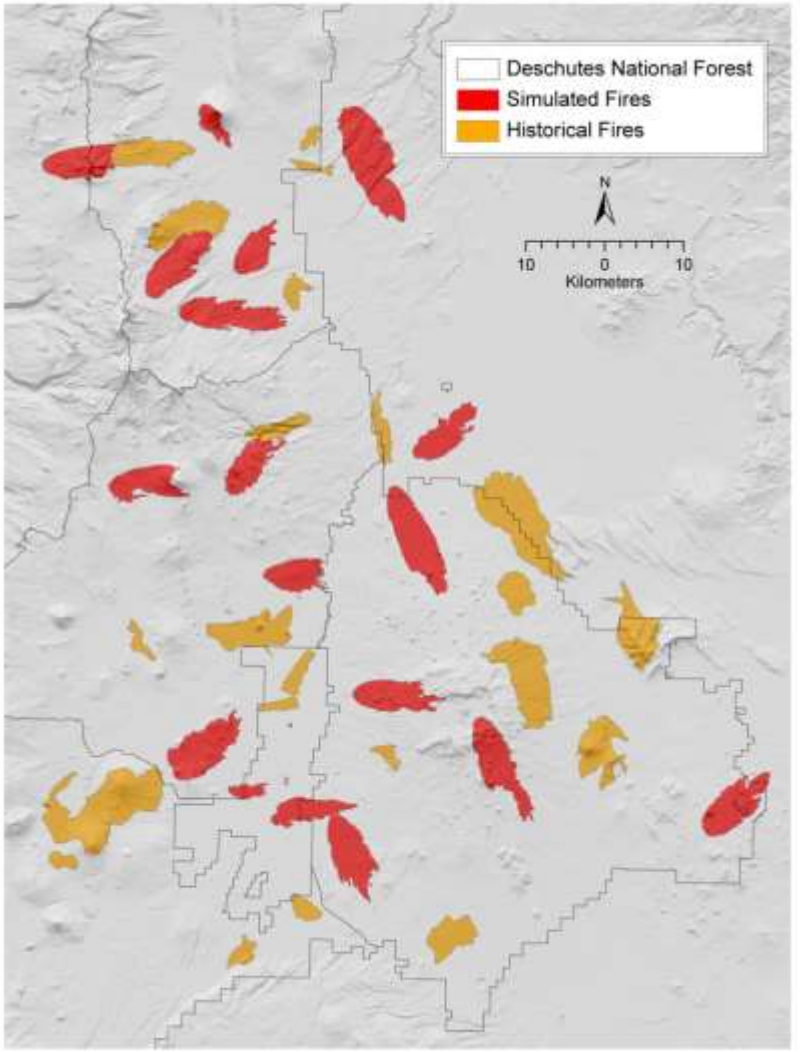


(Salis et al.; Arca et al.)

Landscape Fire Simulation Models

Need to simulate thousands wildfires to saturate the study areas and identify exposure profiles

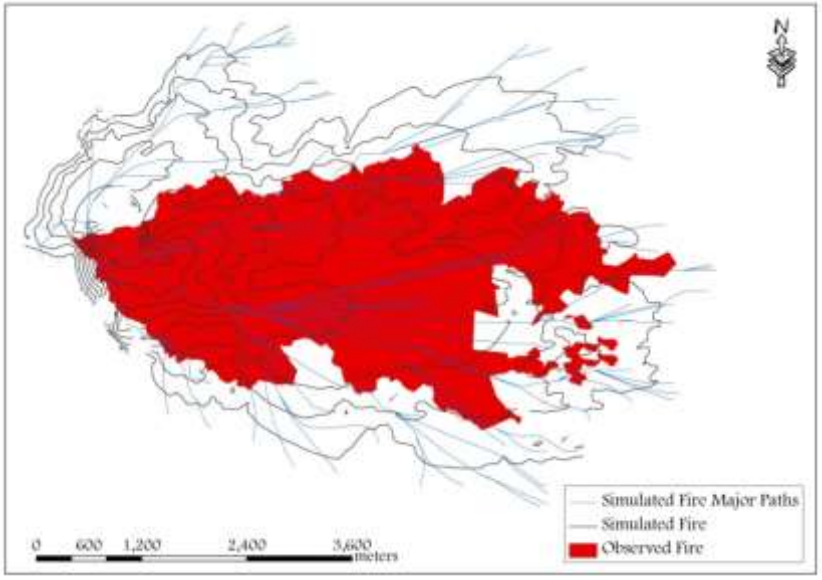




Landscape Fire Simulation Models

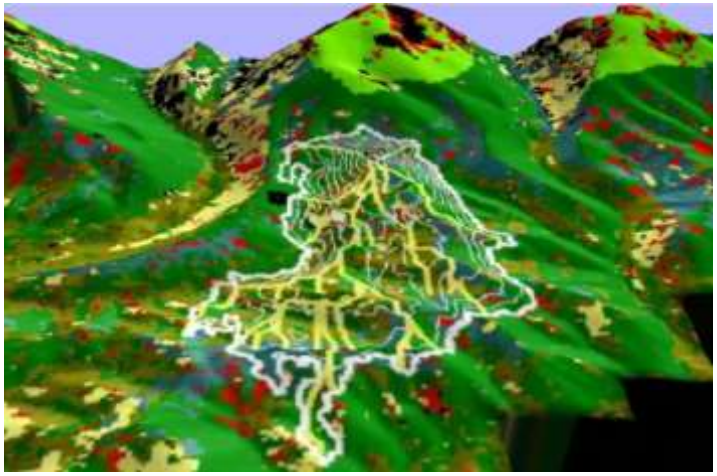
Wildfire Simulations Modeling (MTT algorithm)

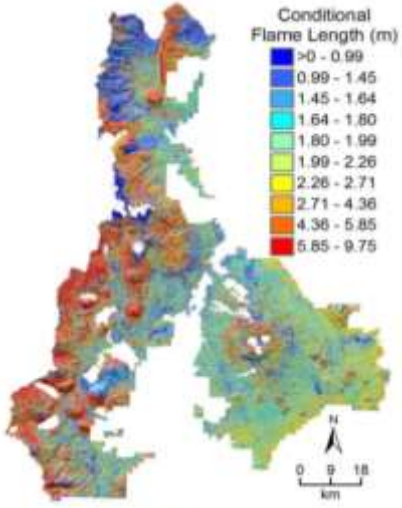
(Finney 2002)



- Minimum time and quickest path for a fire to spread on each node of the landscape

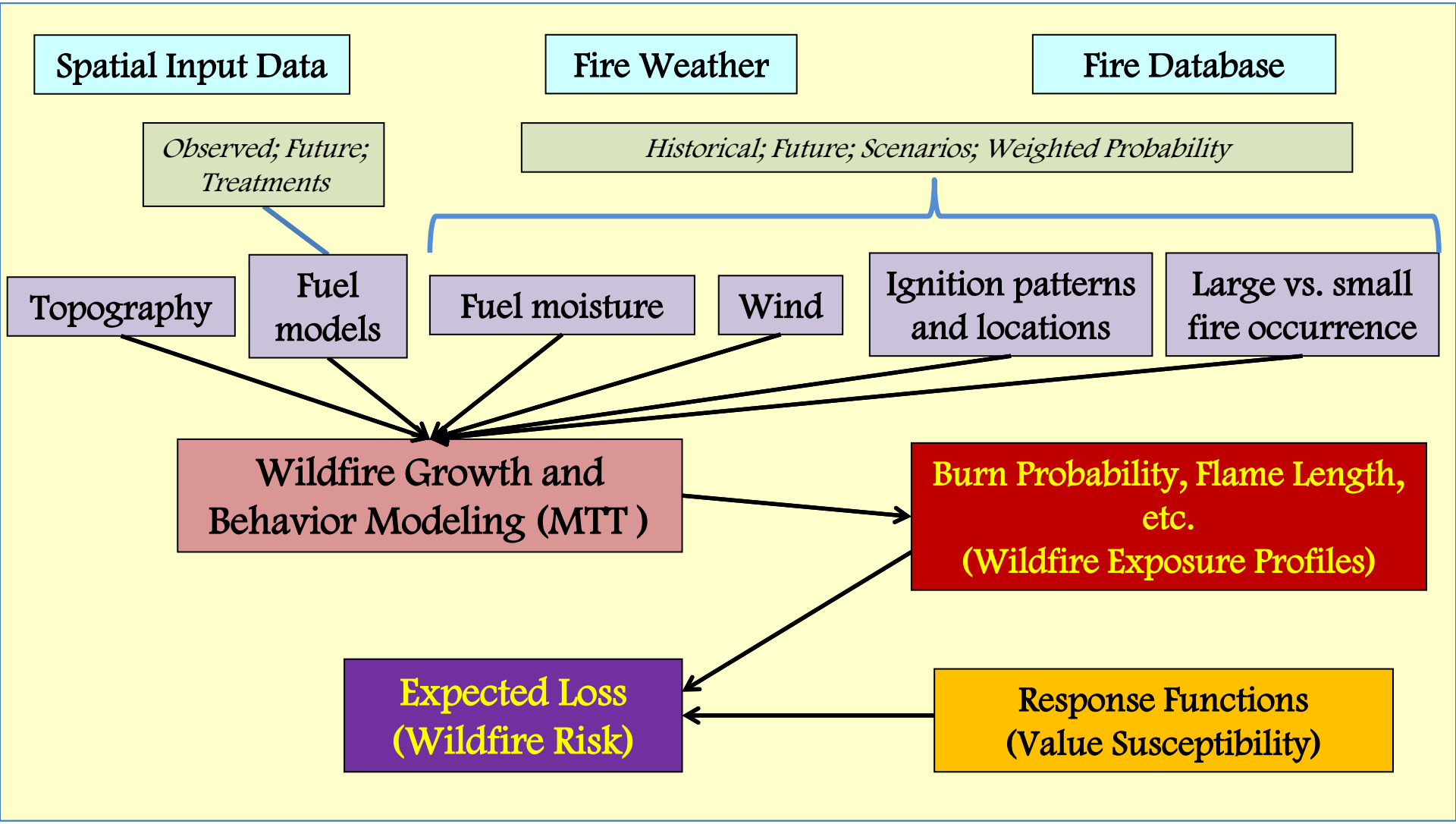
- Rate of spread and intensity vary by:
  - Fuel model and moisture
  - Wind speed and direction
  - Direction of the fire
  - Topography





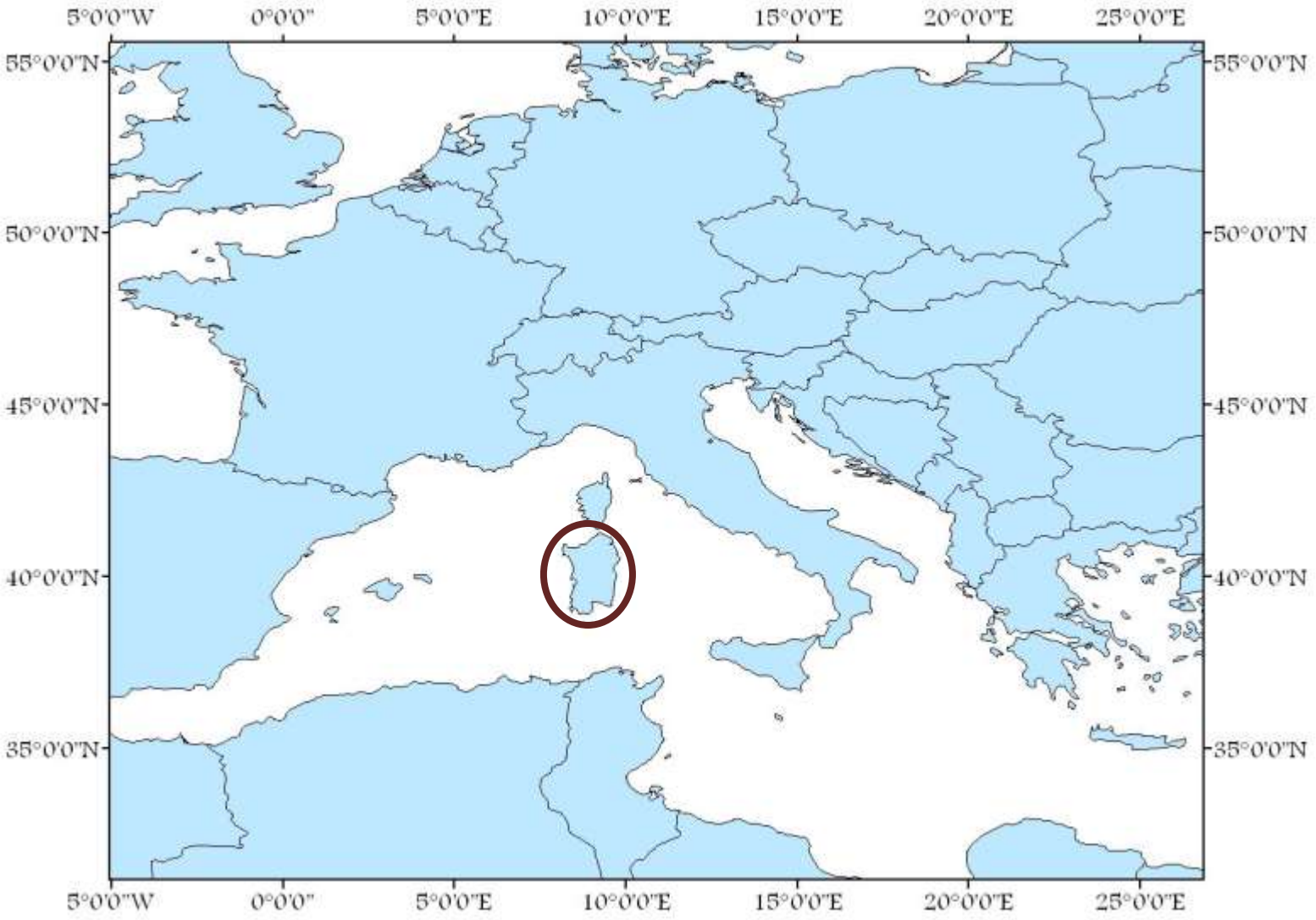
Landscape Fire Simulation Models

Methodological Framework

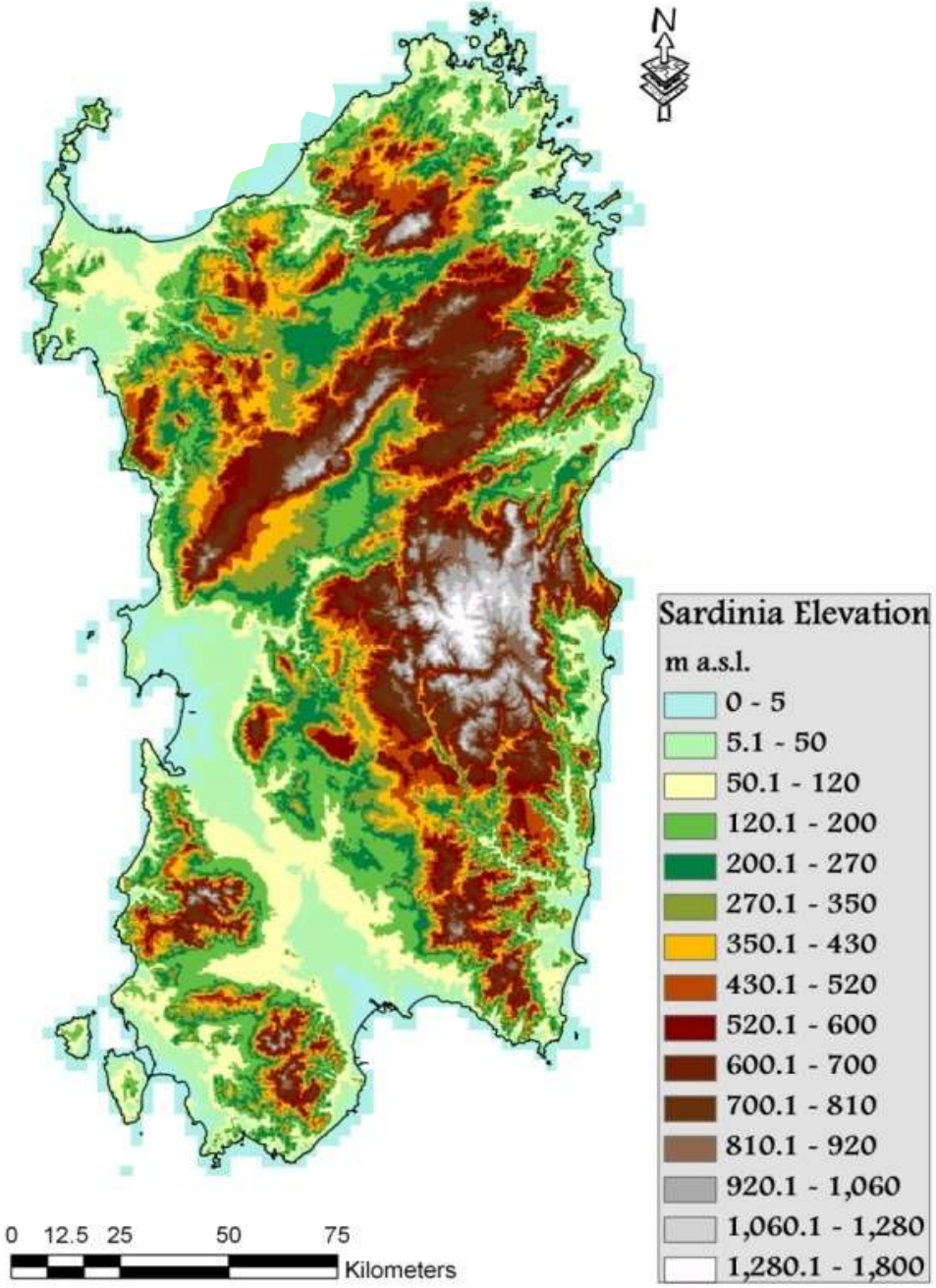


Fire Exposure Assessment in Sardinia

Many diverse values at risk!



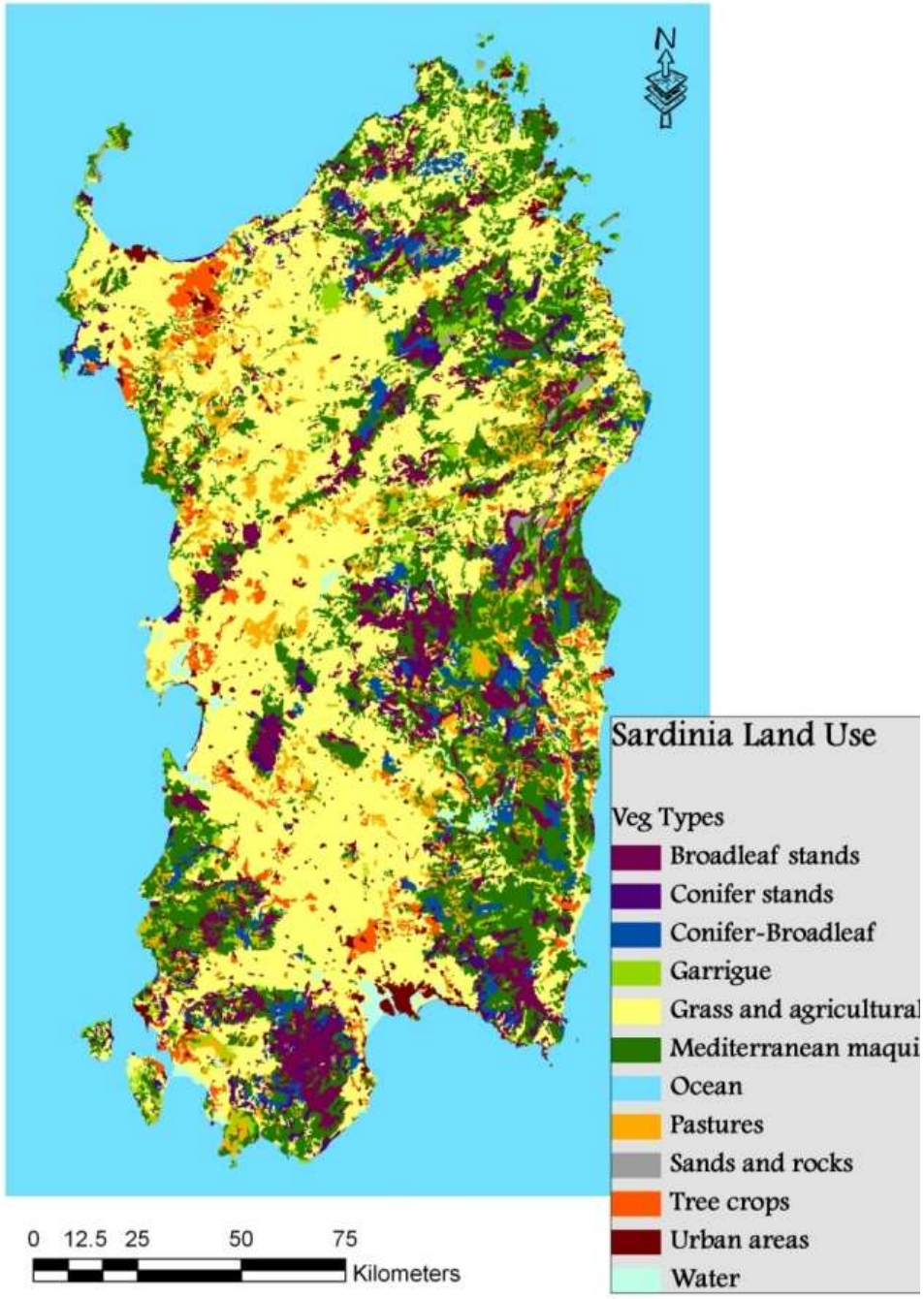
With a surface of about 24,000 km^2, Sardinia is located in the western part of the Mediterranean Basin and is the second largest island in the Mediterranean Sea



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

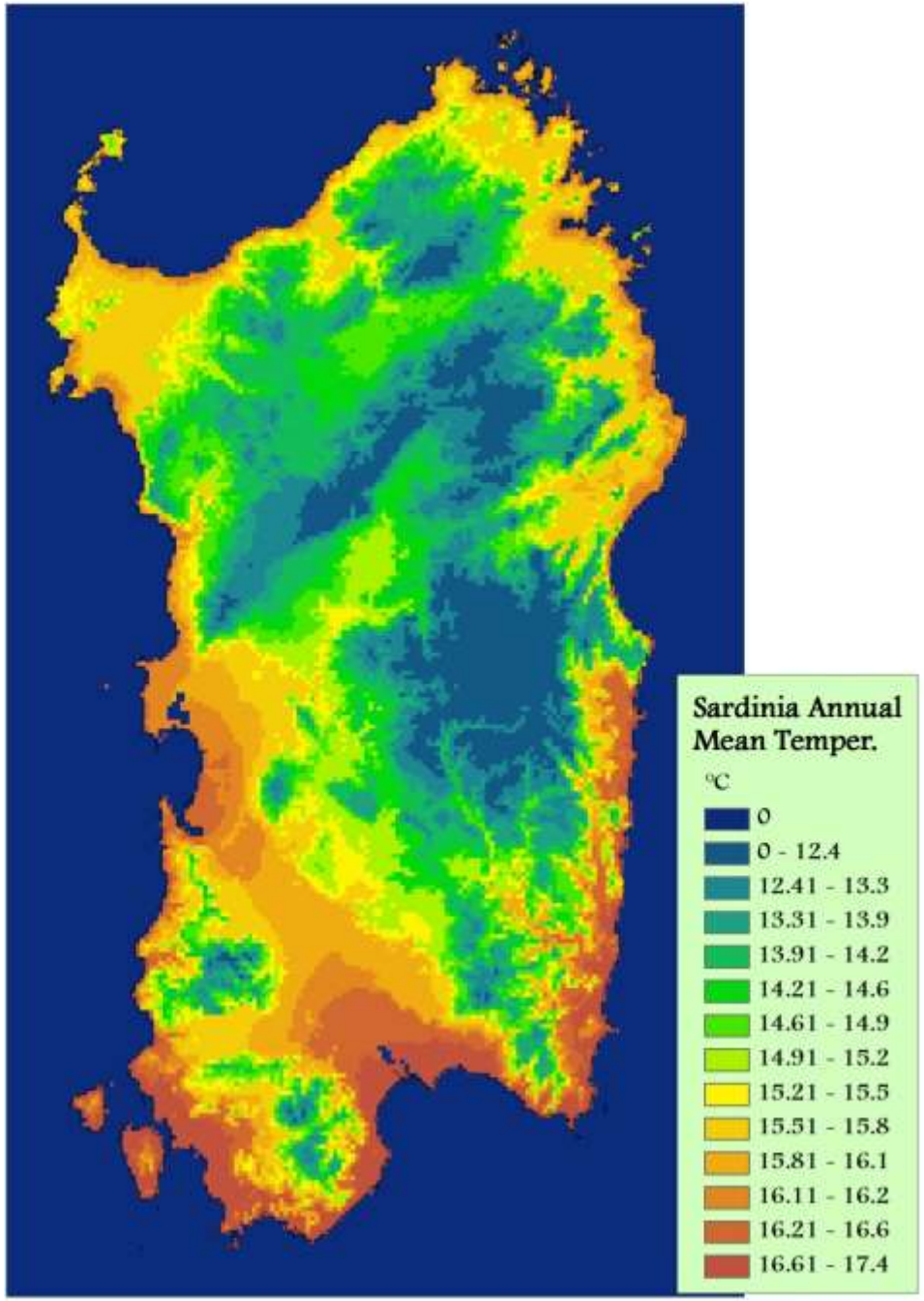
Wood and forest represent approximately 16% (year 2000) of the Sardinian vegetation, and are mainly represented by *Quercus ilex*, *Quercus suber*, *Quercus pubescens*. At higher elevation the oak formation mainly merges with *Castanea sativa*.

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

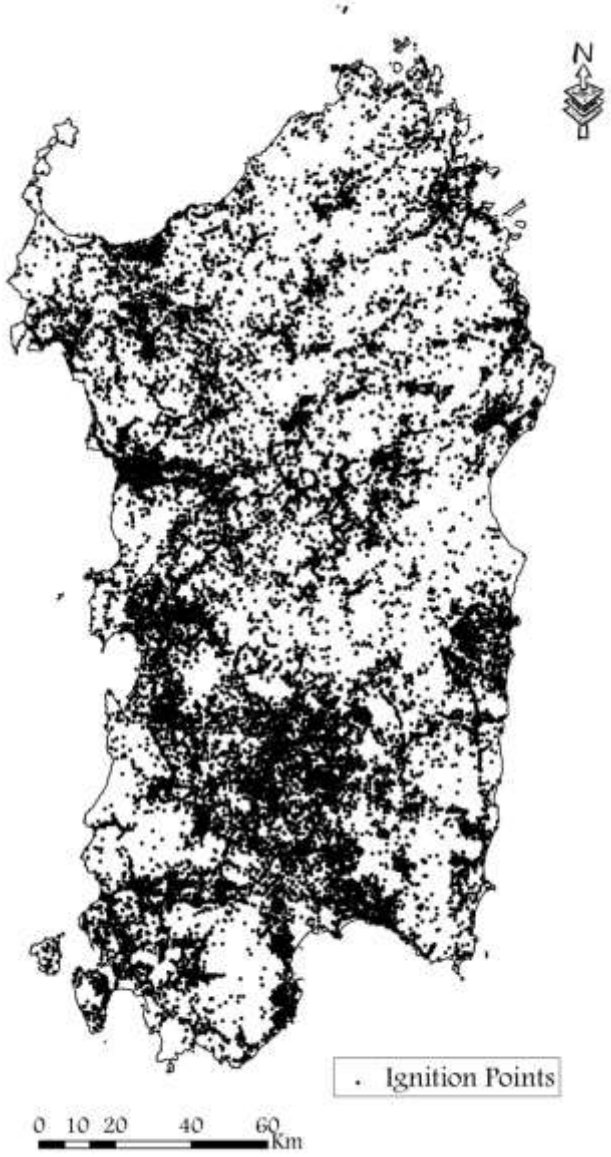
The climate is Mediterranean sub-arid, with a remarkable water deficit from half May until half September.

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

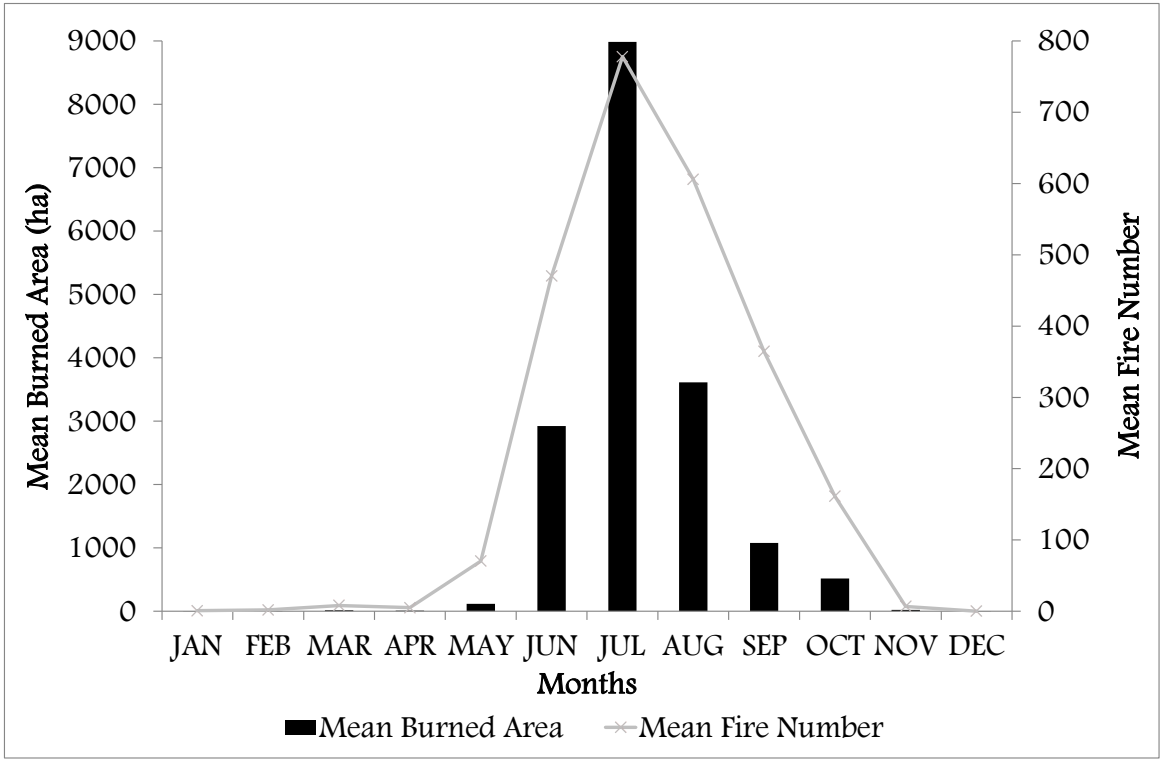
The Sardinia mean annual temperature along the coast line is approximately 17 °C, mostly in the southern part of the island.

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

Sardinian fires



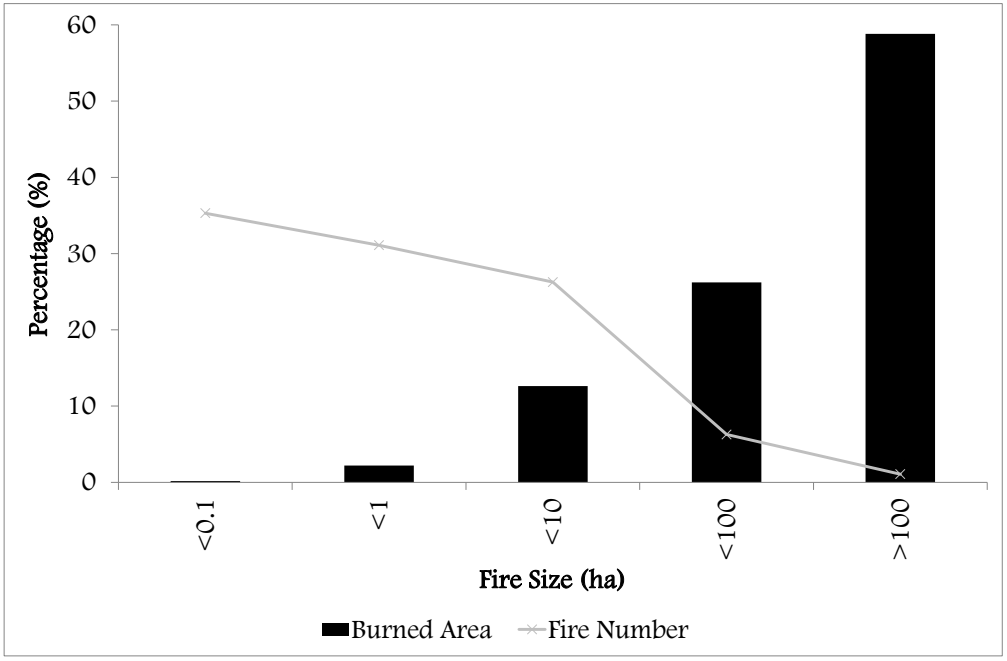
Fire ignitions (1995-2009)



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

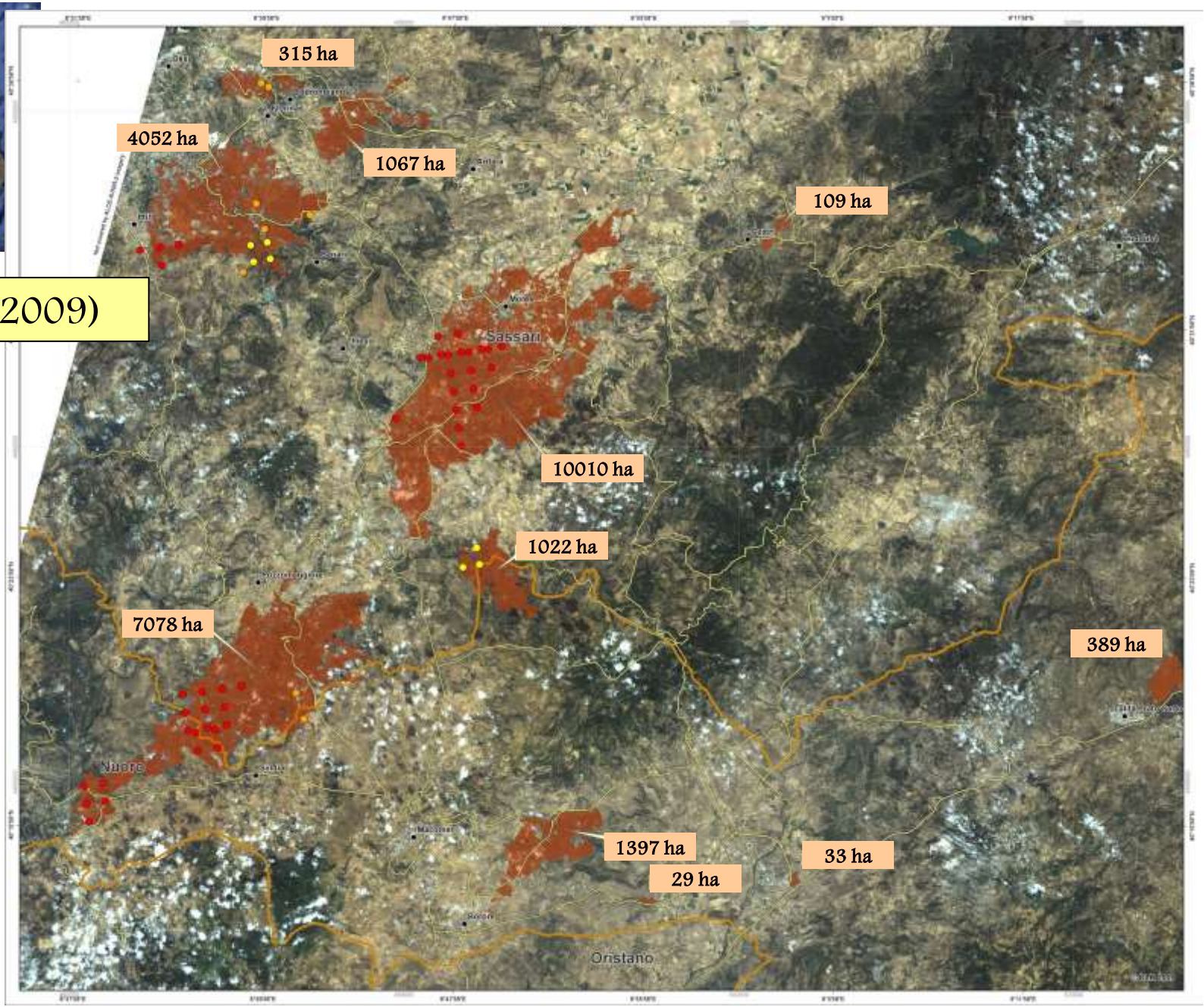
Sardinian fires



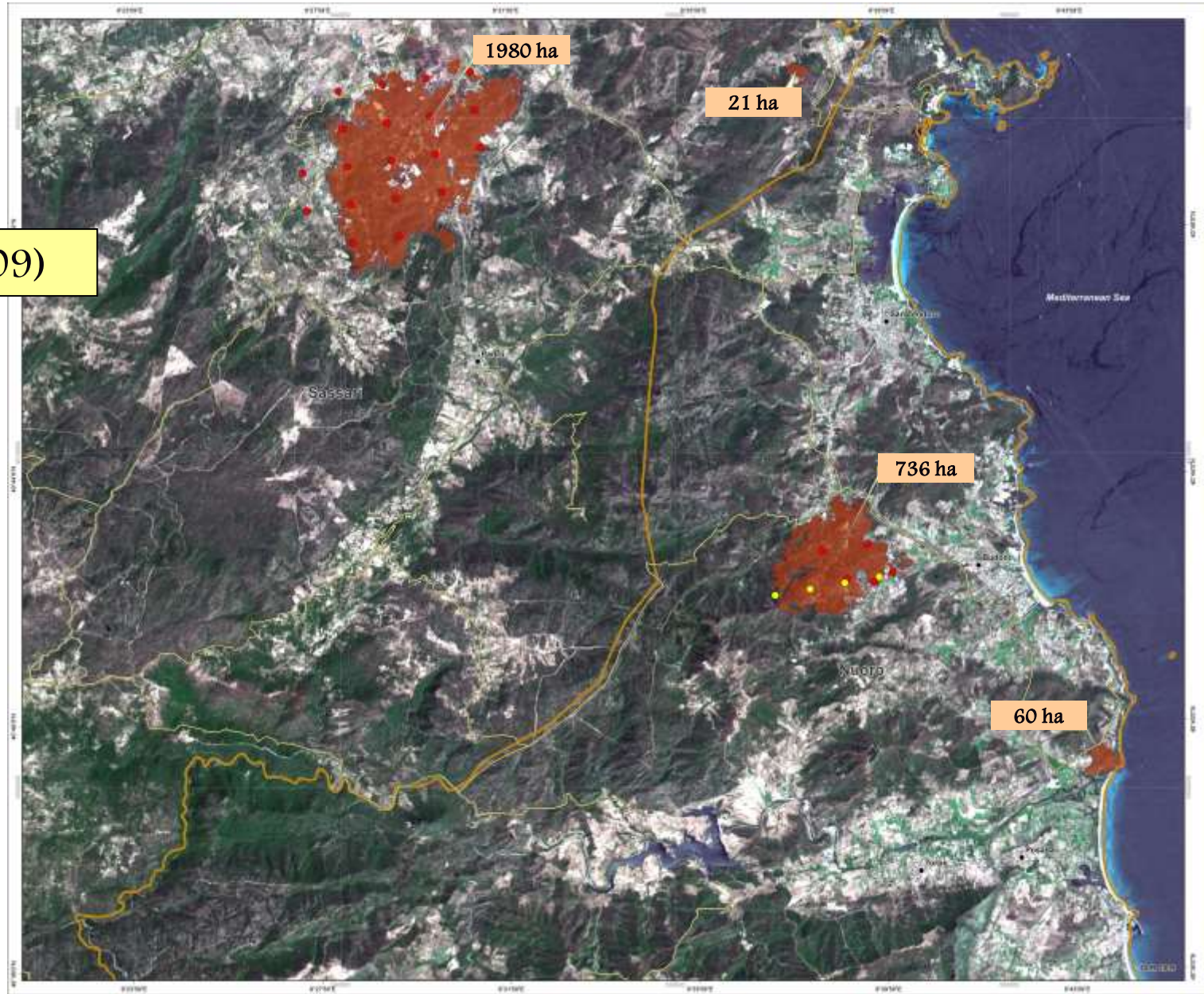
Wildfires with size > 100 ha account for only 2% of fires, but for about 60% of the total area burned in the island

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; huge damages to flora, fauna, urban areas, anthropic values, and farms

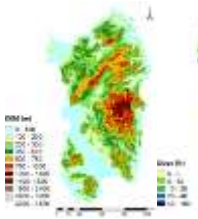
Fire Exposure Assessment in Sardinia

Many diverse values at risk!

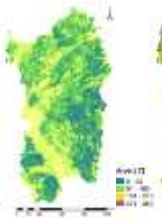
Spatial Input Data | **Historical Fire Database** | **Weather**

INPUTS

Topography



Elevation



Slope

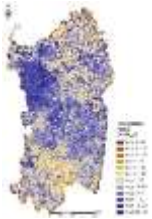
Aspect

Fuels

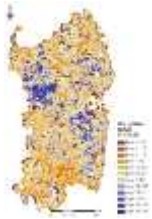
1980-1994

1995-2009

Ignition patterns and locations

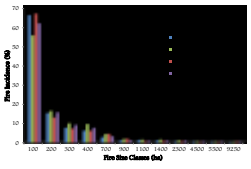


1980-1994



1995-2009

Burn period



Wind

Fuel moisture

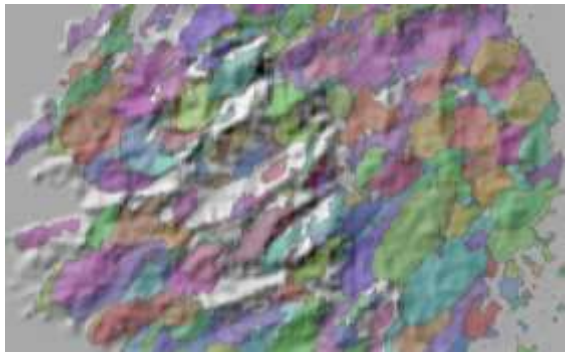
Study period	(1980-1994)	(1995-2009)
Wind Speed (km h^{-1})	29.0	29.0
Temperature (°C)	36.0	36.5
Rain (mm)	0	0
1 hr dead FM (%)	7	7
10 hr dead FM (%)	9	9
100 hr dead FM (%)	11	11
Wind Direction (°)	315 (35%); 225 (22%); 270 (19%); other (24%)	315 (40%); 225 (24%); 270 (14%); other (22%)

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

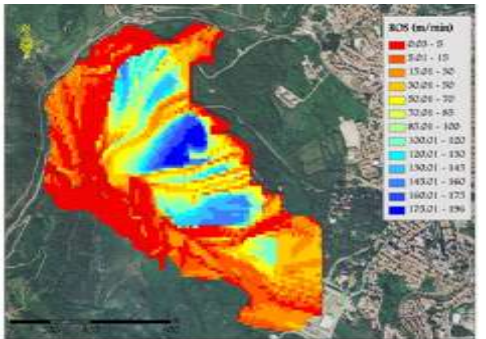
Burn Probability (BP)

Conditional Flame Length (CFL)

Fire Size (FS)

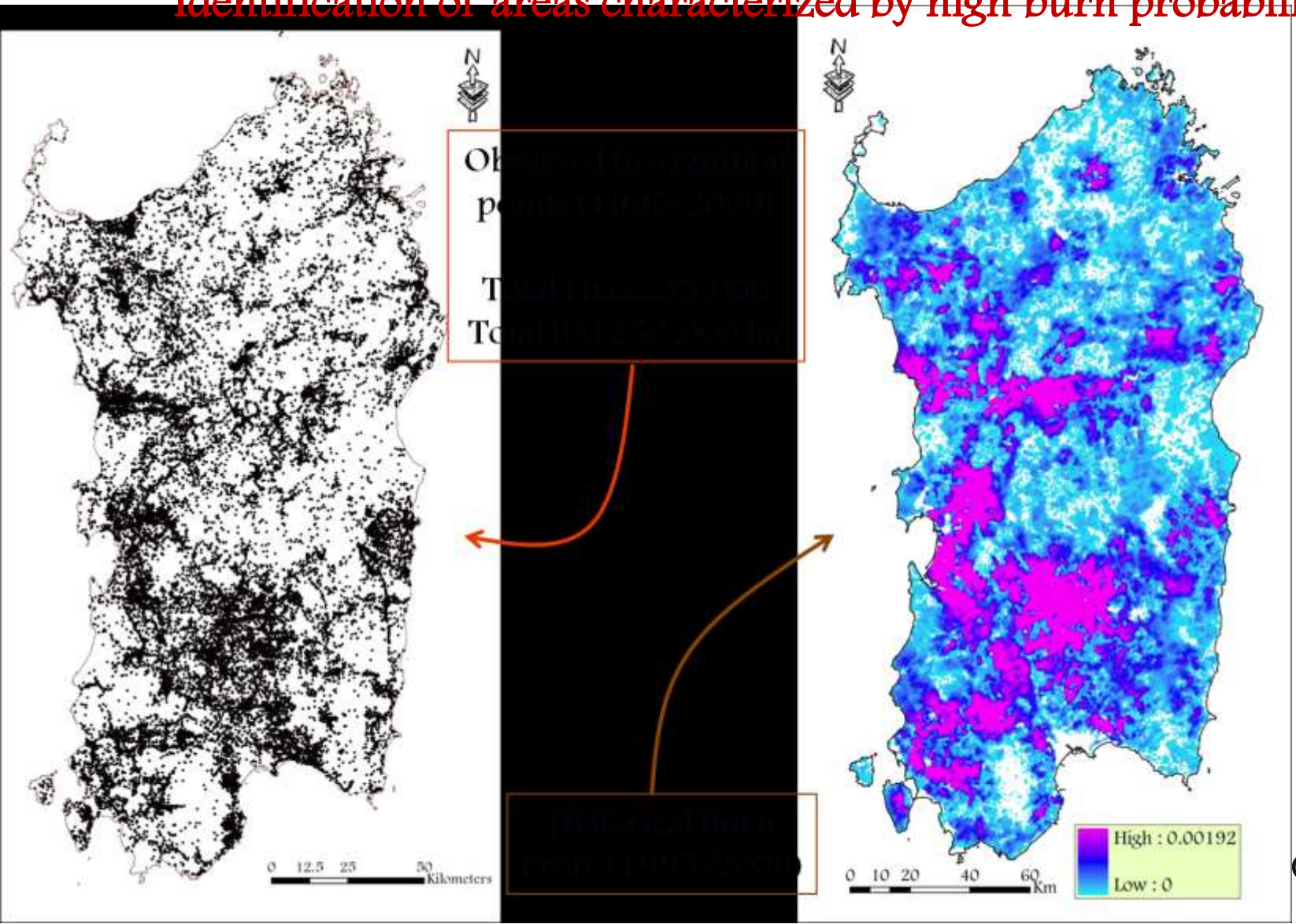
Fire Potential Index (FPI) and more…

(Salis et al. 2013 - IJWF)



Fire Exposure Assessment in Sardinia

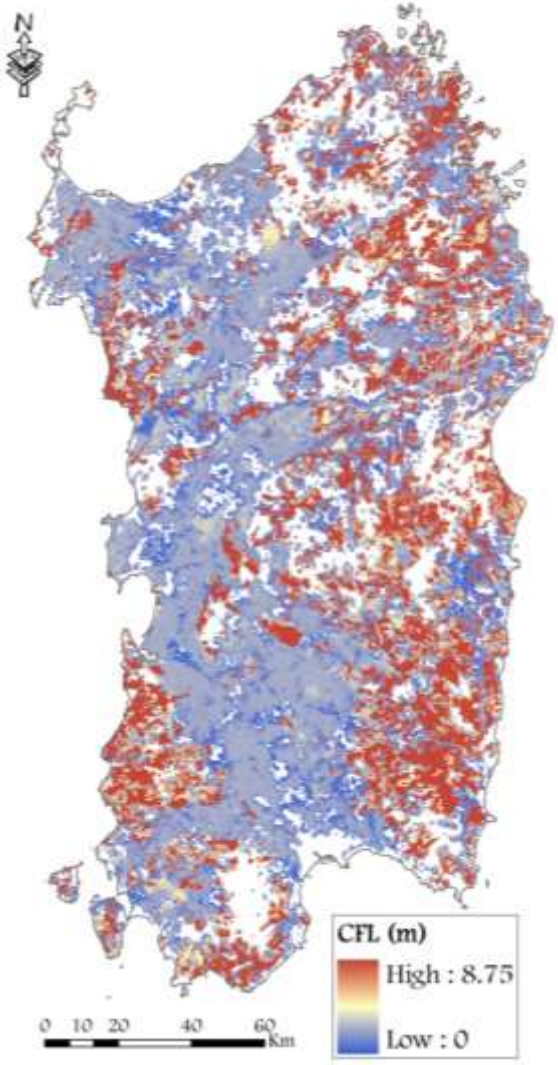
Identification of areas characterized by high burn probability

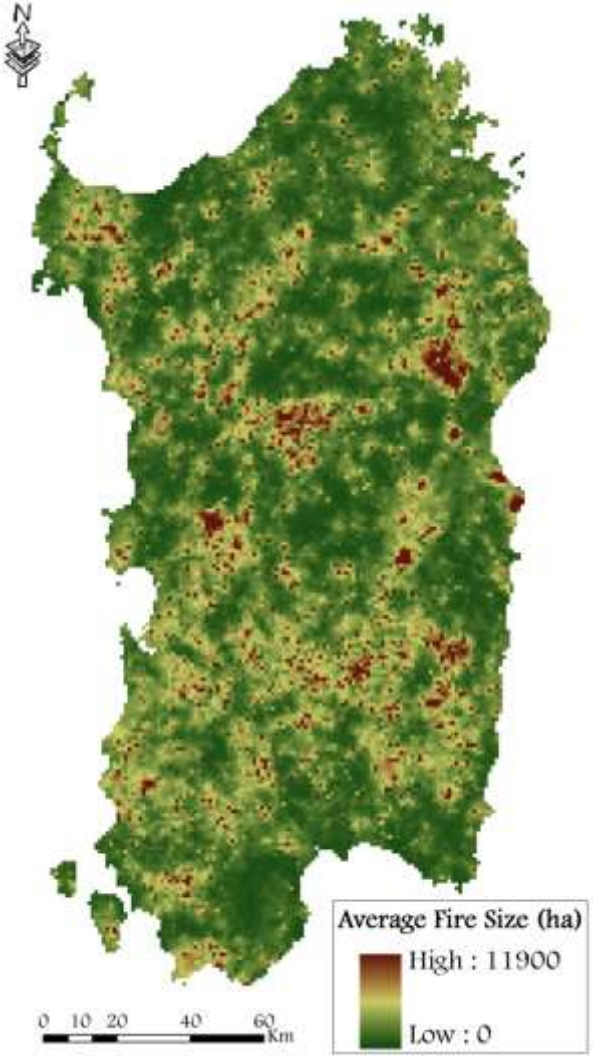


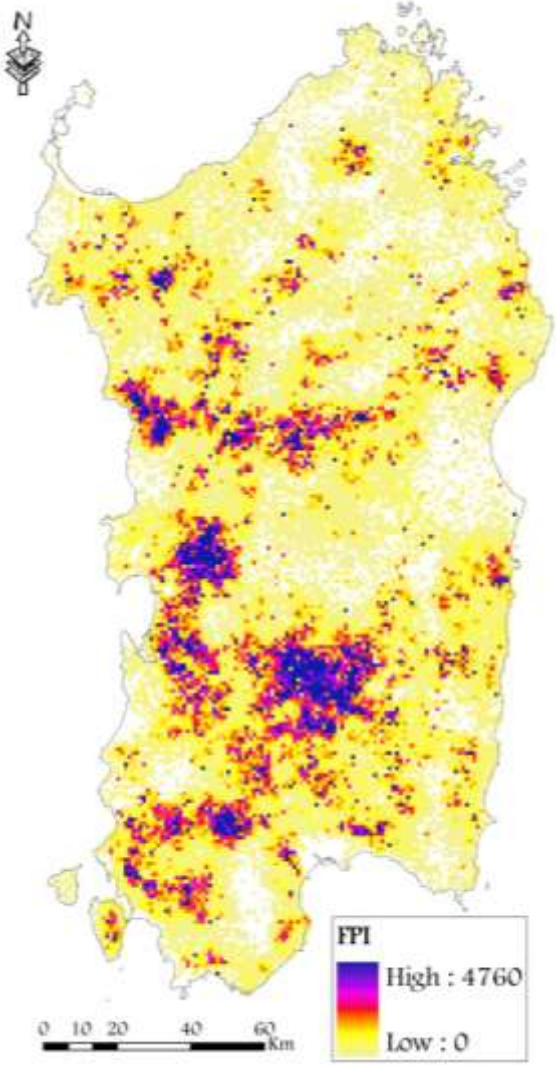
(Salis et al. 2013 - IJWF)

Fire Exposure Assessment in Sardinia

Identification of areas characterized by high fire exposure



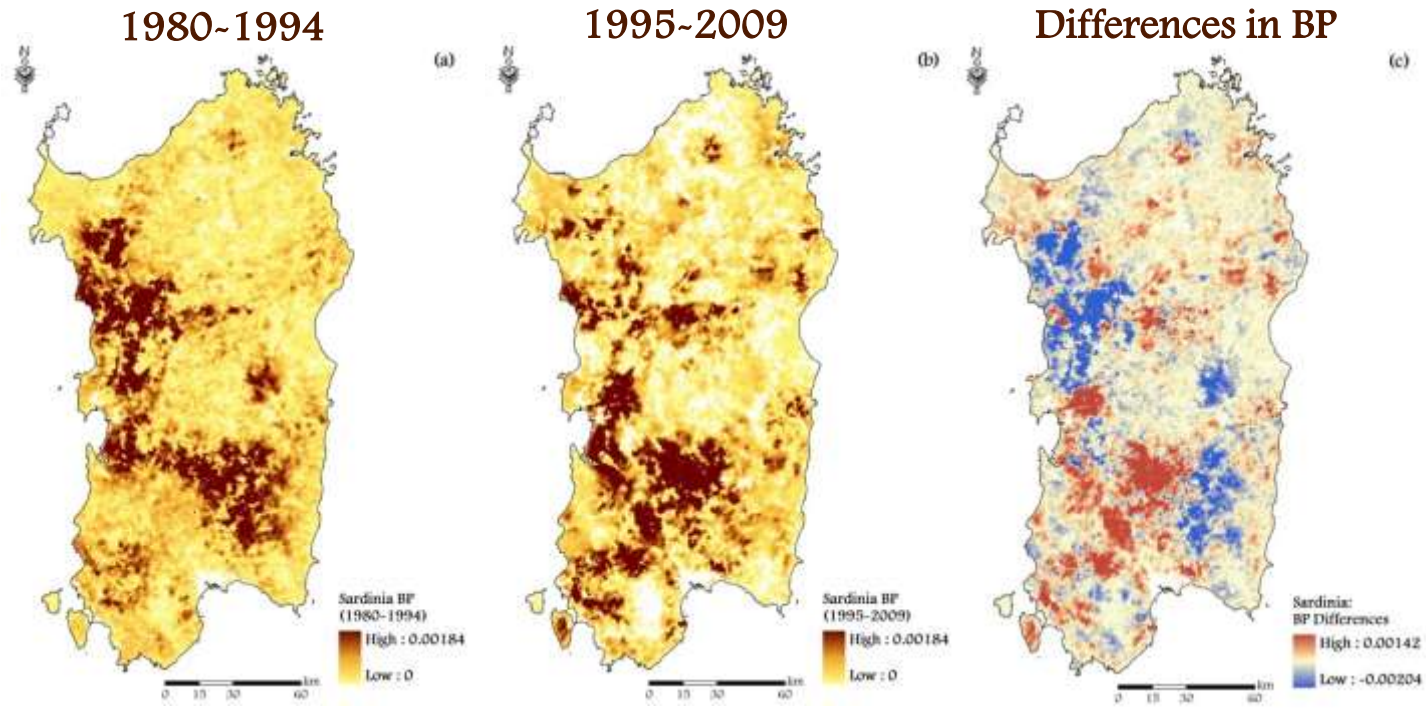


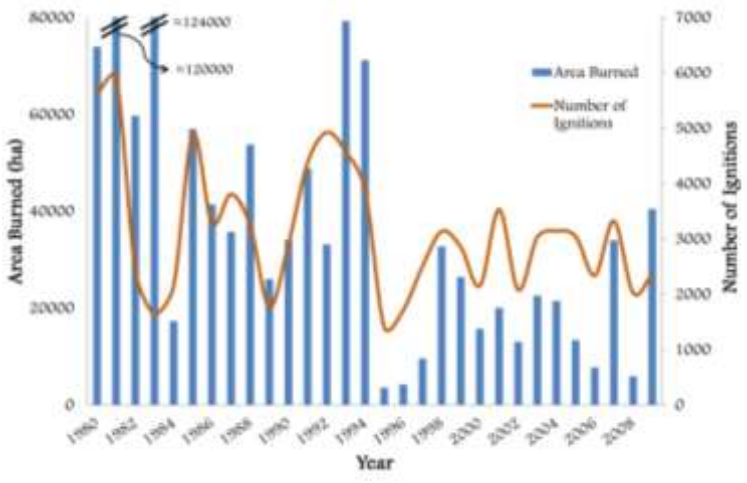


(Salis et al. 2013 - IJWF)

Fire Exposure Assessment in Sardinia

Fire exposure varies depending on the study period





Strong reduction in FN and AB

Increase of fire ignitions nearby urban interfaces and agricultural areas

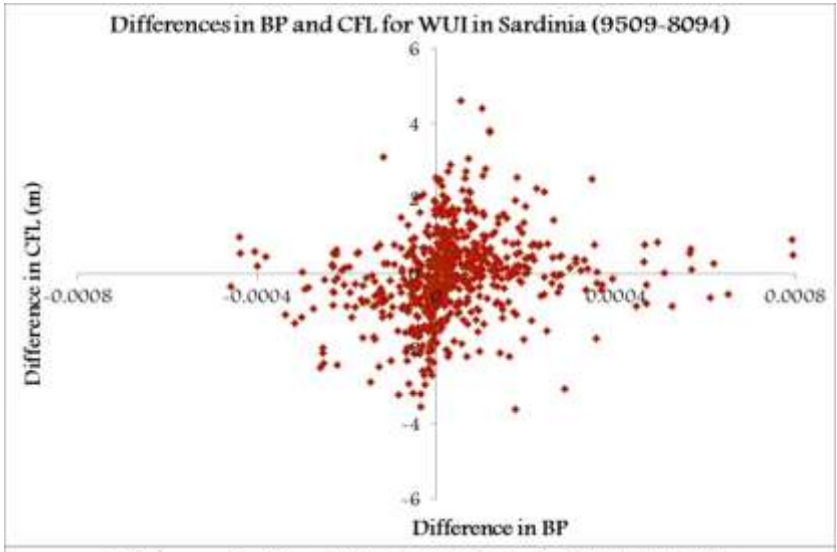
Anticipation of the fire seasons of about 15 days

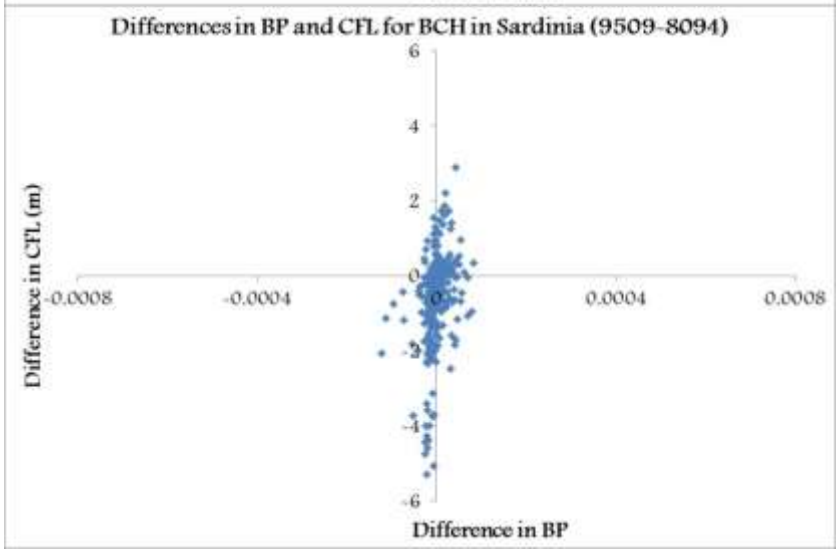
Improvements in fire suppression capacity

(Salis et al. 2014 - NHAZ)

Fire Exposure Assessment in Sardinia

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

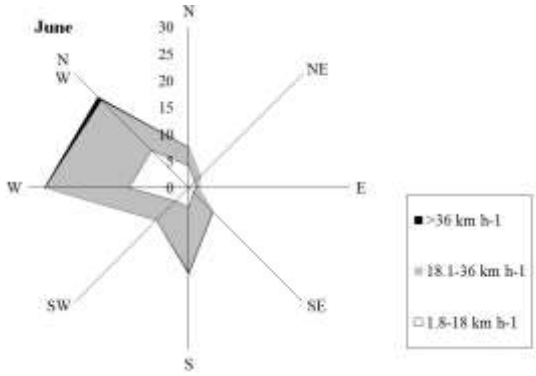


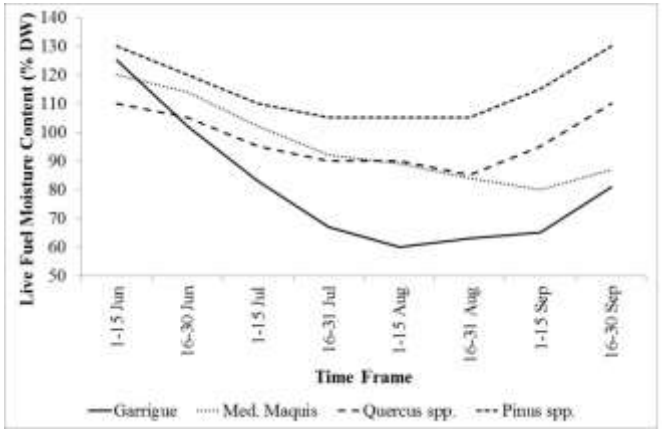


Fire Exposure Assessment in Sardinia

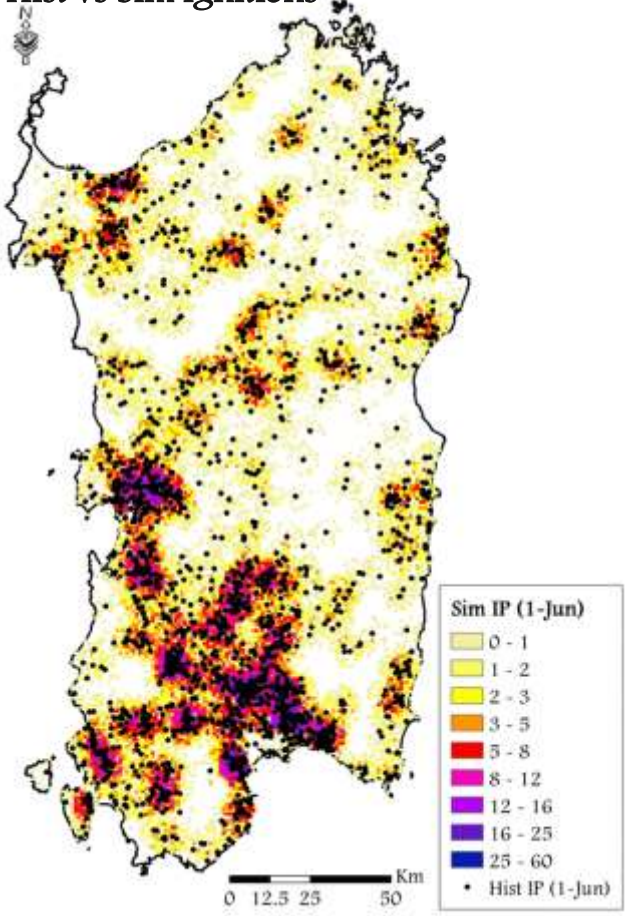
Fire exposure varies depending on the time of the year

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

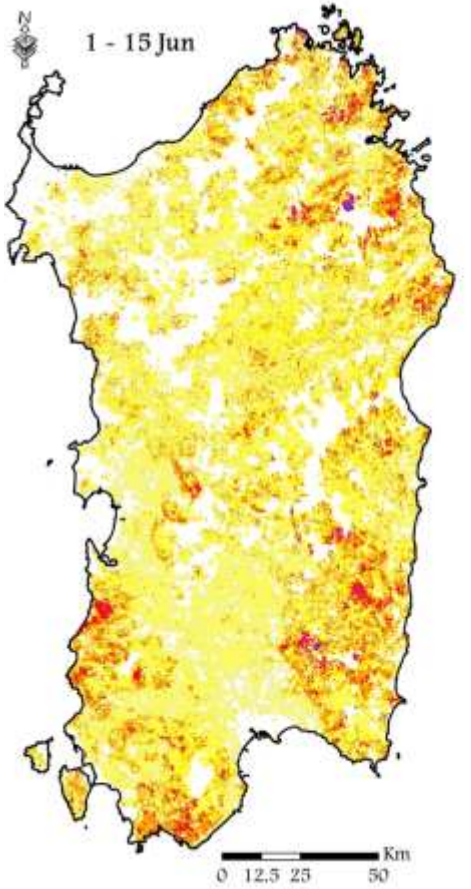




Hist vs Sim Ignitions

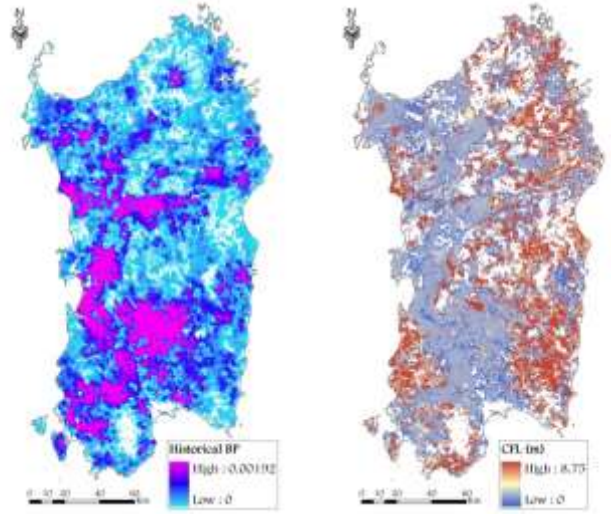


Flame Length



(Salis et al. 2014 - EMAS)

Landscape Management: Risk Assessment vs. Mitigation



Assessment

Map risk factors and how they contribute to overall fire exposure or risk

Mitigation

Changing the expected output (risk):

a) Reducing wildfire probability $P(f_i)$

b) Reducing wildfire intensity f_i

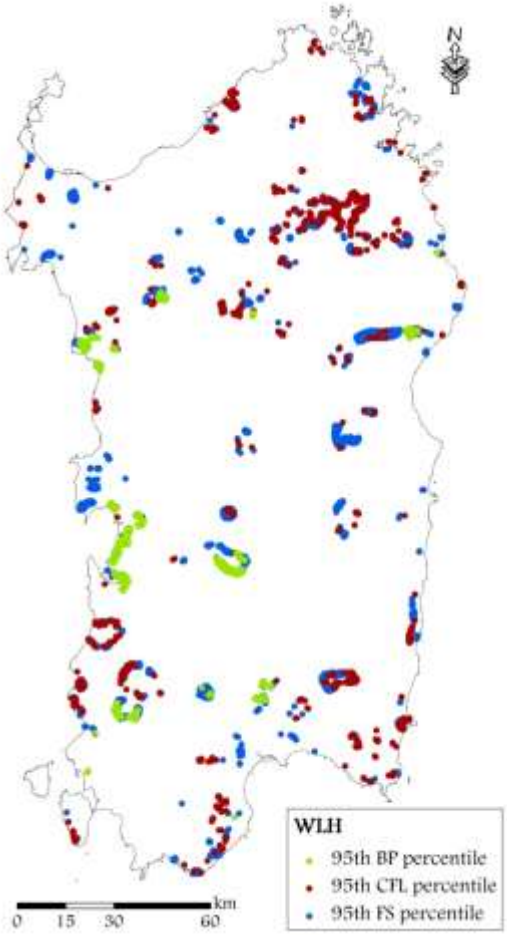
c) Reducing the landscape response or susceptibility

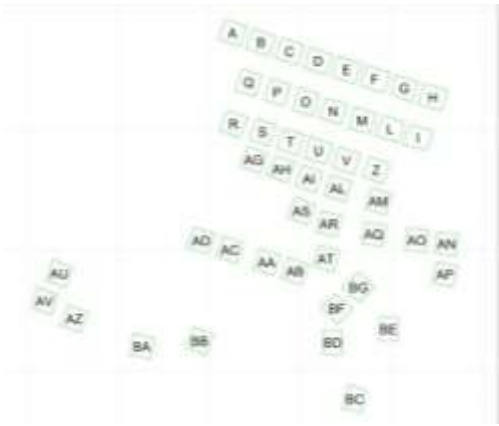
Landscape Management: Risk Assessment vs. Mitigation

Why not just mitigate without an assessment?

Assessment permits to:

- Identify the risk drivers
- Identify leverage points
- Evaluate treatment strategies
- Evaluate cost effectiveness
- Prioritize activities

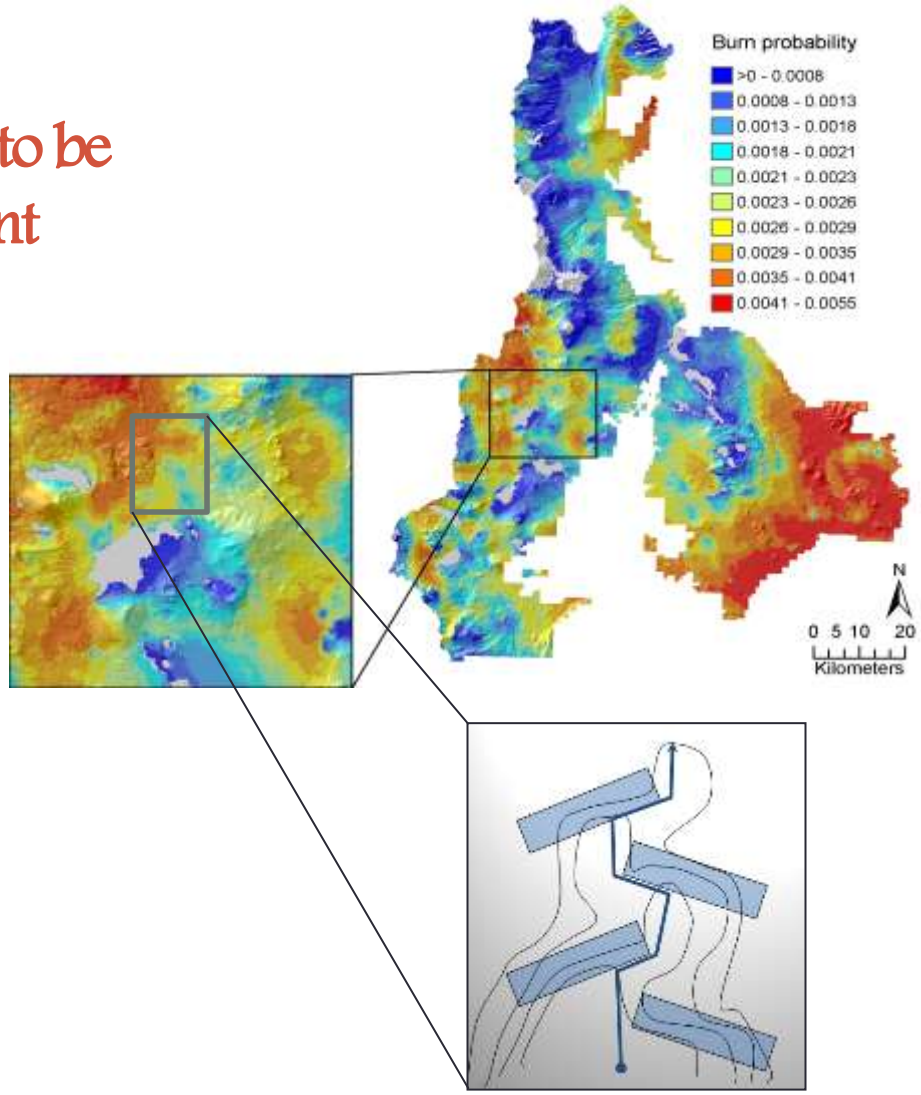




Fuel Management Strategies

Fuel management strategies need to be informed by fire risk assessment

- Prioritizing fuel management activities requires understanding:
  - Spatial variation in risk
  - Risk transmission
  - Potential to manage
- Designing stand and landscape projects requires understanding how proposed management reduces risk



(Ager 2013)

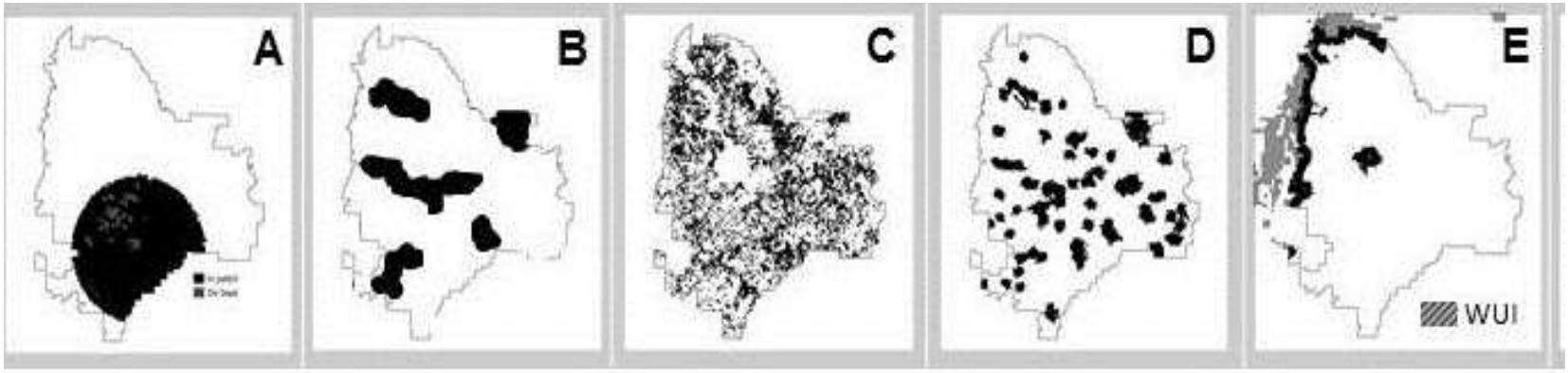
Fuel Treatment Effects on Growth

Fuel Management Strategies

There are many fuel management strategies

Restoration of fire adapted forests → Protection from fire

Low hazard fire containers	Strategic Restoration	Treatment optimization model	Dispersed fuel breaks	Focused defensible fuel breaks

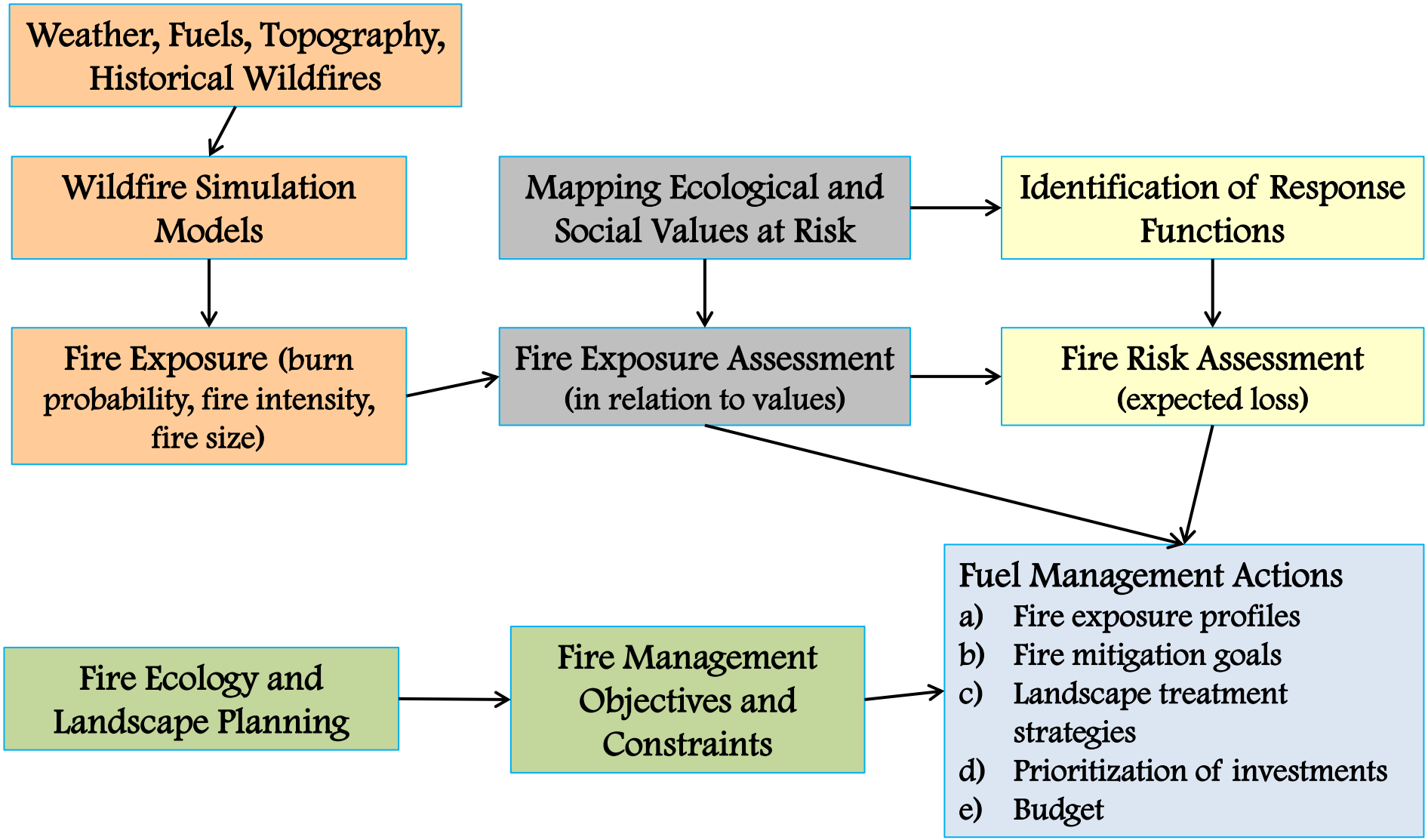


Black areas represent treatment units

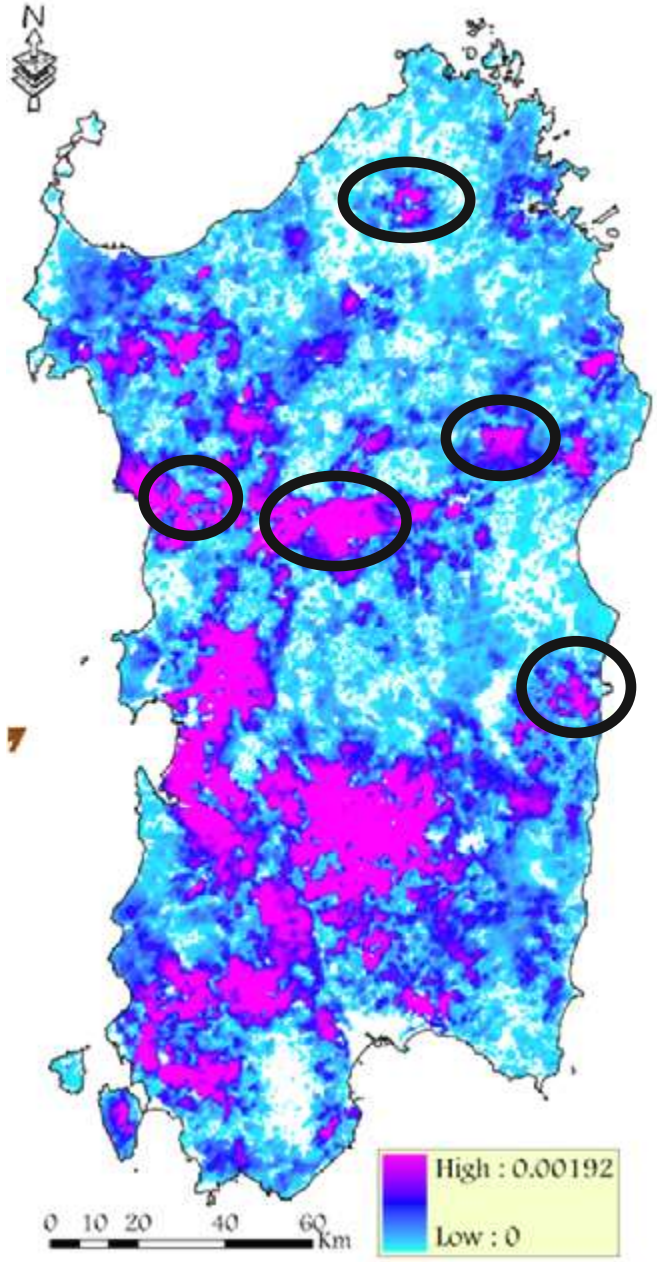
(Ager 2013)

Fuel Management Strategies

Wildfire Risk Assessment and Fuel Management Framework



Fuel Management Strategies



1) Selection of different case studies

2) Analysis of the issues at local/landscape scale

3) Definition and test of the best strategies depending on environmental and socio-cultural conditions

4) Application of fuel management strategies in the field & preliminary modeling studies

Fire Risk Management in Sardinia

(Salis et al., in prep.)

SIMULATIONS

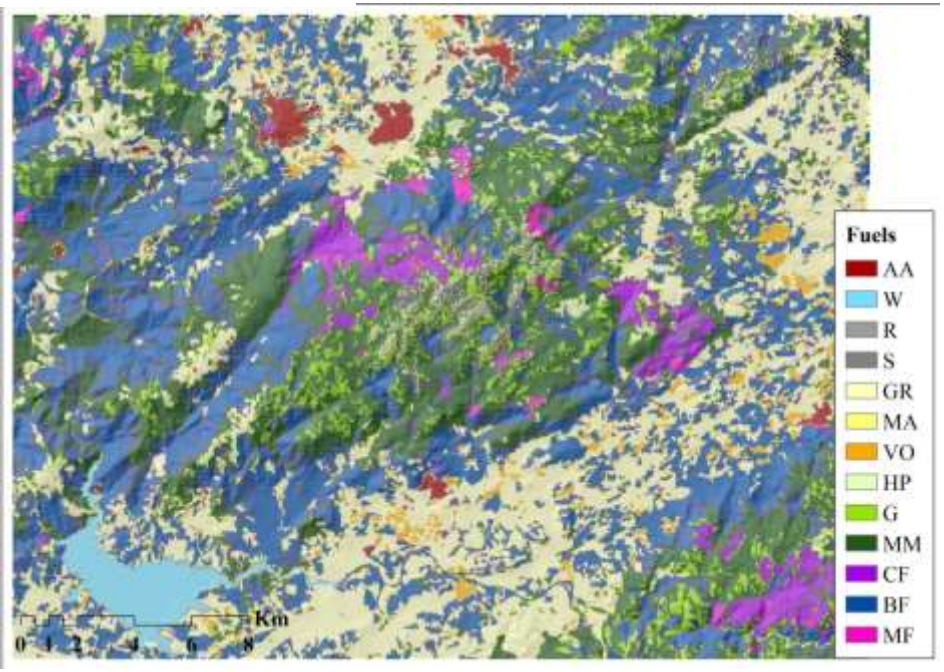
Randig, MTT algorithm (Finney 2002)

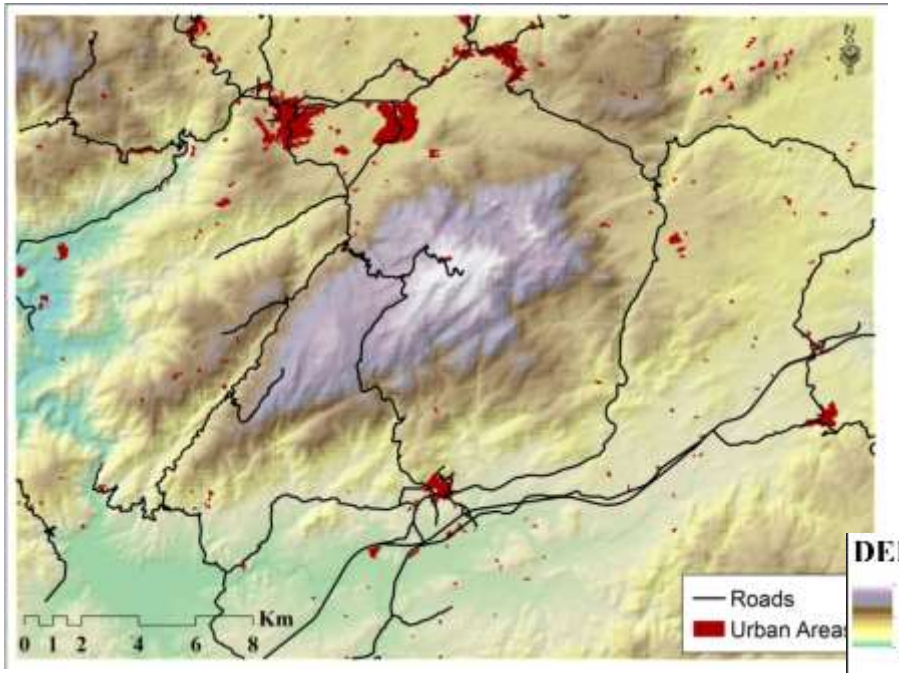
Data resolution: 50 m over 700 km2 (North Sardinia)

Simulation of 25,000 fires, randomly sampling from historical conditions

Diverse treatment strategies and intensities tested, with the goal of minimizing BP and FPI

Treatment strategies created in GIS environment coupling spatial values and fire exposure outputs

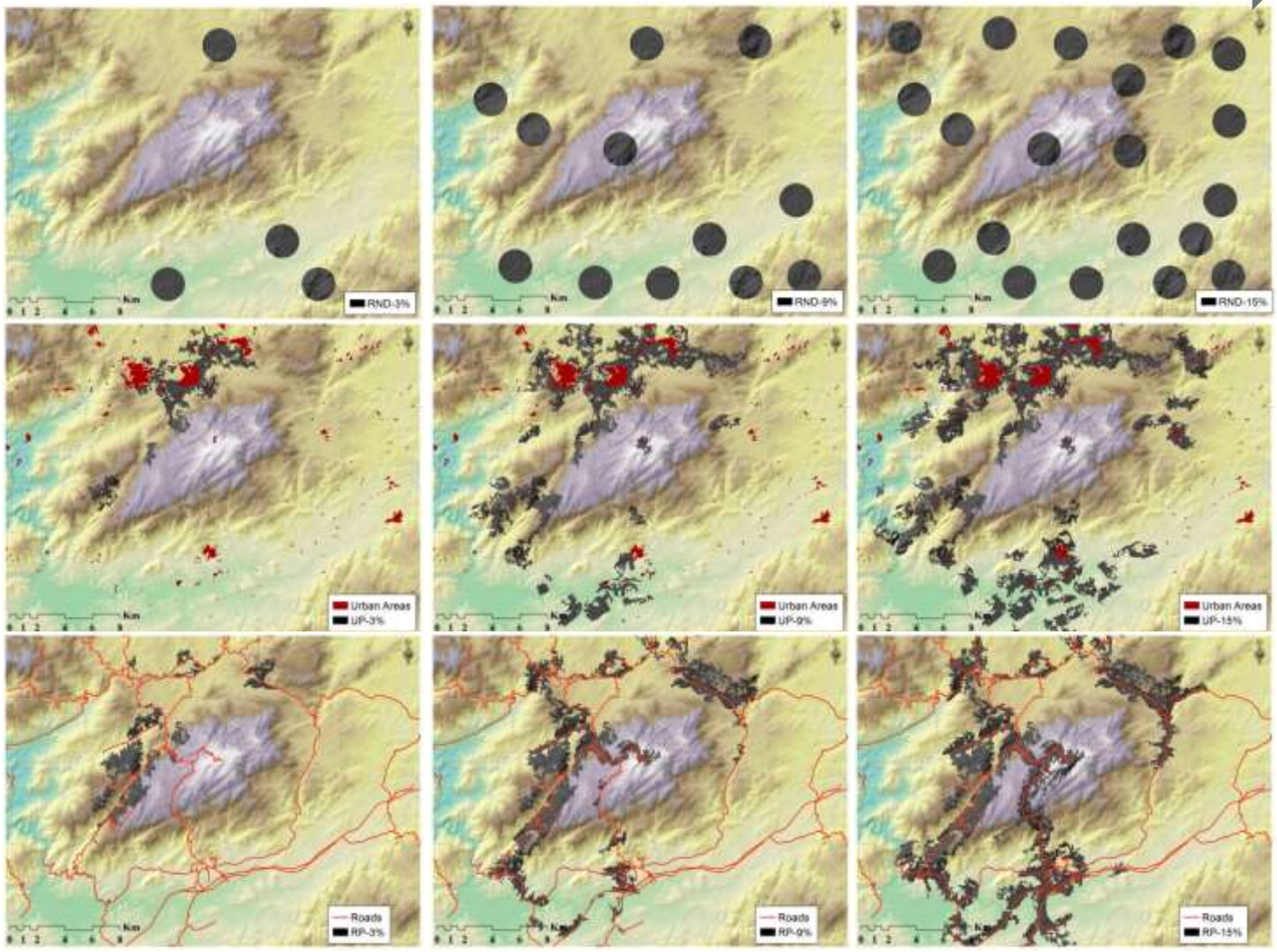




Fire Risk Management in Sardinia

(Salis et al., in prep.)

Area Treated, Cost, Risk reduction, Teams, Time



No Priorities: Random Areas

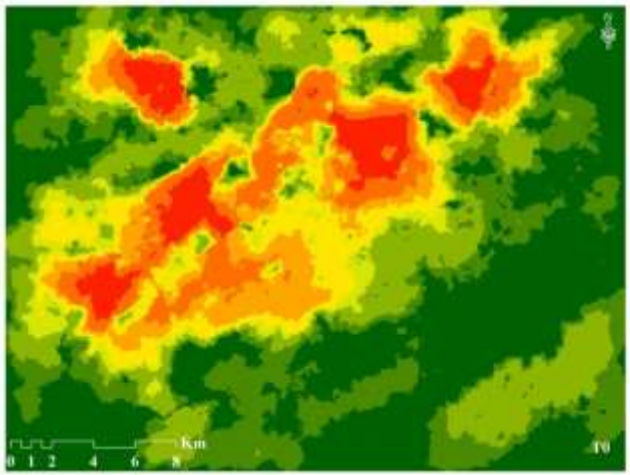
Priority: Urban Protection

Priority: Road Protection

Fire Risk Management in Sardinia

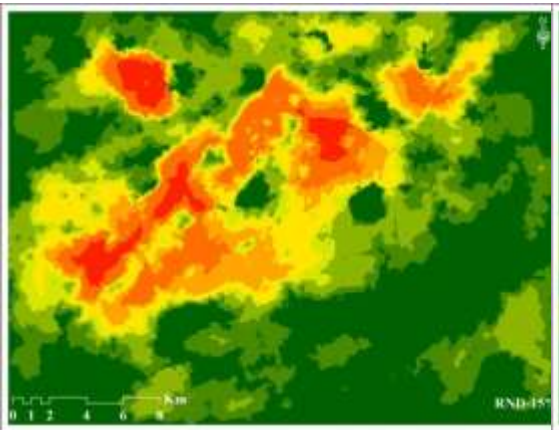
(Salis et al., in prep.)

No Treatment

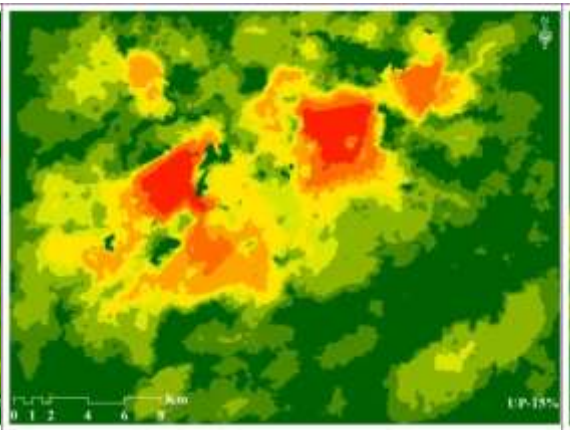


Spatial variation in burn probability (BP) with the diverse fuel treatment strategies

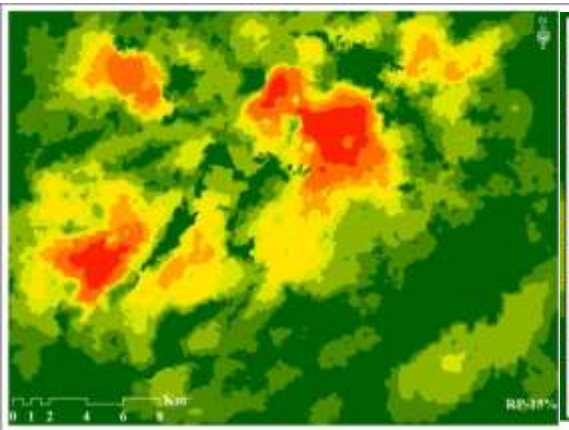
Random



Urban Protection



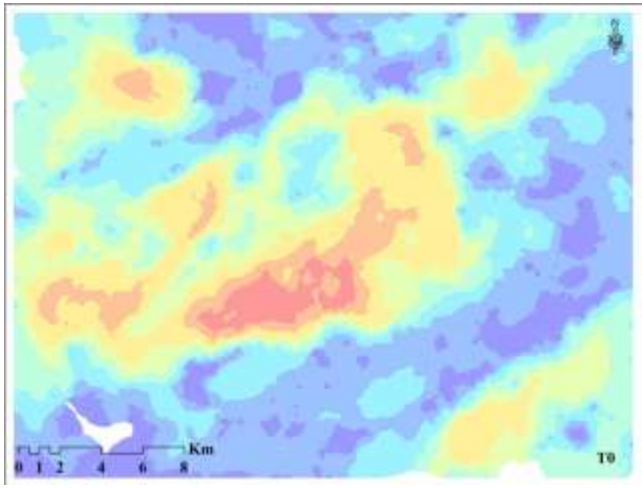
Road Protection



Fire Risk Management in Sardinia

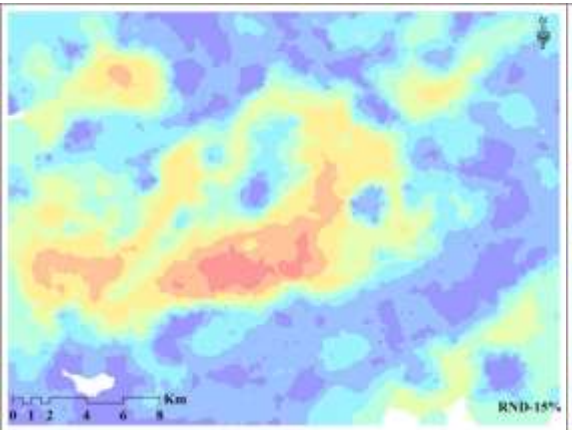
(Salis et al., in prep.)

No Treatment

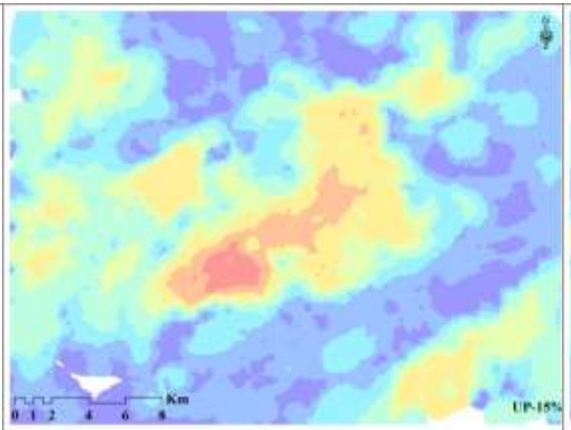


Spatial variation in fire size (FS) with the diverse fuel treatment strategies

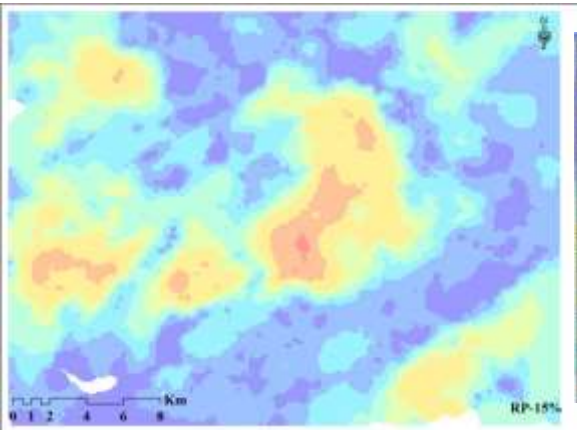
Random

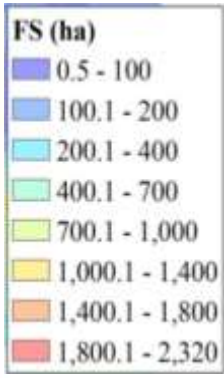


Urban Protection



Road Protection

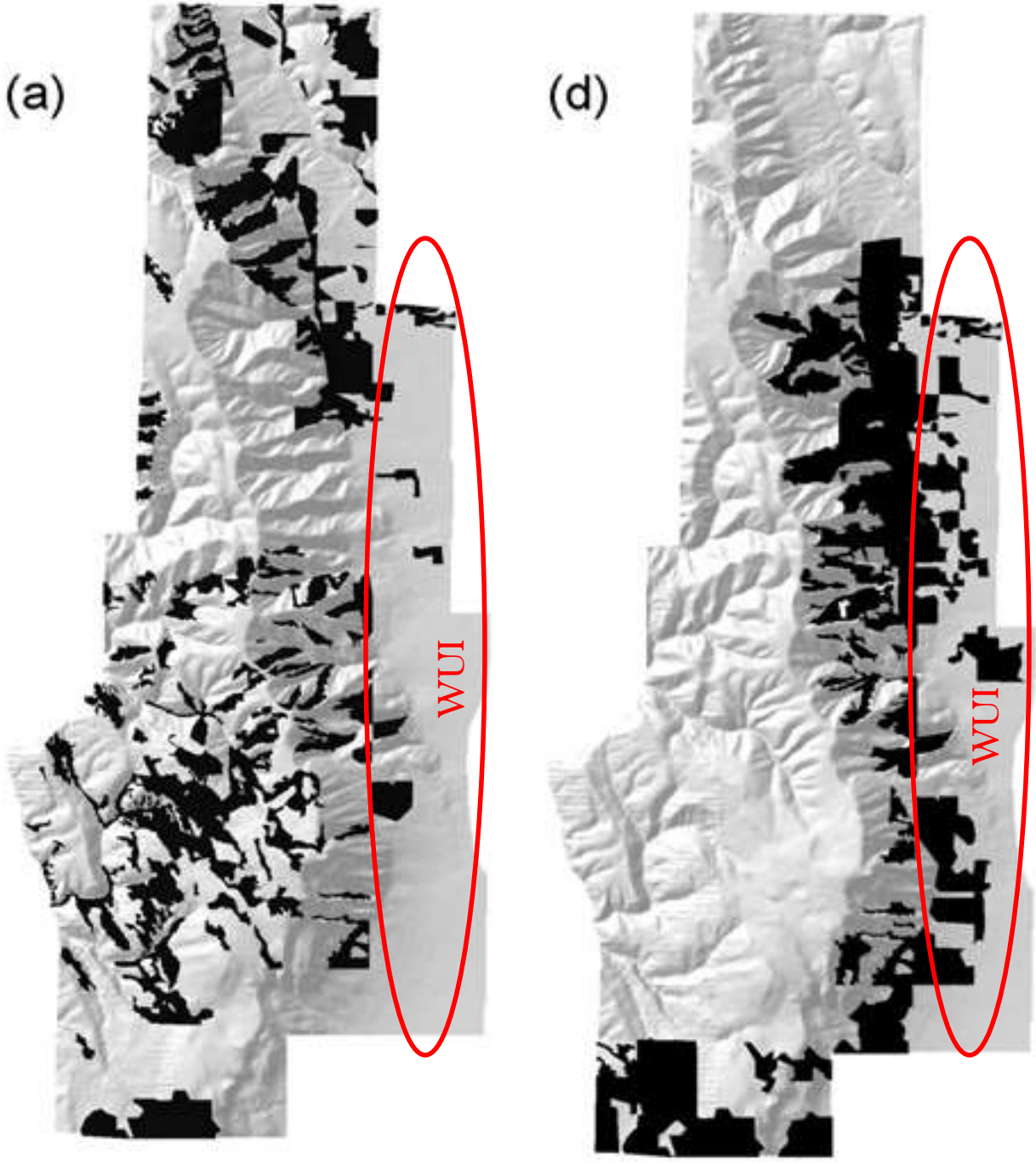




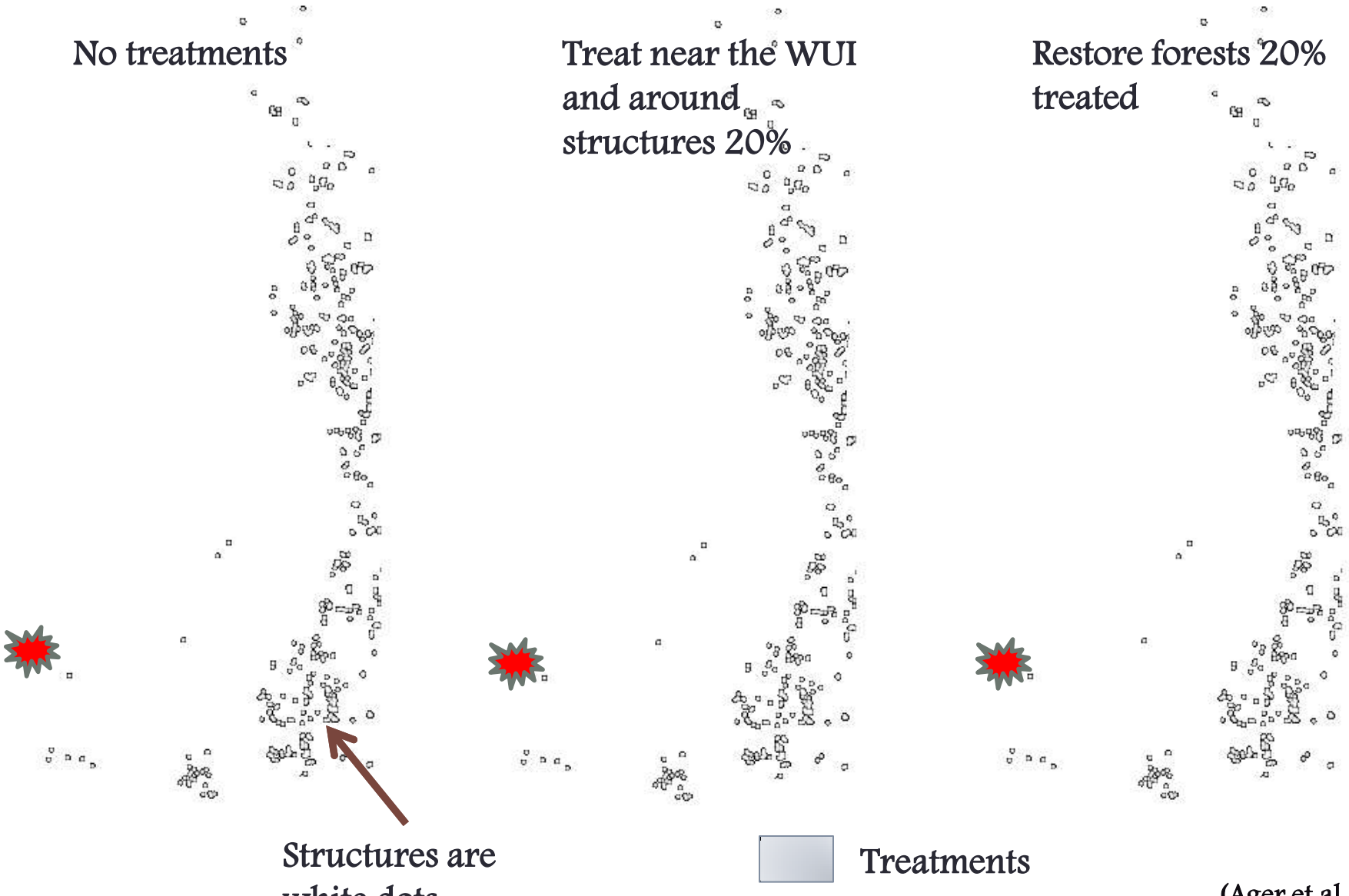
- Two alternative strategies: Treat for fire resiliency in the upland forest, or treat around homes
- Which is better?
- How do we test this?

(Ager et al., 2011)

Black areas represent treatment units



Fire Risk Management in Sardinia



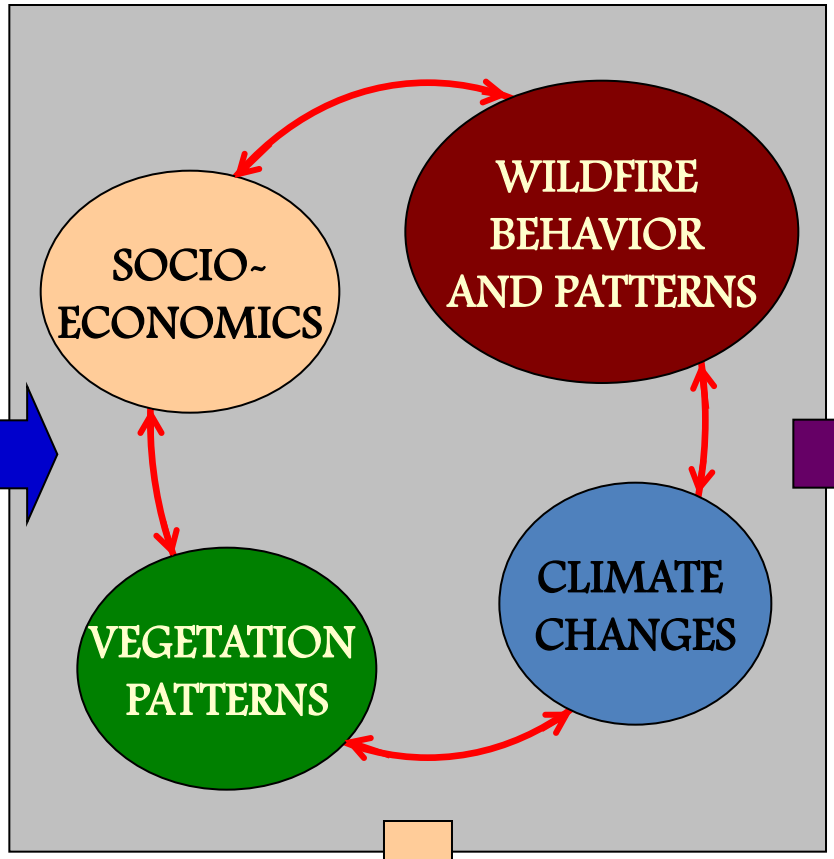
(Ager et al., 2011)

WILDLAND FIRE REGIME (PAST, PRESENT AND FUTURE)

INPUT FACTORS

- Climate and Weather
- Topography
- Fuels, Land Use and Forest Management
- Socio-Economics
- Policy Decisions
- Education, Awareness and Training

PROCESSES



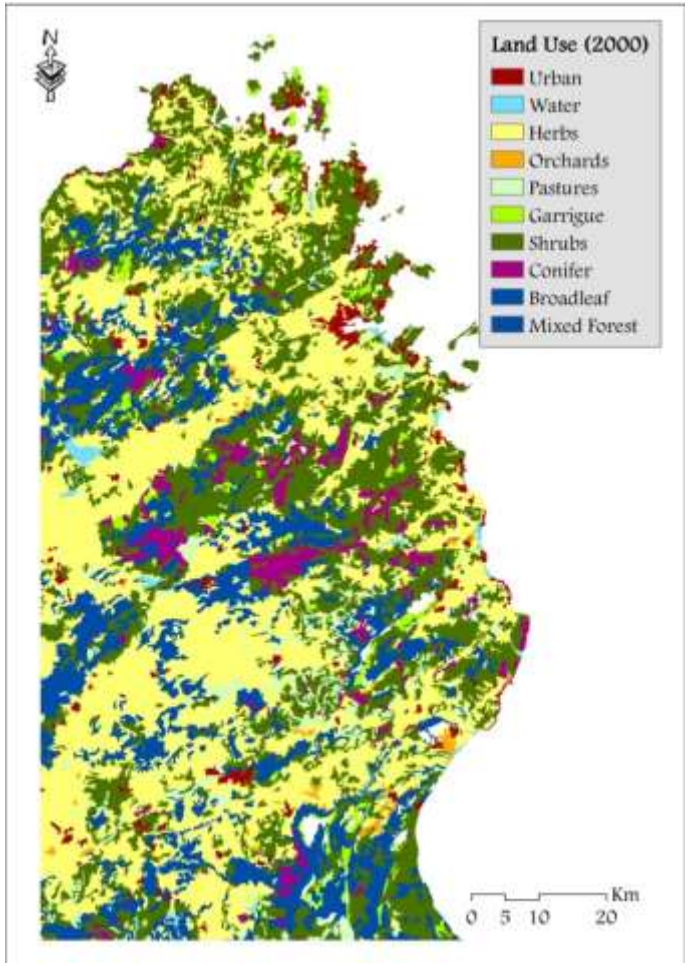
MAIN TOPICS

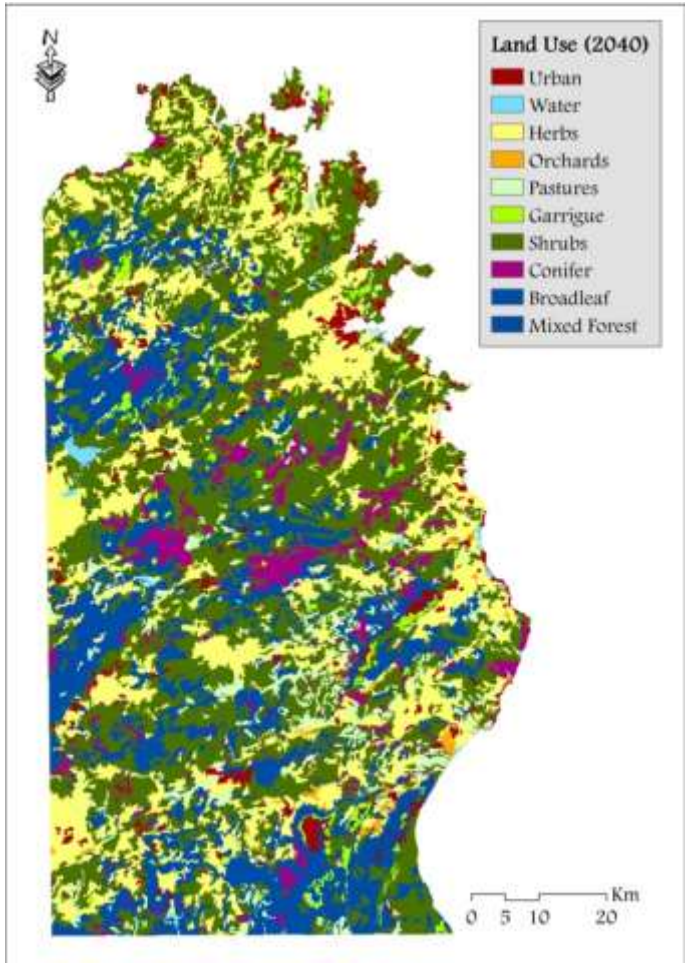
- Risk, Spread and Behavior Analysis
- Extreme Fire Events
- Human Safety
- Wildland Urban Interfaces
- Fire Management
- Fire Suppression
- New Fire Prone Areas
- Fire Smoke Emissions

WILDLAND FIRES UNDER CHANGING ENVIRONMENTAL CONDITIONS

Future Issues for Fire Management

Land use changes (2000 vs 2040)





(A1B, FUME Project IAFENT-CMCC)

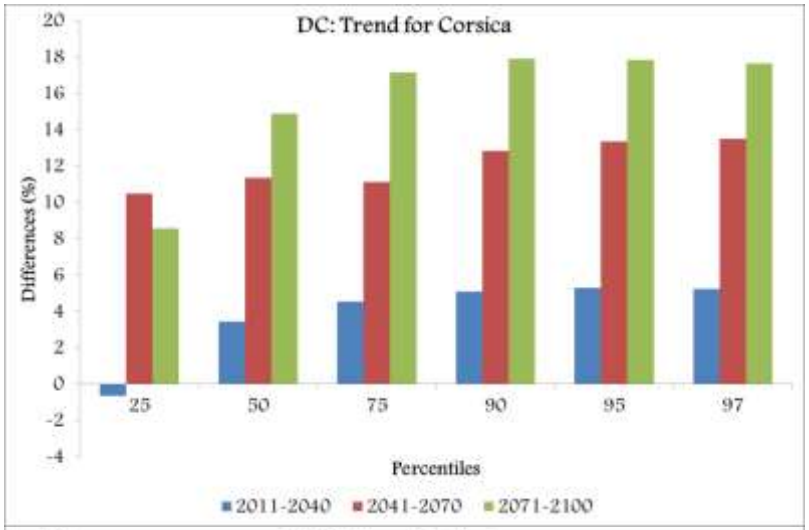
Future land use maps predict an increase in forest areas, shrublands and urban areas, along with a reduction of agricultural areas and pastures, for both Sardinia and Corsica

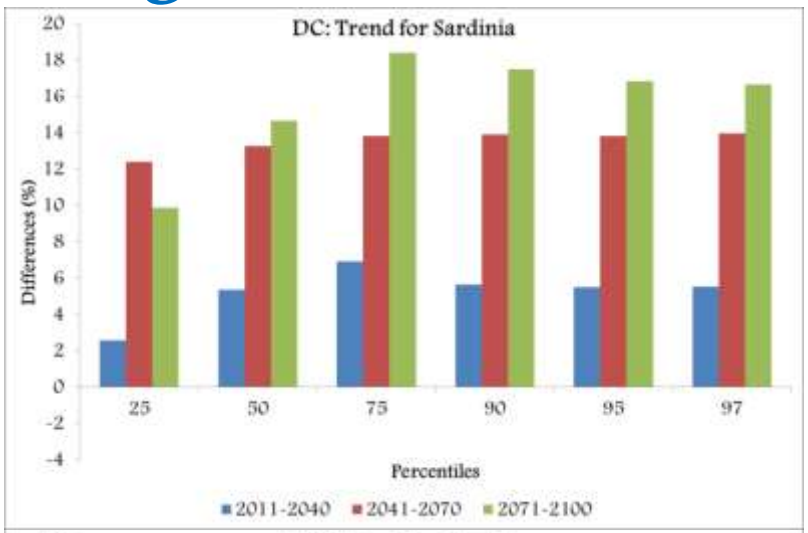
Future Issues for Fire Management

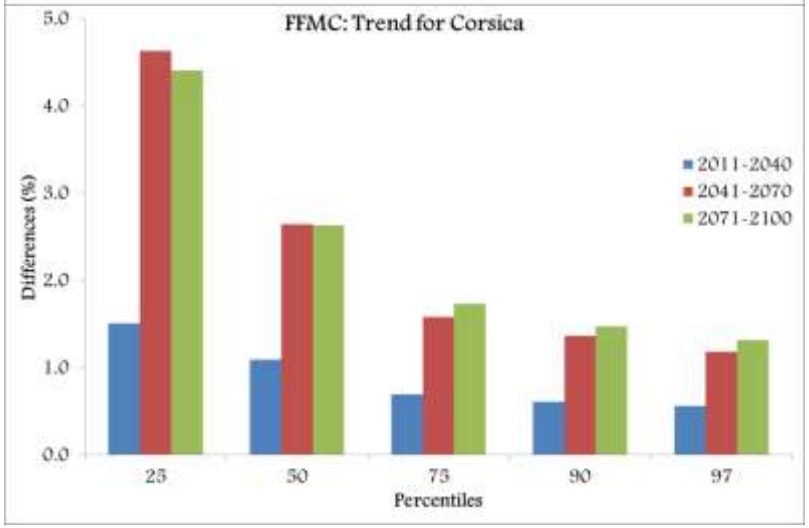
Fuel Moisture

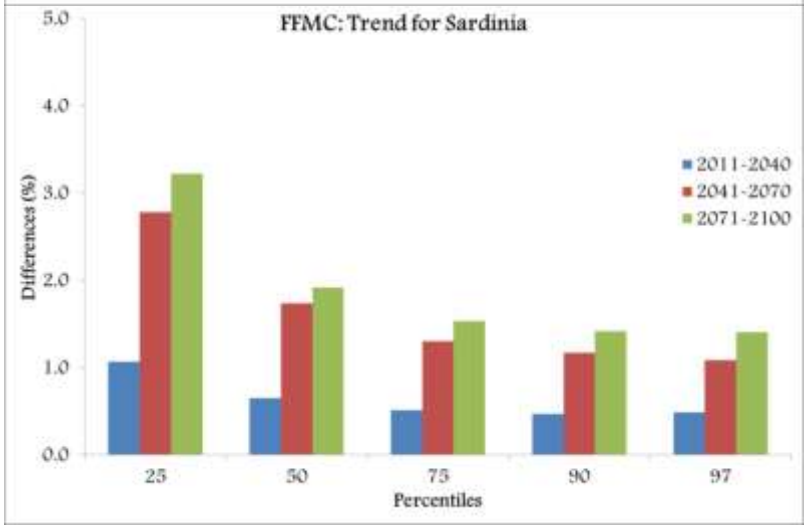
DC

FFMC









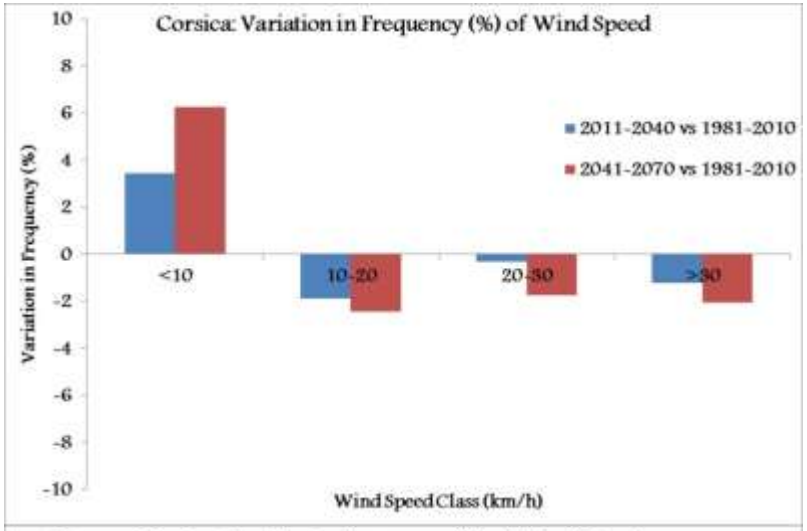
Corsica

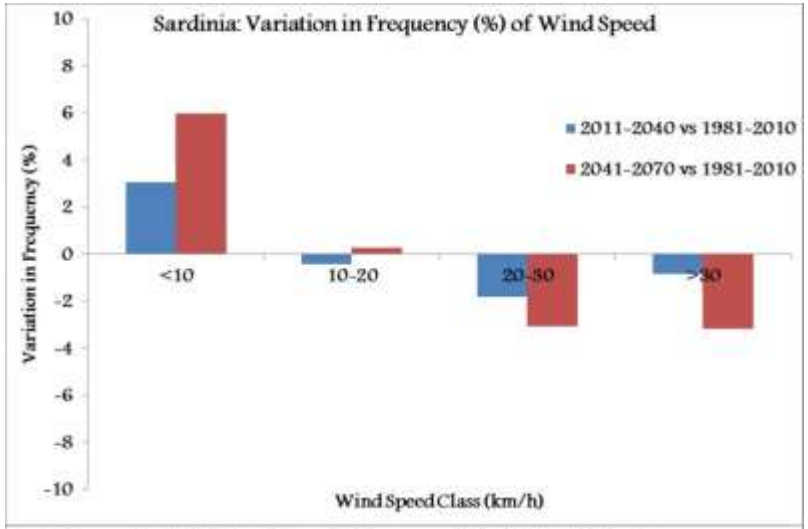
Sardinia

It is likely that, in the future, fuel moisture of dead and live vegetation could shift towards higher dryness conditions than nowadays (A1B, FUME Project, ANS-CMCC)

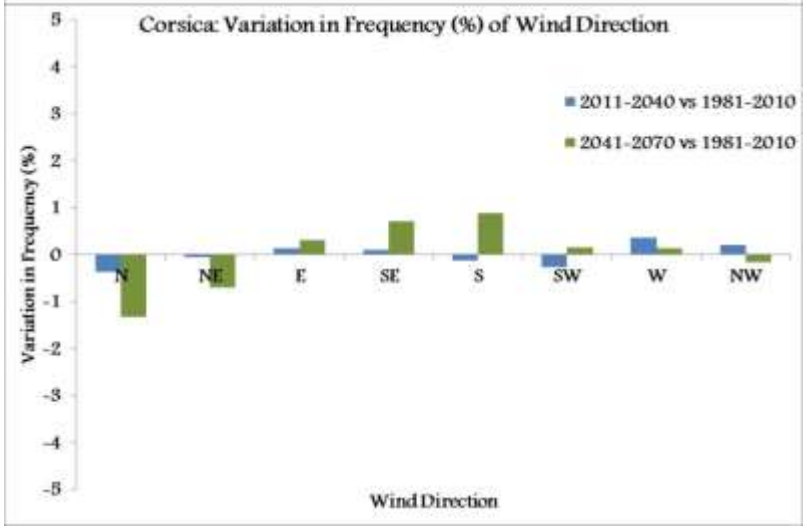
Future Issues for Fire Management

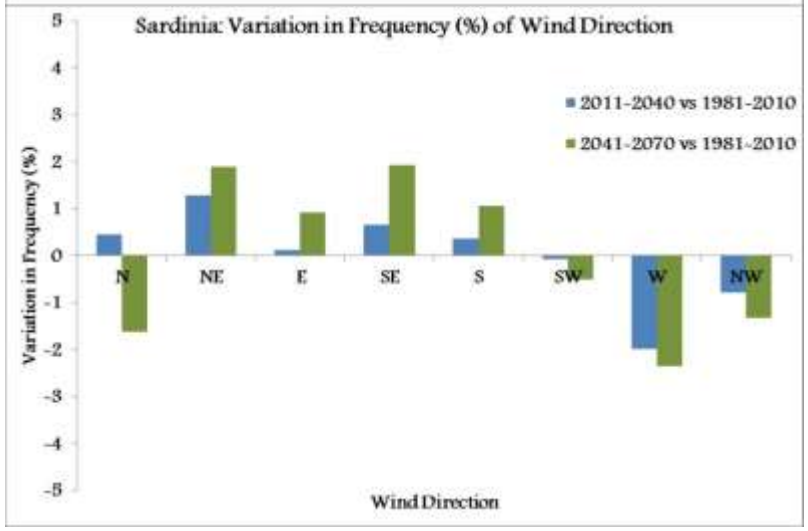
Wind Speed





Wind Dir.





Corsica

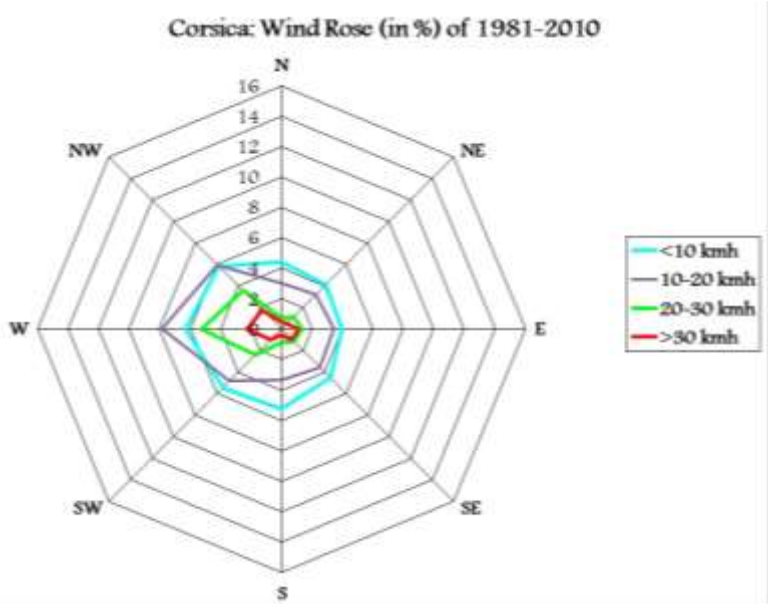
Sardinia

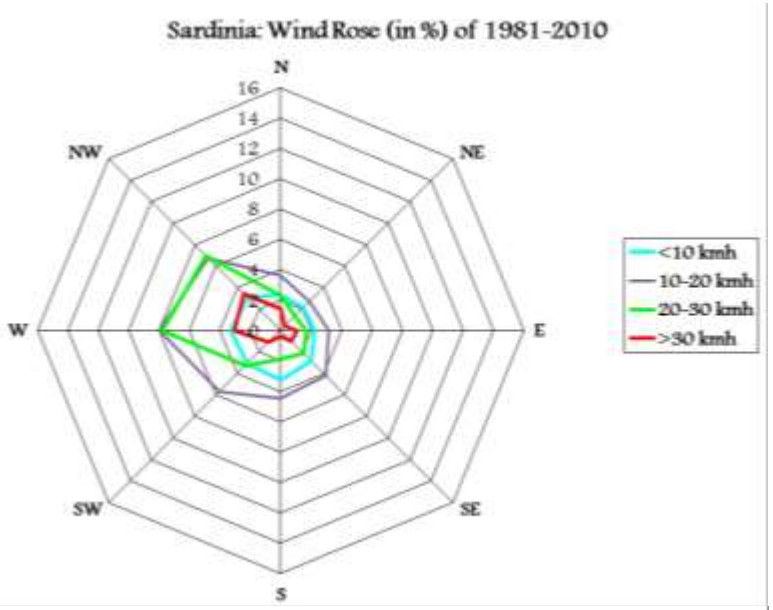
It is likely that overall wind speed will decrease in Corsica and Sardinia, along with very slight variations in wind directions

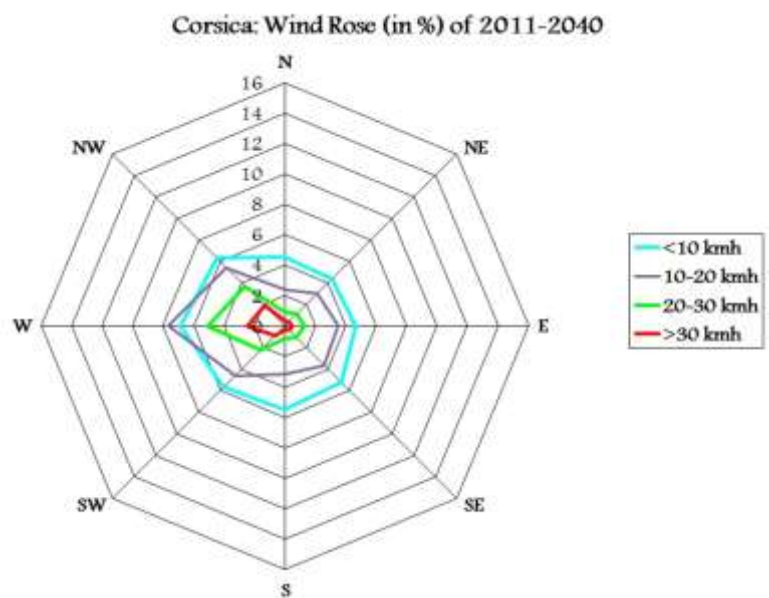
(A1B, FUME Project, ANS-CMCC)

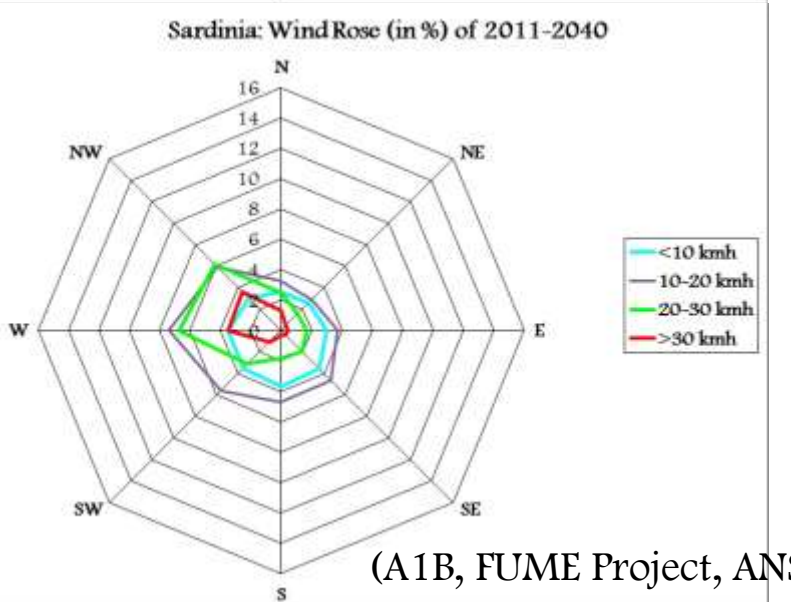
Future Issues for Fire Management

Winds





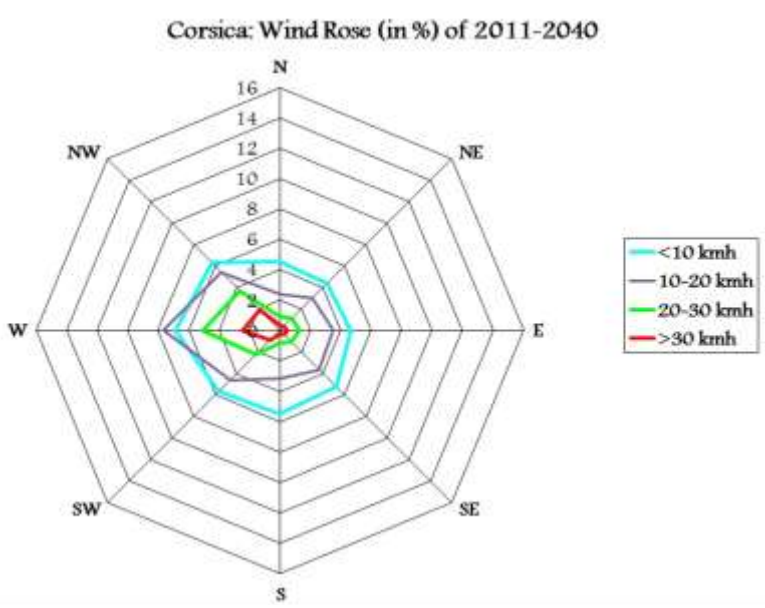


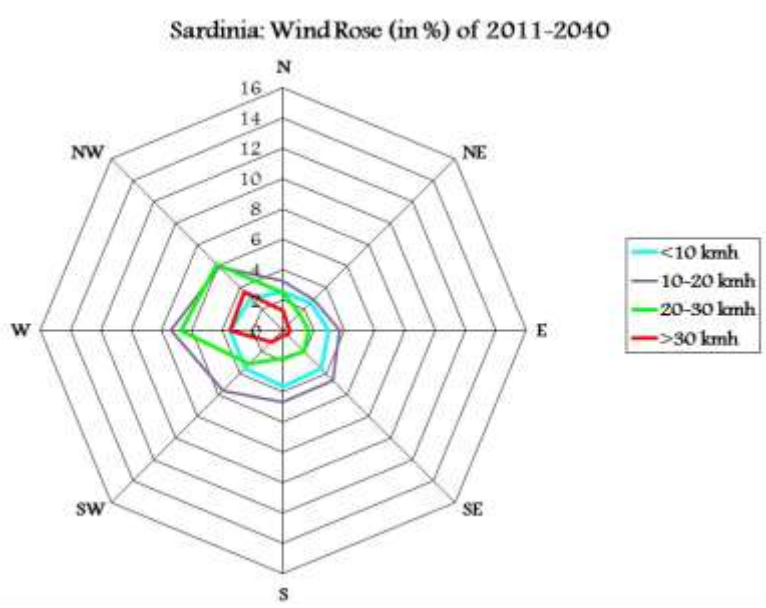


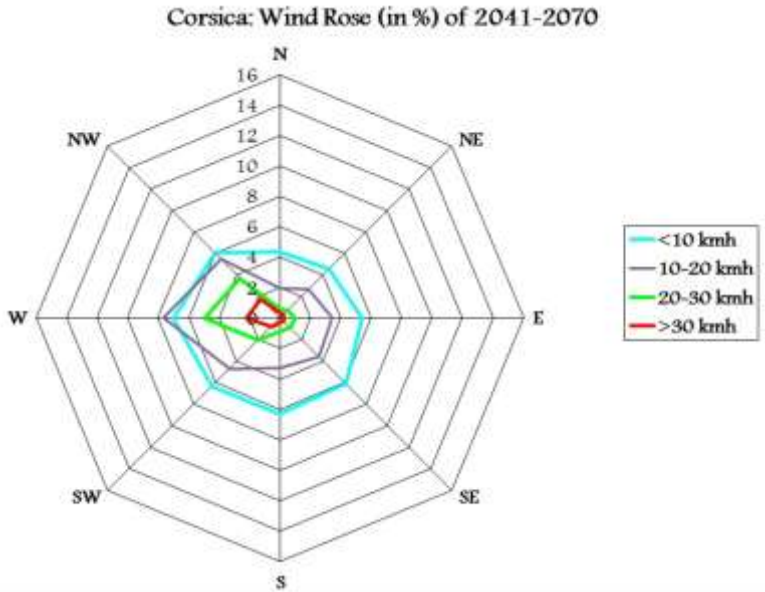
(A1B, FUME Project, ANS-CMCC)

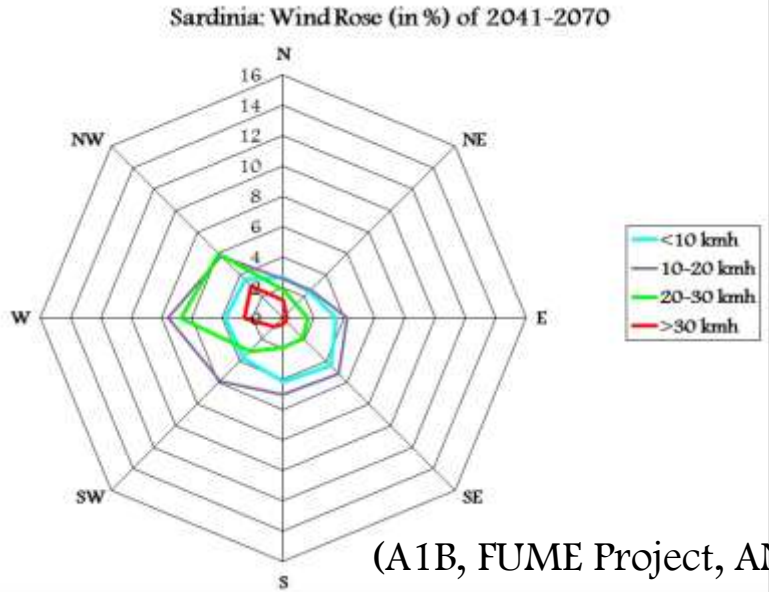
Future Issues for Fire Management

Winds





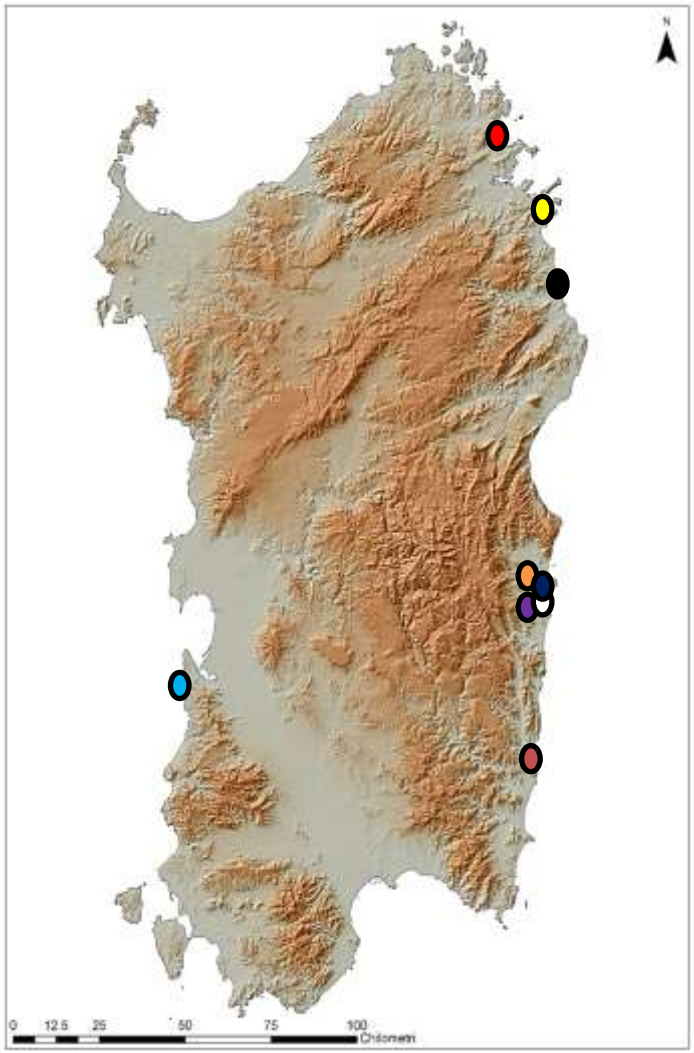




(A1B, FUME Project, ANS-CMCC)

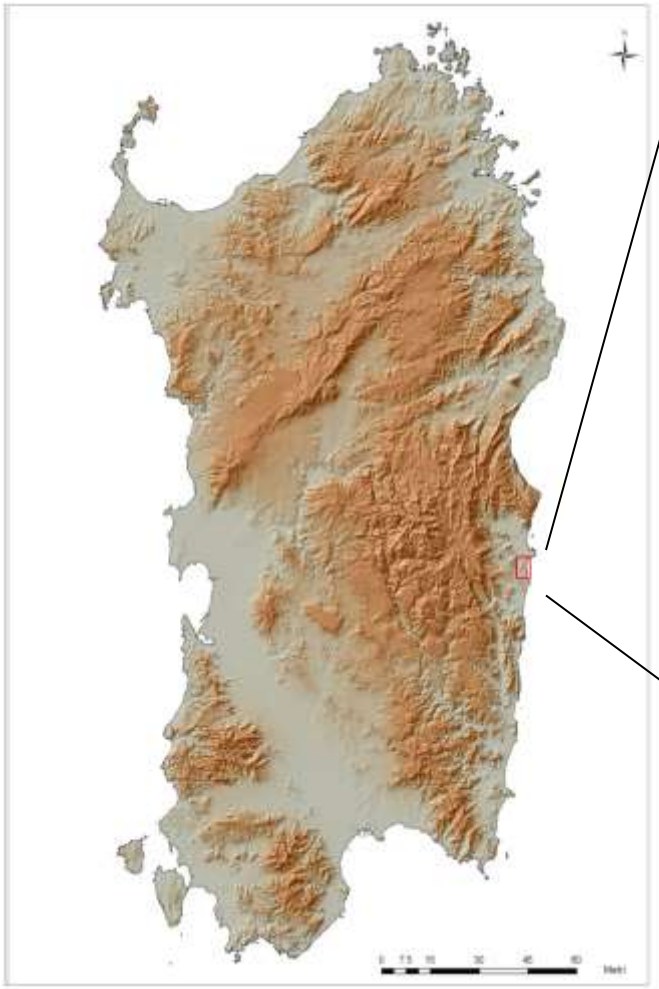
Fire Risk Management in Sardinia

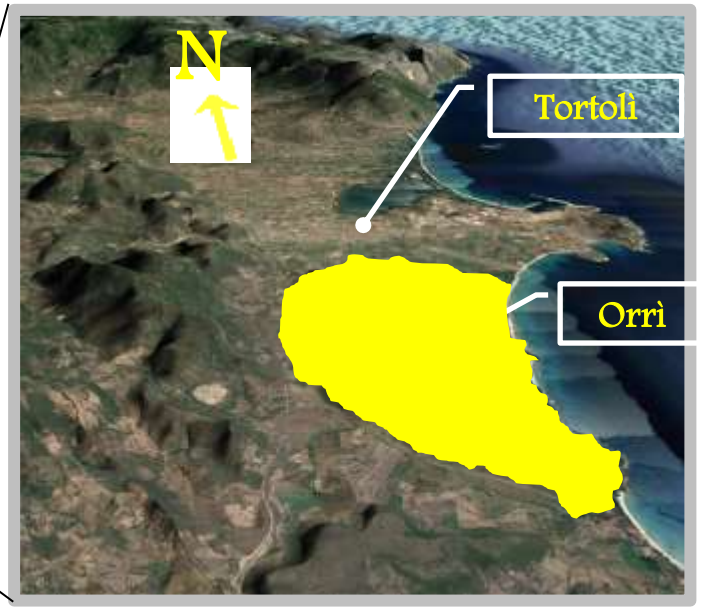
Protecting Communties and WUIs from wildfires



Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires





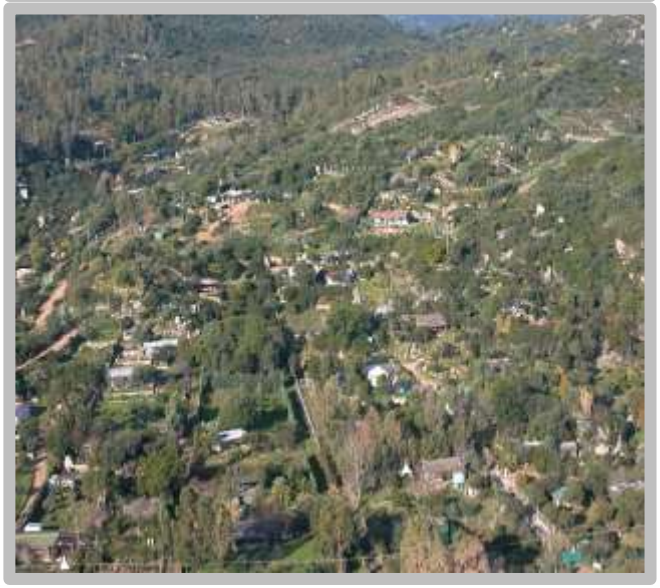
- CHARACTERIZE FIRE EXPOSURE AND HOUSE VULNERABILITY;
- IDENTIFY AND ADOPT STRATEGIES TO PREVENT AND/OR MITIGATE POTENTIAL FIRE RISK AT WUI LEVEL IN OGLIASTRA

(Cabiddu et al., in prep.)

Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

Comunità Preparata al Fuoco

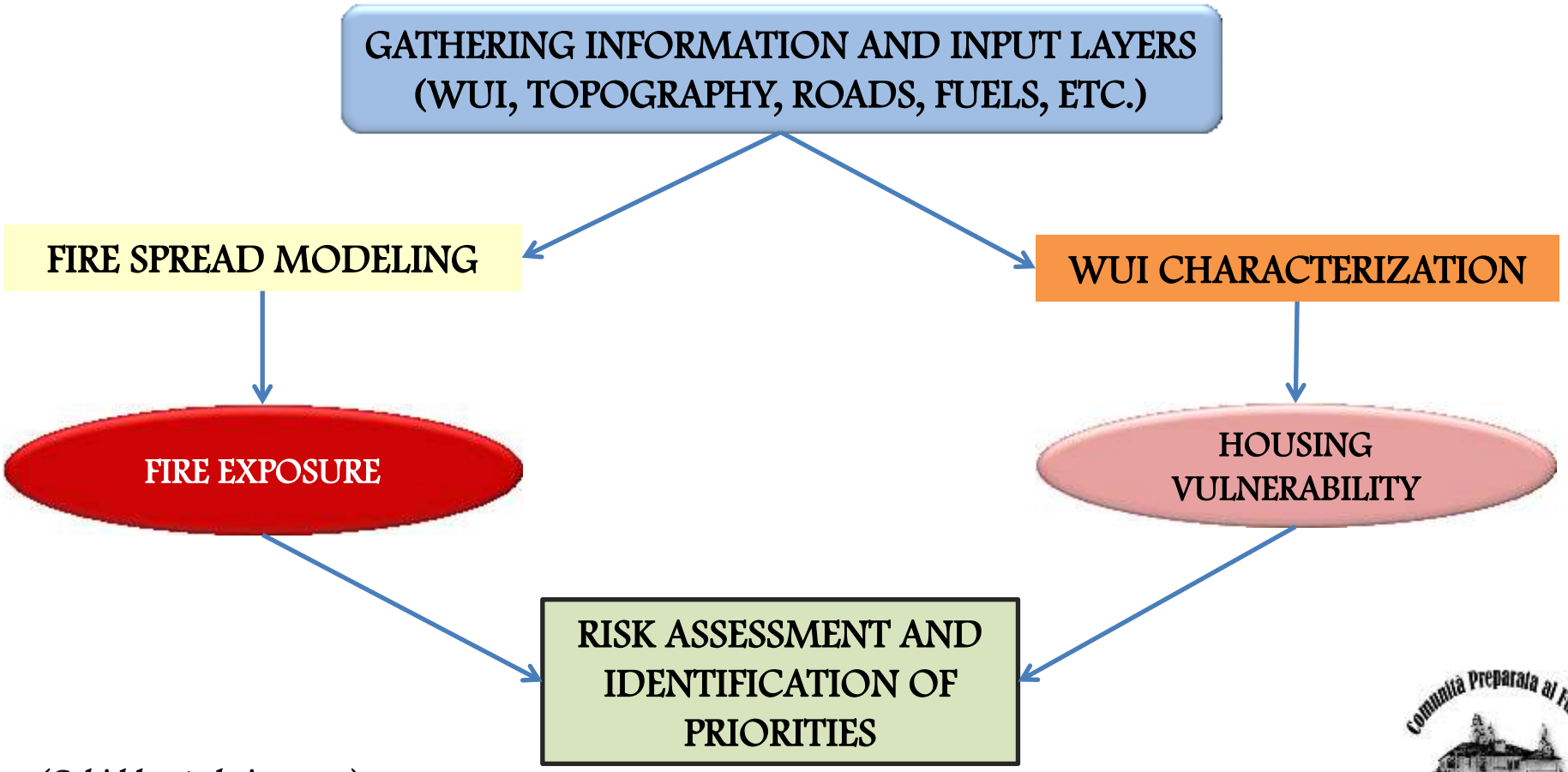


Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

Fire Risk Management in Sardinia

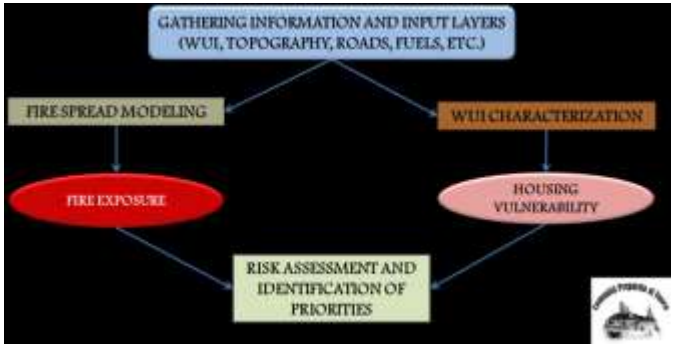
Protecting Communties and WUIs from wildfires



(Cabiddu et al., in prep.)

Fire Risk Management in Sardinia

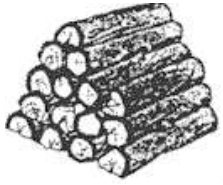
Protecting Communties and WUIs from wildfires



HOUSING VULNERABILITY

TYPE OF STRUCTURE

INFLAMMABILITY

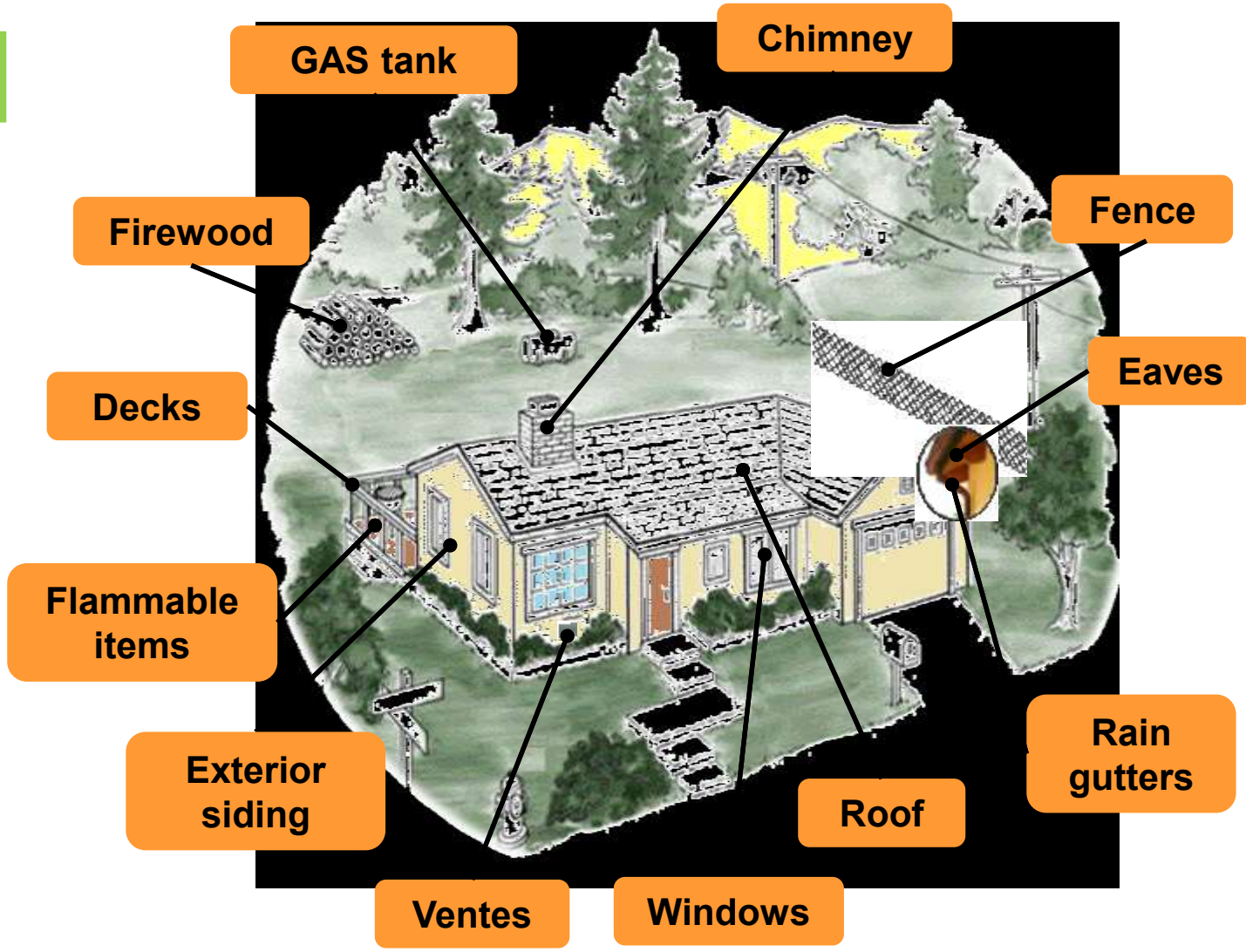


ACCESSIBILITY

Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

INFLAMMABILITY

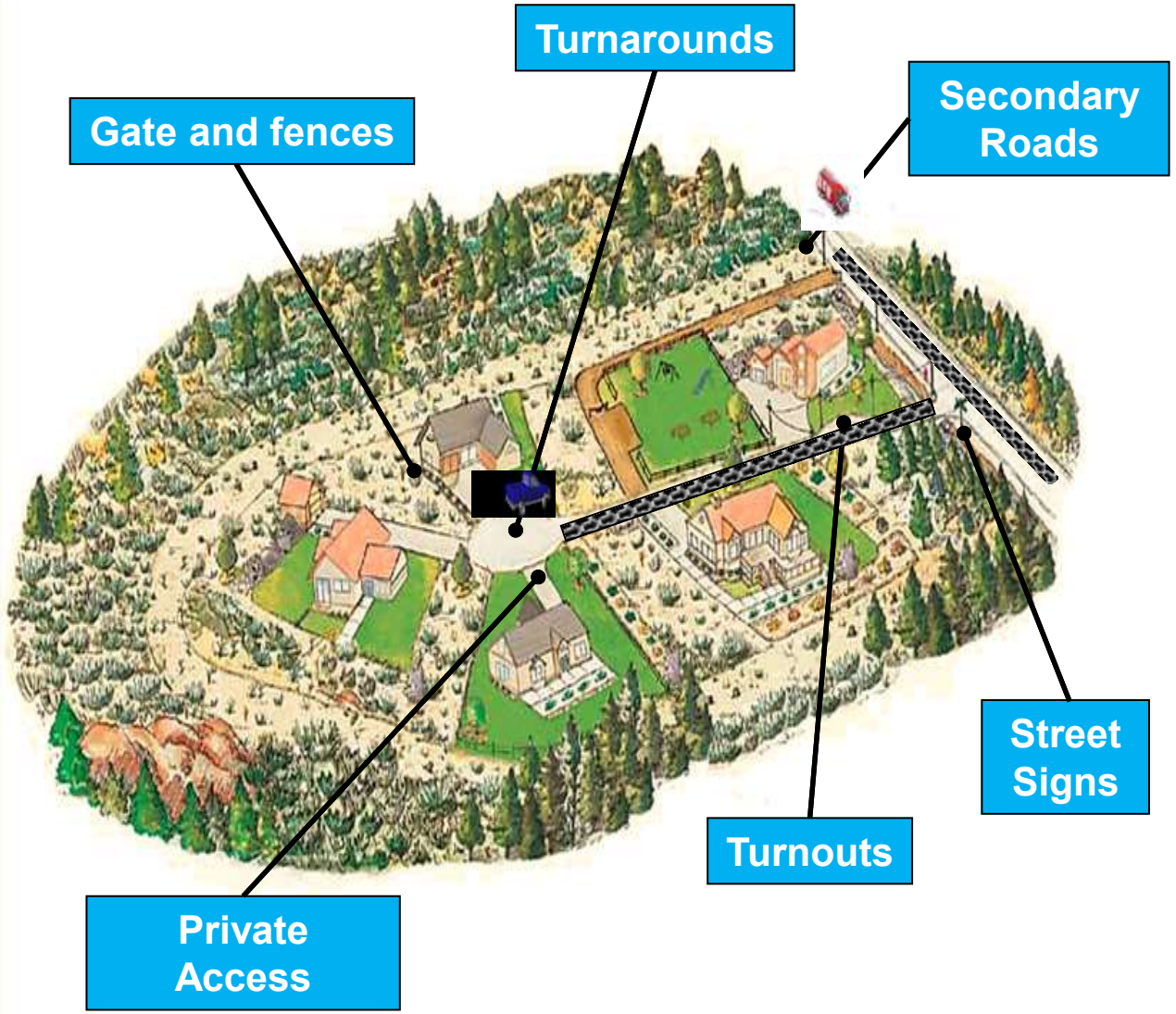


(Cabiddu et al., in prep.)

Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

ACCESSIBILITY



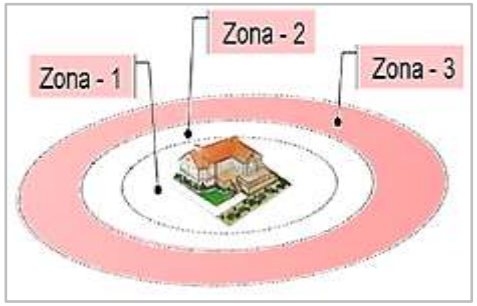
(Cabiddu et al., in prep.)

Fire Risk Management in Sardinia

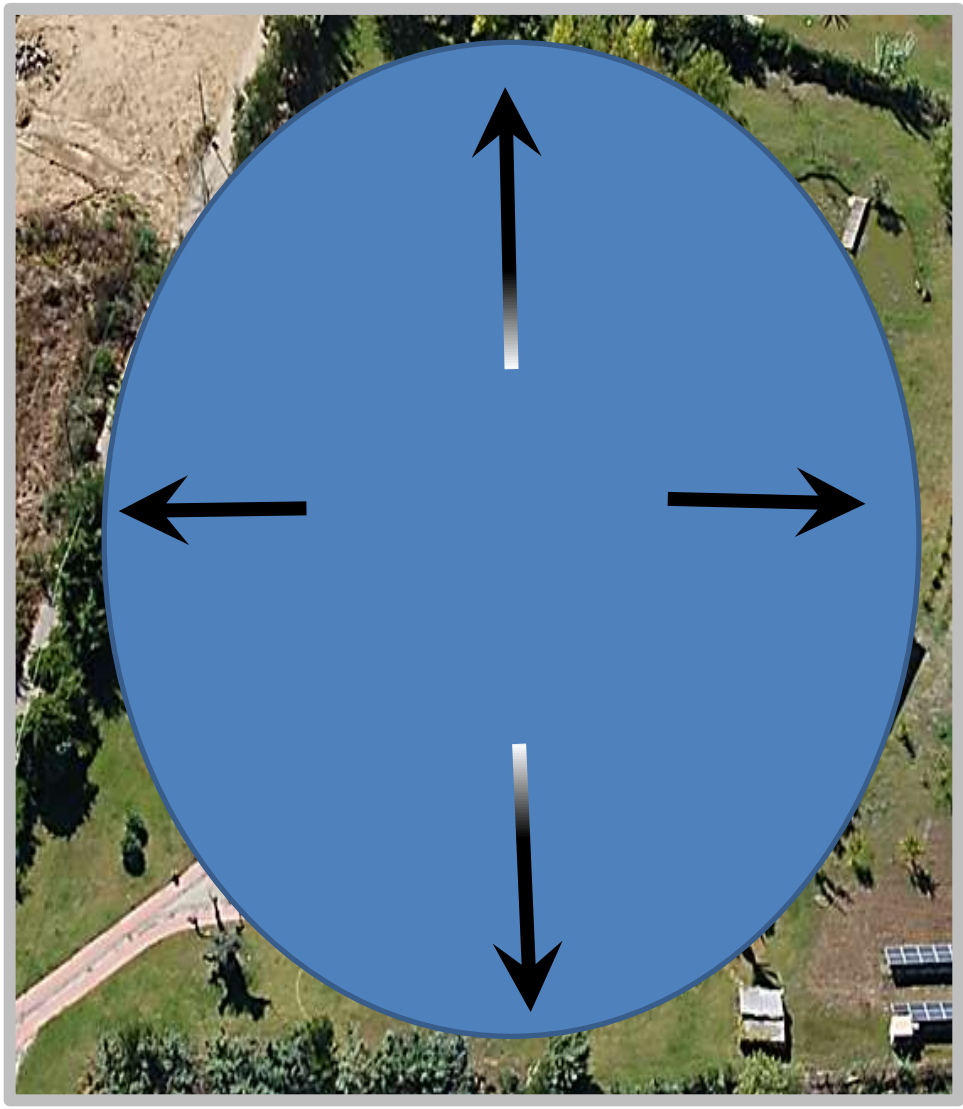
Protecting Communties and WUIs from wildfires

ACCESSIBILITY

Defensible spaces



(Cabiddu et al., in prep.)



Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

Providing information and indications of distances allows to understand positions and to reach safe areas, particularly for tourists

Fire Risk Management in Sardinia

Protecting Communties and WUIs from wildfires

GATHERING INFORMATION AND INPUT LAYERS (WUI, TOPOGRAPHY, ROADS, FUELS, ETC.)

FIRE SPREAD MODELING

WUI CHARACTERIZATION

FIRE EXPOSURE

HOUSING VULNERABILITY

(Cabiddu et al., in prep.)

Comunità Preparata al Fuoco

Conclusions

- In the last years, a strong effort in the integration of models and tools, scientific findings and data for operational application of the fire behavior models was carried out in Sardinia

- Fire simulation models, previously calibrated and validated, represent a useful method for quantifying fire exposure and risk, supporting management and planning, and evaluating mitigation strategies

- "Smart" fire prevention and mitigation programs are crucial to limit threats posed by large and severe fires and could provide relevant help to reduce fire risk in Mediterranean areas and elsewehere

- Burn probability modeling and exposure analyses can play an important role to address/support a number of other management problems, including analyzing carbon offsets, post fire recovery, soil erosion, climate changes, understanding temporal and spatial tradeoffs of fuel treatments, and wildfire impacts to ecological conservation reserves

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REGIONE AUTONOMA DELLA SARDEGNA

"Proterina-2" Project (Italia-Francia Marittimo Programme)

PROTERINA²

Sardinia Forest Service CFVA


Thank you for your attention!
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