Application des modèles du feu/outils pour le prévenir, gérer et atténuer les risques d'incendie dans un climat changeant

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ClimaSouth

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

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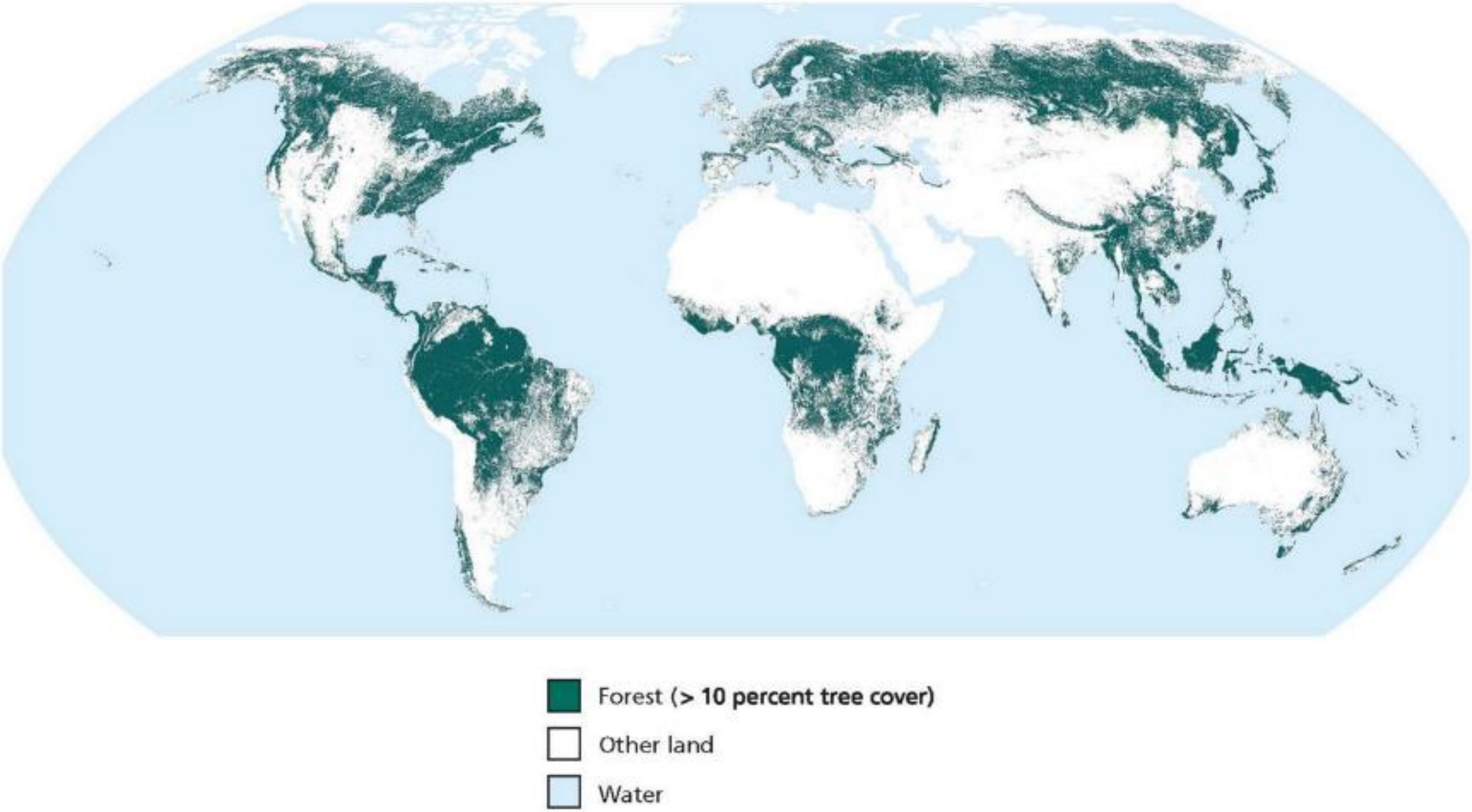
Les forêts au niveau global

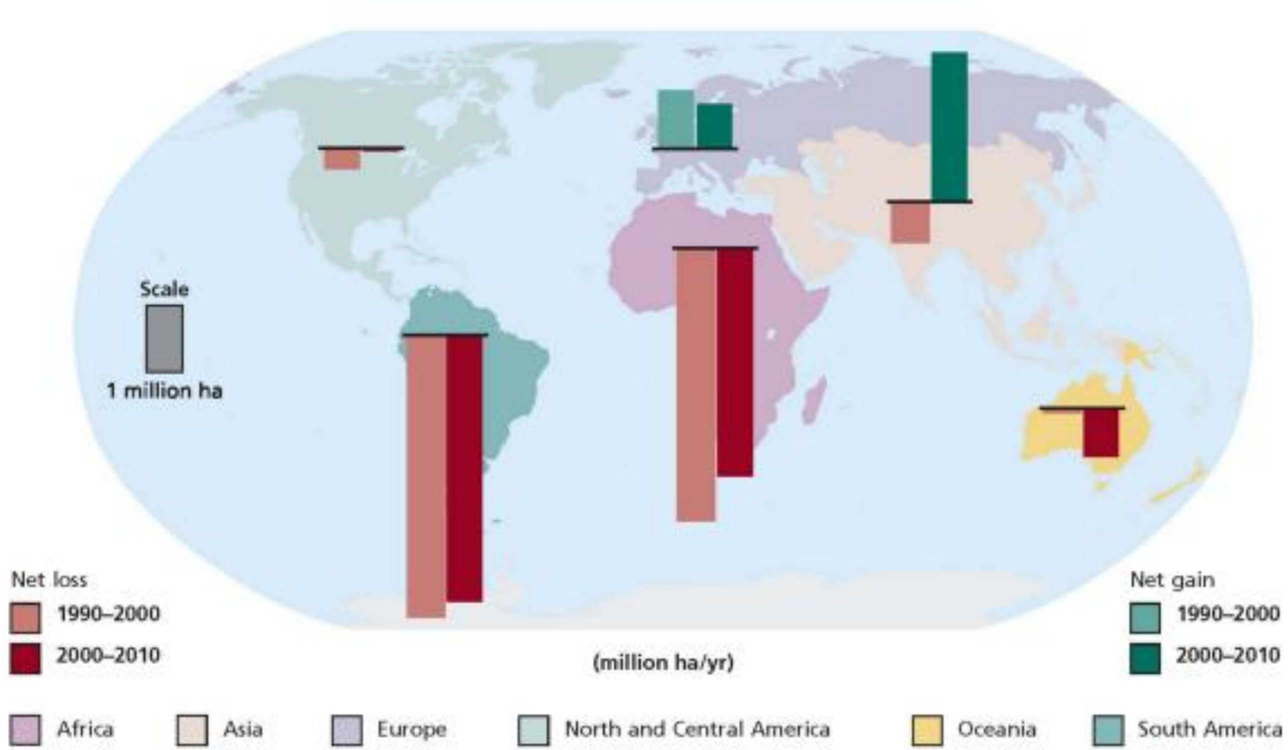


- Forests comprise ≈4 billion ha (30% of land surface, 434 billion m^3)
- 89% natural (36% primary and 53% modified)

Source: FAO Global Forest Resource Assessment 2010

Les forêts au niveau global

Change 1990 – 20010



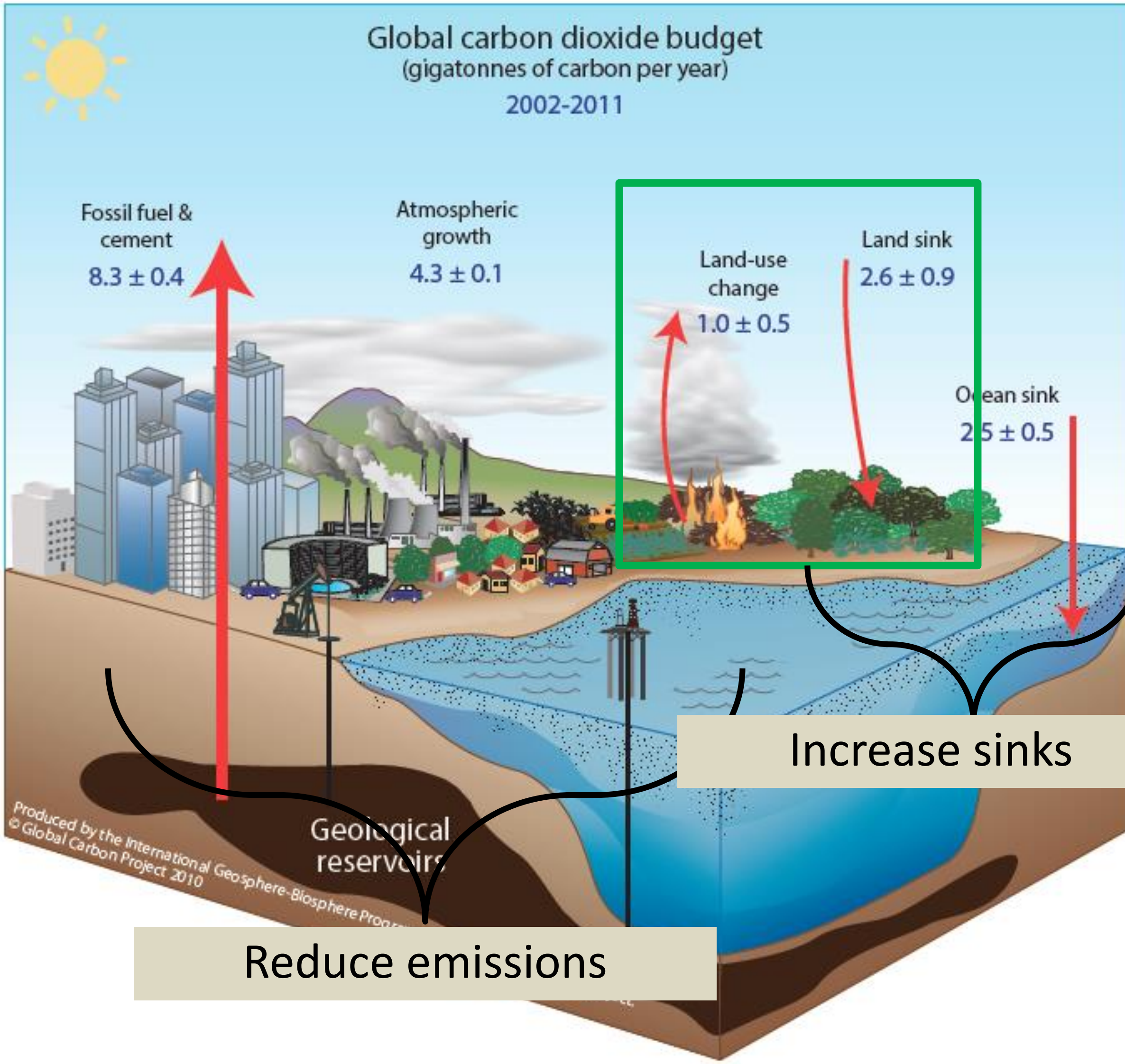
- Greatest forest loss in low-income, low-latitude countries
- Average annual net loss:
  Brazil – 3.1 million ha
  Indonesia - 1.9 million ha
- Average annual net gain:
  China – 4.0 million ha

Source: FAO Global Forest Resource Assessment 2010

Implications en raison de changements dans la couverture forestière

- Forests: both large sources and sinks of carbon
- The global forest sector:
  - Emissions from deforestation ≈1.6 Gt C/yr
  - Equivalent to 20% of anthropogenic GHGs
- Forests affect and are affected by climate change
  - Outcome determines mitigation/adaptation potential

Implications en raison de changements dans la couverture forestière



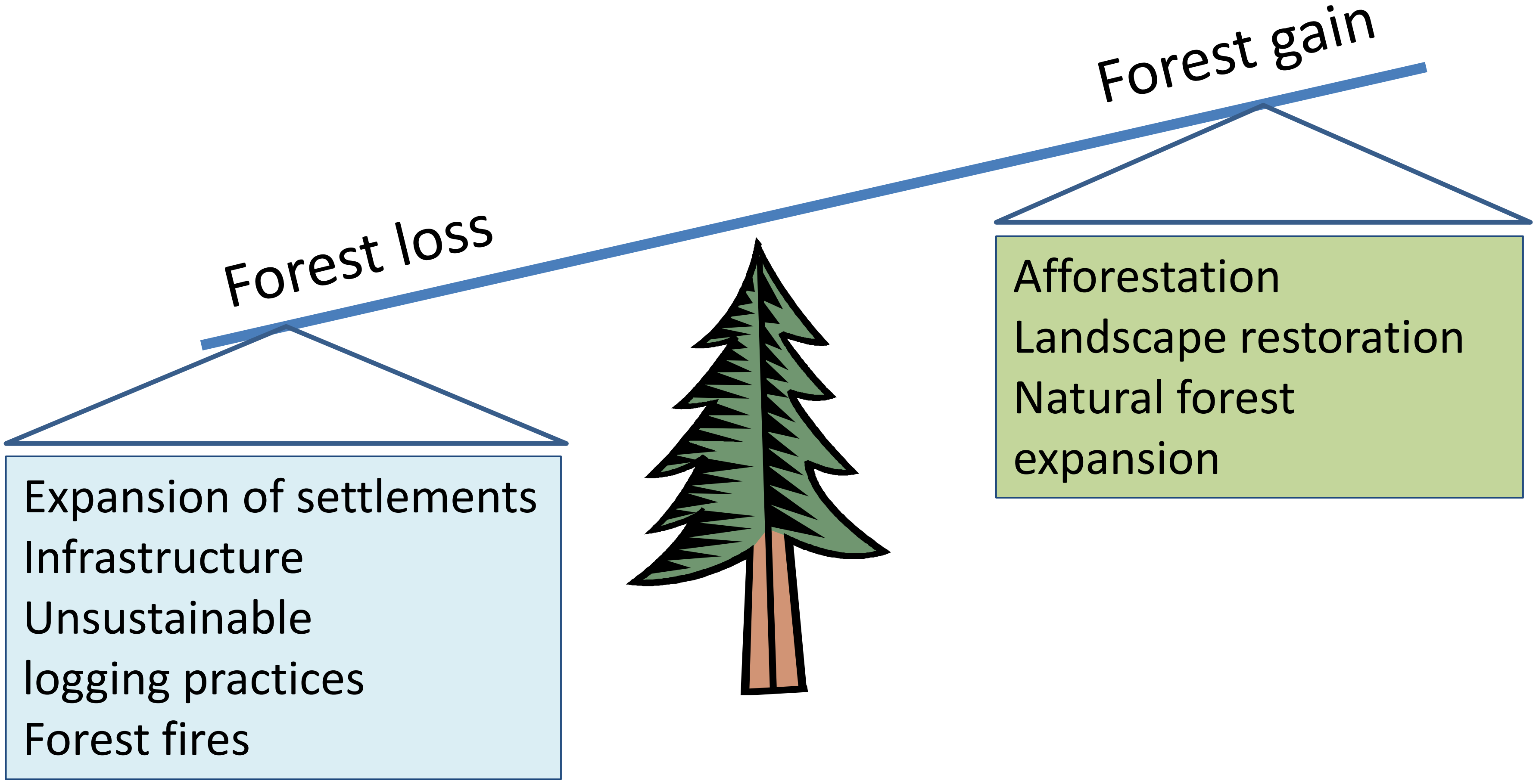
Increase sinks

Reduce emissions

- Less than half of human emissions stay in atmosphere
- Mitigation = reduced emissions and/or increased sinks
- Forests/forestry can have significant impacts on future atmospheric C concentrations

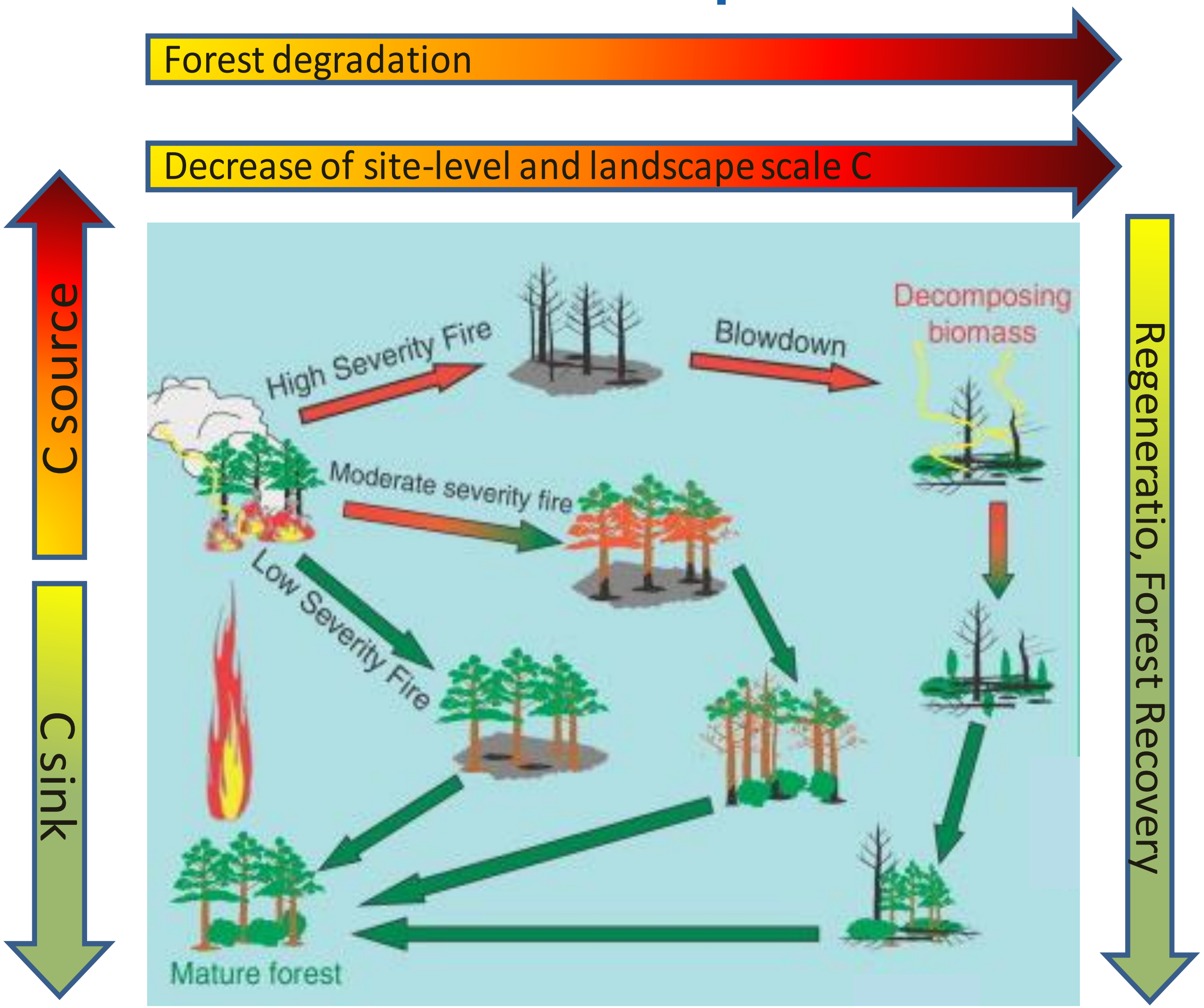
Source: Le Quéré et al. 2012; Global Carbon Project 2012

Implications en raison de changements dans la couverture forestière



Feux de forêt

Wildfire has the potential to reverse C storing

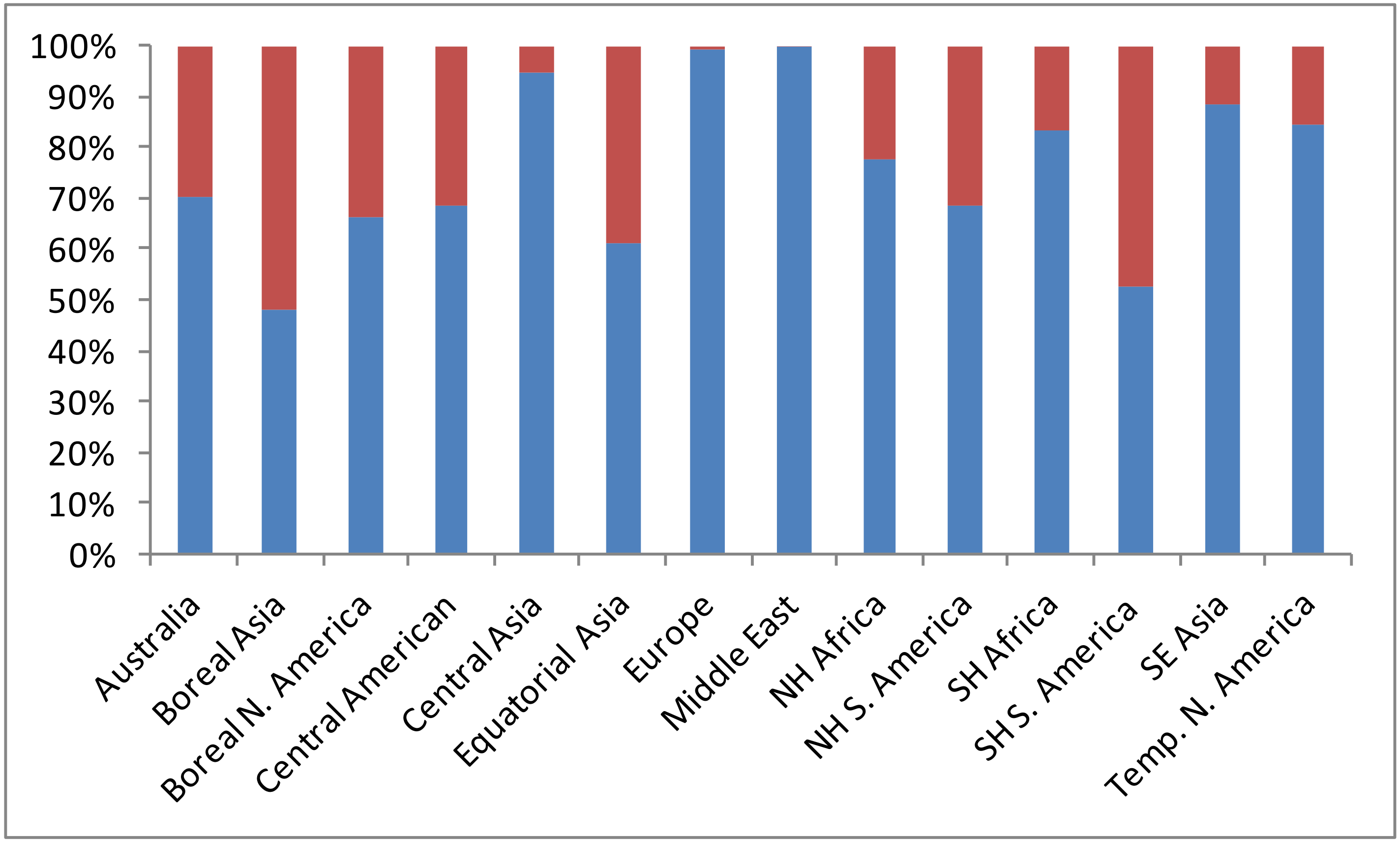


- Degradation
- Deforestation
- Soil erosion
- Decrease of biodiversity

Modified from Conard & Solomon, 2008

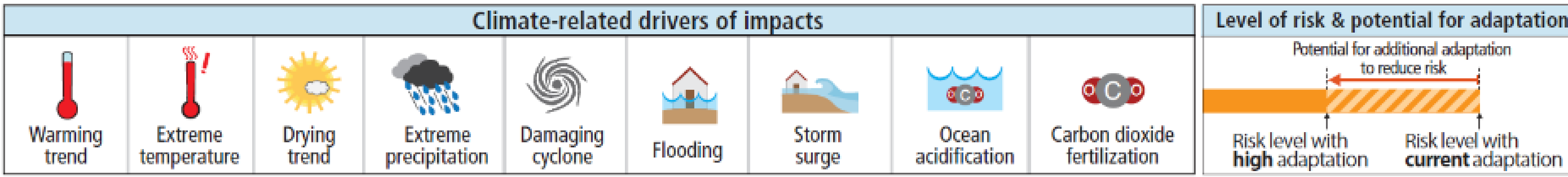
Les émissions d'incendie

CO, CH_4, NO_x, SO_2 gasses for the period 1900-2000 from forest fires (red) and anthropogenic emissions (blue)



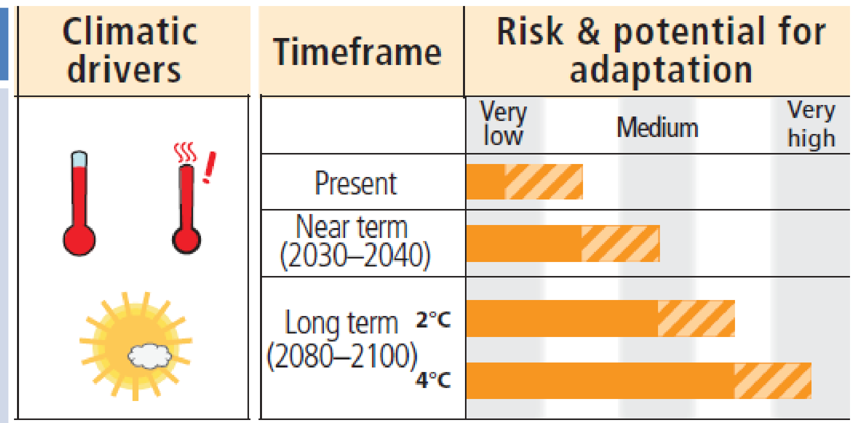
Data from ACCMIP dataset (Lamarque et al., 2010) distributed by ECCAD

Les changements climatiques et les forets



KEY GLOBAL RISK

Reduction in terrestrial carbon sink: Carbon stored in terrestrial ecosystems is vulnerable to loss back into the atmosphere, resulting from **increased fire frequency** due to climate change and the sensitivity of ecosystem respiration to rising temperatures (medium confidence)



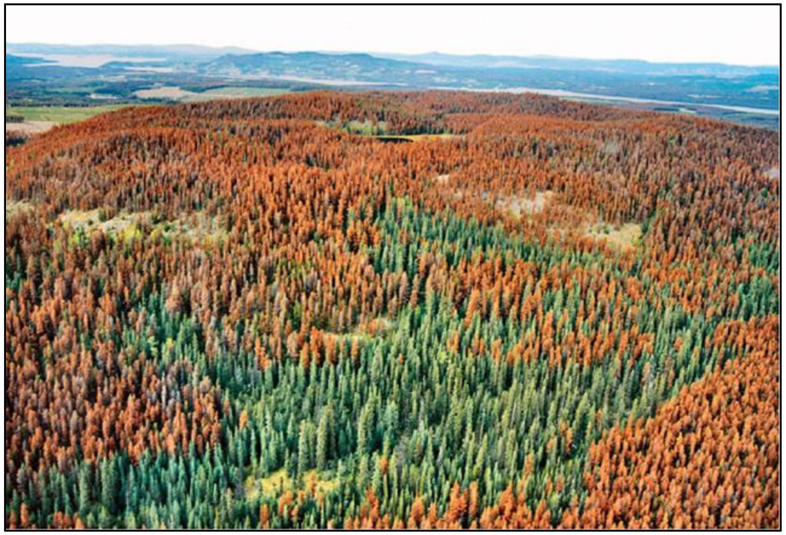
Le changement climatique et les forêts: les impacts (à court terme)

Increased productivity

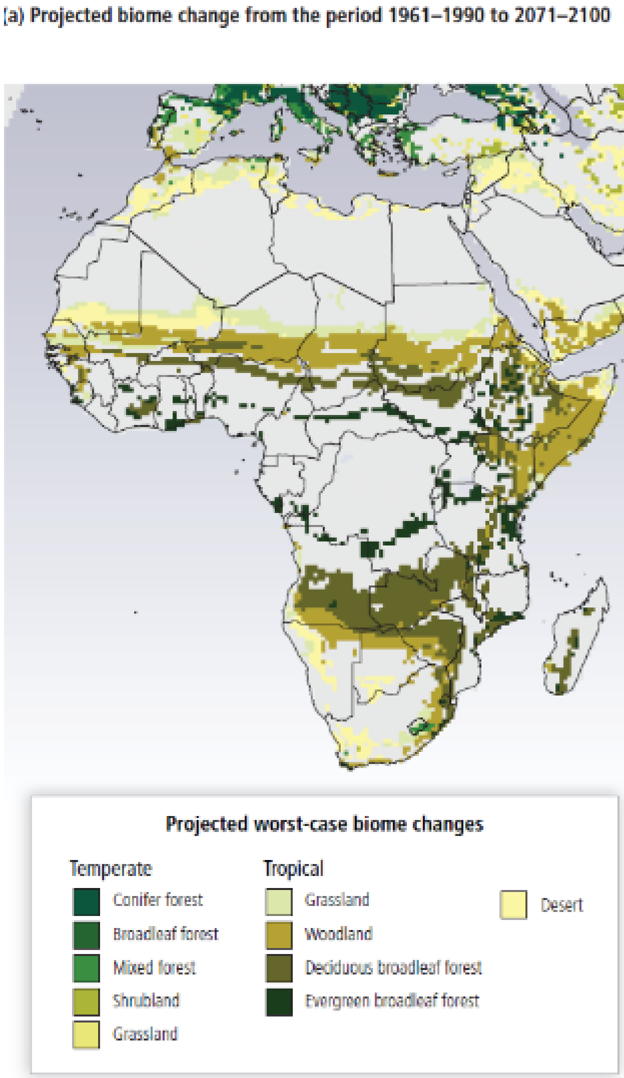
- CO_2 fertilization
- Higher temperature (inc. growth rate)
- Nitrogen mineralization
- Longer growing season
- Range expansion

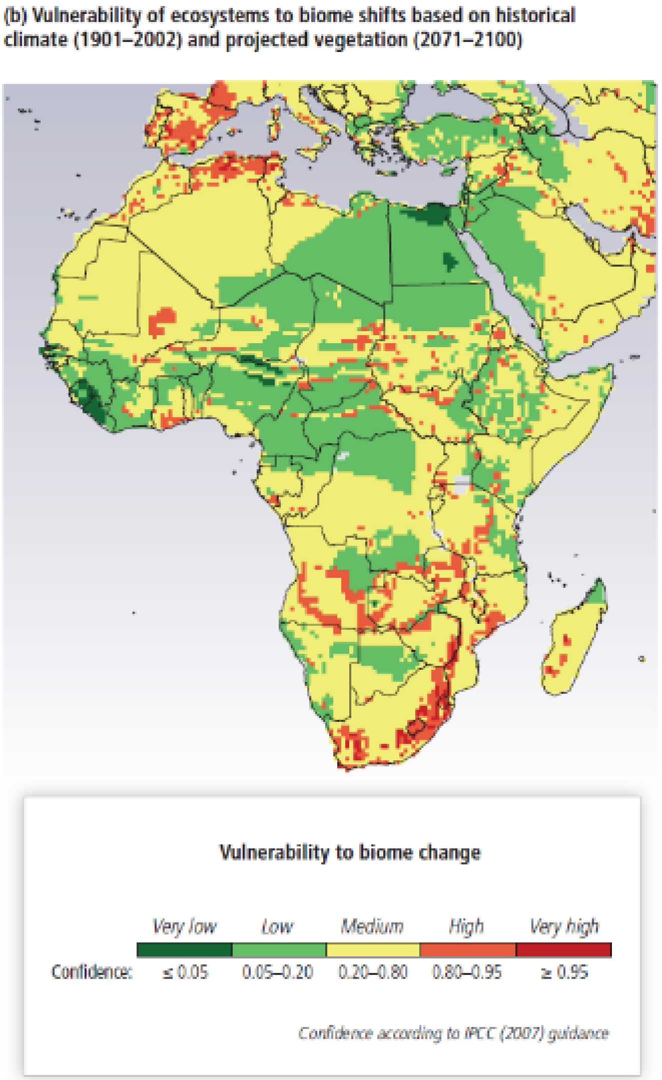
Increased disturbance

- Size/severity of forest fires, wind damage, floods
- Rate/severity/range of native insect and disease impacts
- Invasive species
- Feedbacks



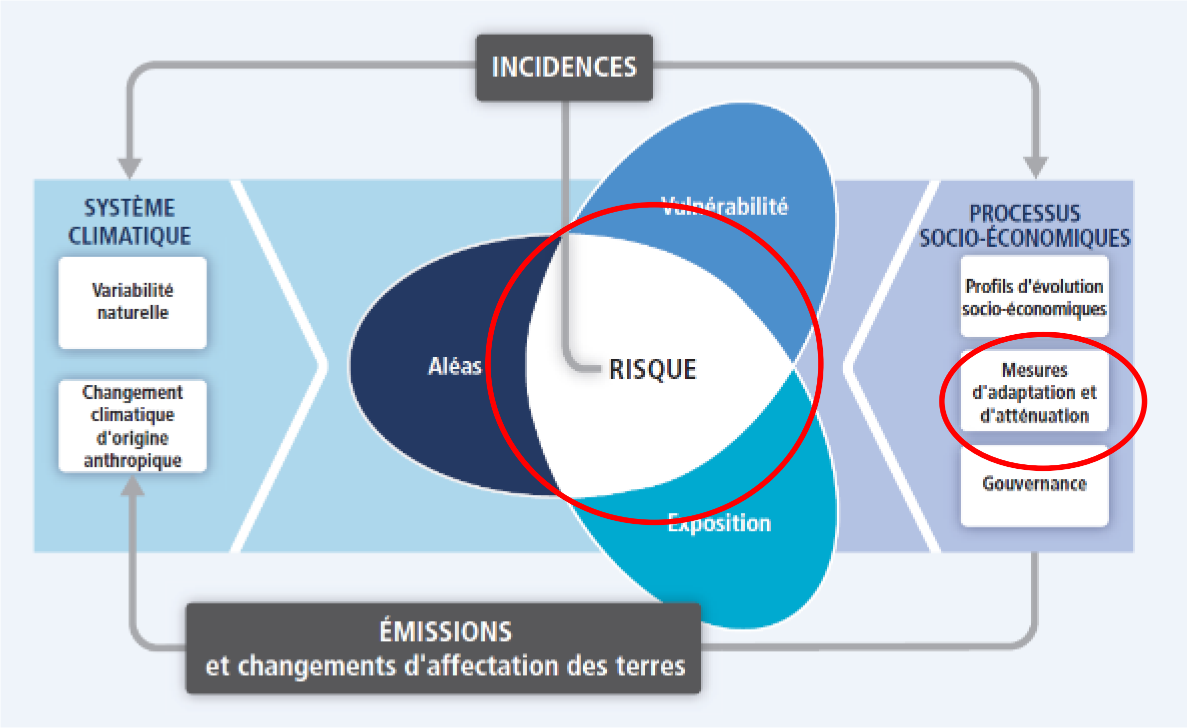
Le changement climatique et les forêts: les impacts (à long terme)





Comment faire face au changement climatique

Le risque d'incidences liées au climat découle de l'interaction entre des aléas climatiques et la vulnérabilité et l'exposition des systèmes anthropiques et naturels



Les changements qui touchent à la fois le système climatique et les processus socio-économiques, y compris l'adaptation et l'atténuation, sont les principales causes des aléas, de l'exposition et de la vulnérabilité

Comment faire face au changement climatique

- **Atténuation**: actions contre le réchauffement mondial d'origine humaine visant à en atténuer ou prévenir les conséquences possibles;
- **Adaptation**: démarche d’ajustement au climat actuel ou attendu, ainsi qu’à ses conséquences. Dans certains systèmes naturels, l’intervention humaine peut faciliter l’adaptation au climat attendu ainsi qu’à ses conséquences.

Comment faire face au changement climatique

Important to assess the impacts of climate change and the prospects for adaptation in such area

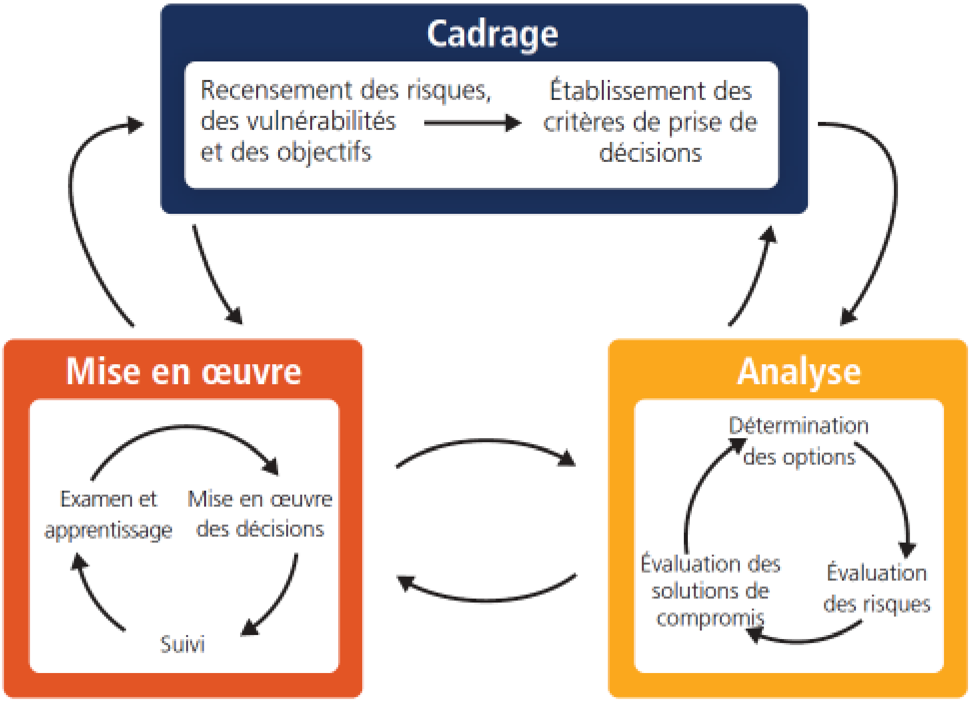
MITIGATION + **ADAPTATION**

↓

1. **DISASTER RISK MANAGEMENT**
2. **INCREASE RESILIENCE**

Contexte de la prise de décisions

1. **Connaissant la situation (baseline)**
2. Entreprendre un processus de **prise de décision** pour la gestion des risques
3. **Mettre en œuvre des actions d'adaptation et d'atténuation**, avec des implications pour les générations futures, les économies et l'environnement



Les options d'atténuation dans le secteur forestier

Mitigation options in the forestry sector may be categorized as those that

(1) Maintain (or increase) forest area

- Avoid emissions from deforestation or forest degradation
- Increase afforestation

(2) Increase stand/landscape level carbon density

- Species selection, reduce residue burning, increase conservation areas, protect against disturbances (fire, pests, diseases)

(3) Reduce fossil C emissions through product substitution and bioenergy

- Longer-lived products, recycling, biofuels

Les options d'adaptation dans le secteur forestier

Adaptation options in the forestry sector

(1) Maintain forest ecosystem health and productivity, increasing resilience in the short and long term

- ❑ Addressing forest insects, diseases, and disturbances
- ❑ Controlling invasive species
- ❑ Adjusting silvicultural practices to establish forests that are more tolerant of future climate conditions

(2) Adaptation and Protection from Wildfire

- ❑ Reduction of fire hazard and restoration of fire-resistant conditions
- ❑ Improvement of land use planning
- ❑ Implementation of fire safe practices around homes and other development
- ❑ Recovery planning and implementation to reduce erosion and watershed damage

Les options d'adaptation dans le secteur forestier

Adaptation options in the forestry sector

(3) Biomass Utilization for Energy and Climate Adaptation

- ❑ Avoid fossil fuel use
- ❑ Job opportunities for local rural communities
- ❑ Avoided costs and environmental impacts from reduced landfill
- ❑ Public health benefits by reducing air quality from both wildfire smoke

Policies that successfully increase the forest protection against natural disturbance agents **may reduce** net emissions from forest lands

(*Richards et al., 2006*).

↓

Wildfire prevention as mitigation strategy and adaptation option

Les options d‘adaptation dans le secteur forestier

National Strategy for Adaptation to Change Climate (SNAC) 2014

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Grey	Green	Soft
Identify indicators for climate change impact monitoring	Fuel management	Early warning systems
Improve efficiency in fire prevention, management and education	Selection of fire-resilient or fire-tolerant species	Territorial planning
Innovation and research	Creation of low fire risk zones in strategic areas	Identification of areas more susceptible to severe forest fires

Modèles pour prévenir, gérer et atténuer les risques d'incendie dans un climat changeant

Tools		Main Applications
Fire danger IFI (Integrated Fire danger Index) (Sirca et al., 2006)	→	- daily/seasonal fire danger forecast - fire danger projections with future scenarios
Fire spread and behaviour FARSITE, FlamMap, RANDIG (Finney, 2003)	→	- fire behaviour and spread simulation - fire spread and behaviour projections using future scenarios - assessing fire risk mitigation strategies (prescribed fires, fuel reduction, etc.)
Fire emissions FOFEM (Reinhardt, 1997)	→	- analysis of fuel consumption -smoke characterization -Fire emission mitigation

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	*

EFFIS – Fire Danger Forecast

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

PERIOD: from 1st of March to 31st of October

DATA: meteorological forecasted data received daily

From Meteo-France

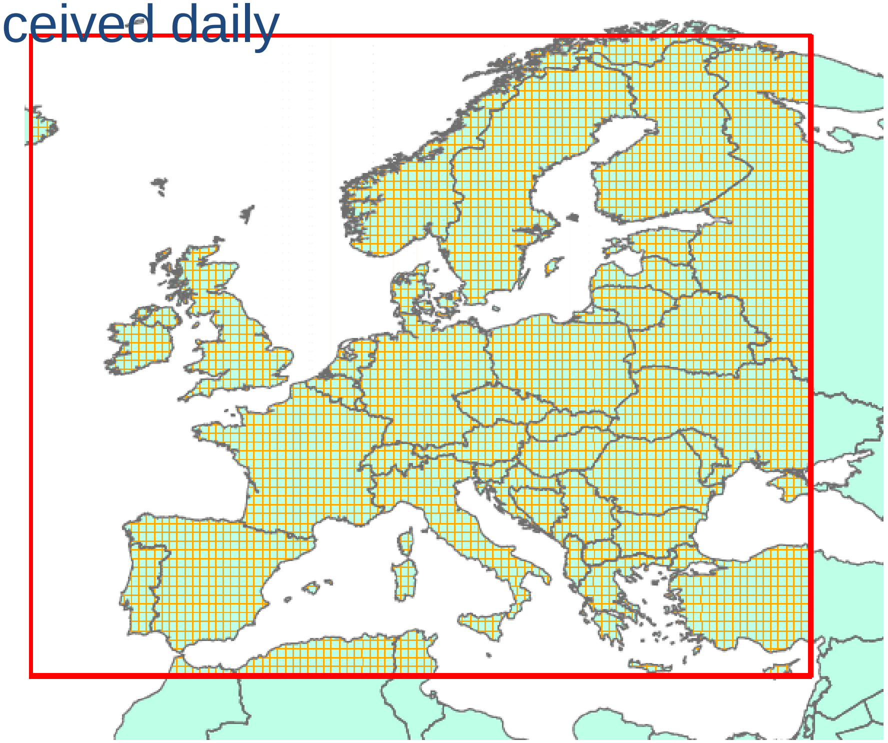
- Spatial resolution of 10km
- Forecast up to 4 days

From DWD (Deutscher Wetterdienst)

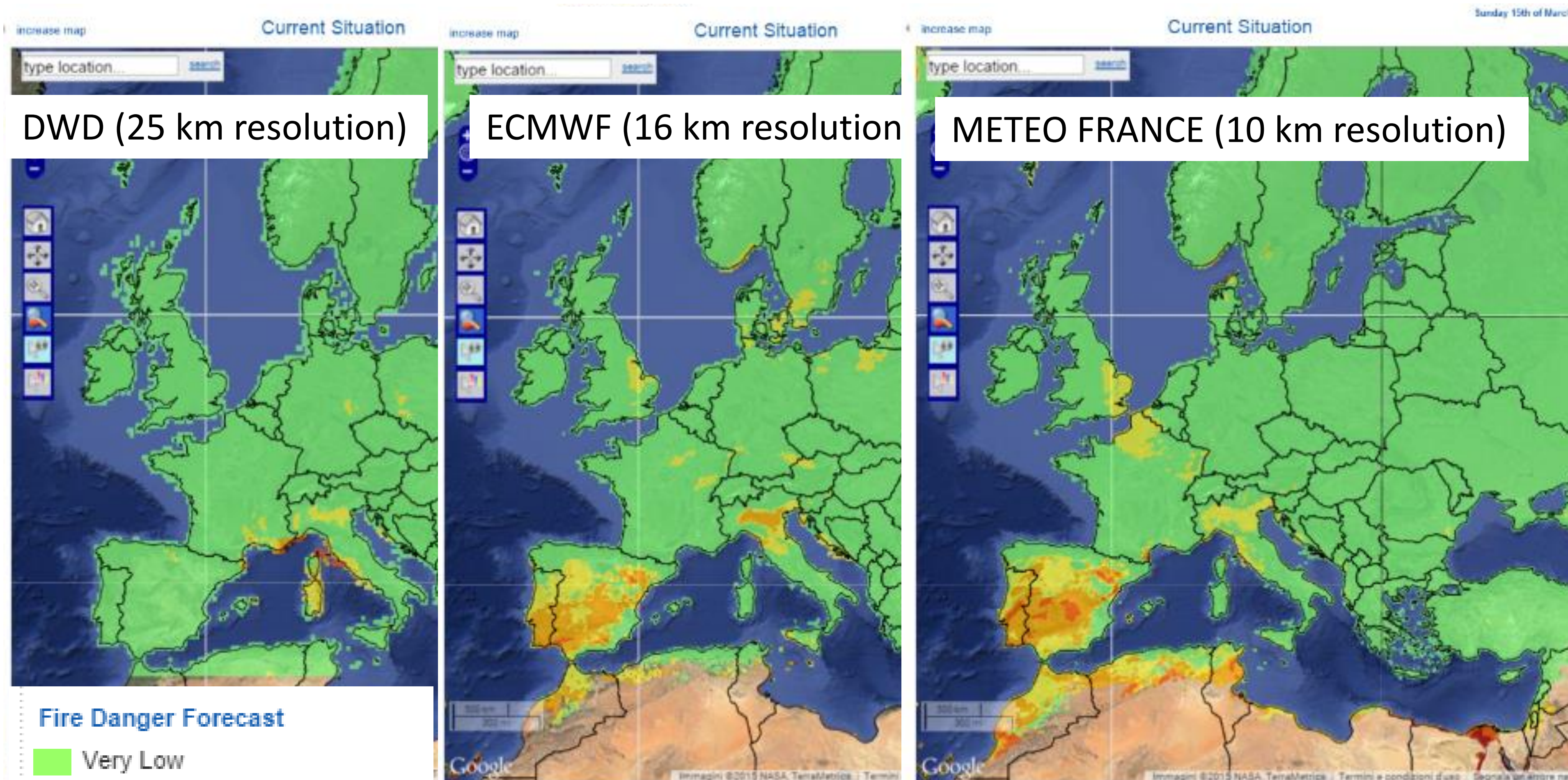
- Spatial resolution of 25km
- Forecast up to 7 days

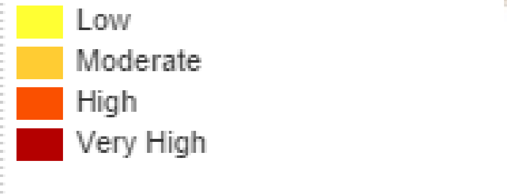
From ECMWF

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



EFFIS – Fire Danger forecast for 16/03





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

EFFIS: Long-term fire weather forecast

Seasonal forecast of temperature and rainfall anomalies

Service started in June 2013

Seasonal forecast maps showing temperature and rainfall anomalies that are expected to prevail over European and Mediterranean areas during the **next 2 months**.

The set of 2 months shown will be updated monthly during the fire season. Normally within the first week of each month a forecast for the next 2 months will be made available.

The maps are based on the ECMWF **(European Centre for Medium-Range Weather Forecasts) Seasonal Forecasting System named S4 (System 4)** and are provided to EFFIS users as **experimental products**. S4 anomalies of temperature and rainfall are estimated from the mean deviation of the seasonal forecast from the model climate. The maps highlight the areas which are expected to be colder/warmer and dryer/wetter (than normal) over Europe and Mediterranean countries, with an **obvious linkage to potentially higher forest fire danger.**

EFFIS: Long-term fire weather forecast

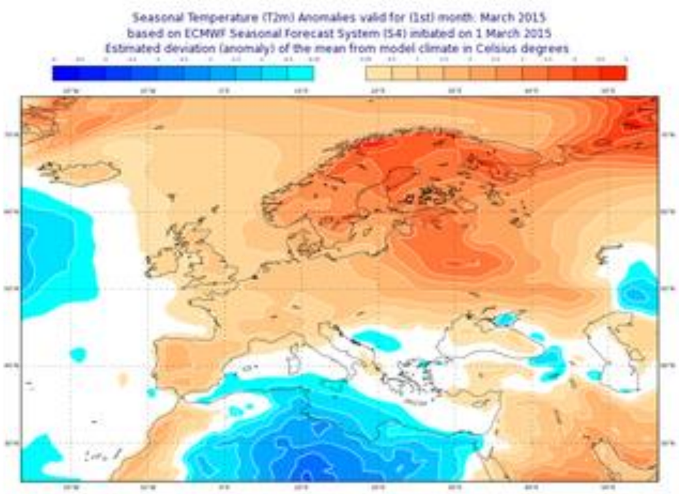
ECMWF (European Centre for Medium-Range Weather Forecasts) Seasonal Forecasting System named S4 (System 4)

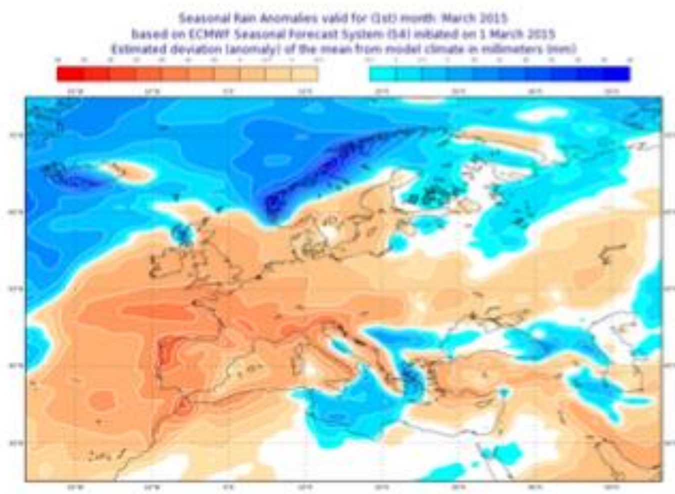
- the most recent ECMWF seasonal forecast system
- includes 51 member ensembles
- consists of 7-month forecasts initialised on the first day of every month
- resolution of ~ 79 km (T255L91)
- coupled with an ocean model with a horizontal resolution of 1◦
- initial perturbations provided by Singular vectors and an ensemble of ocean analysis

Spessa et al., 2015

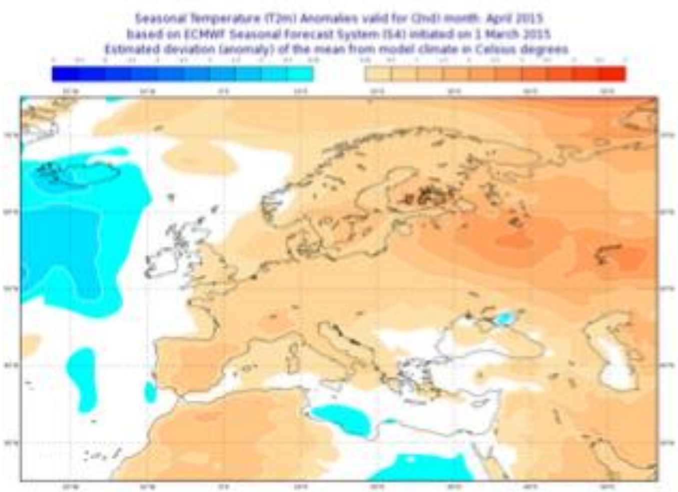
Temperature | Rainfall

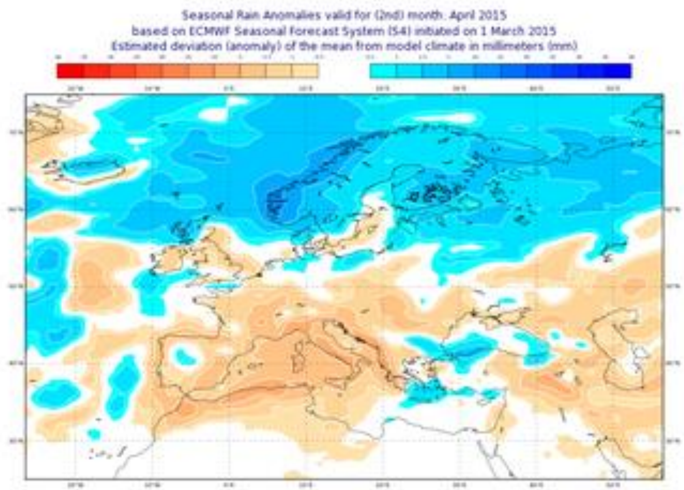
MARCH 2015





APRIL 2015

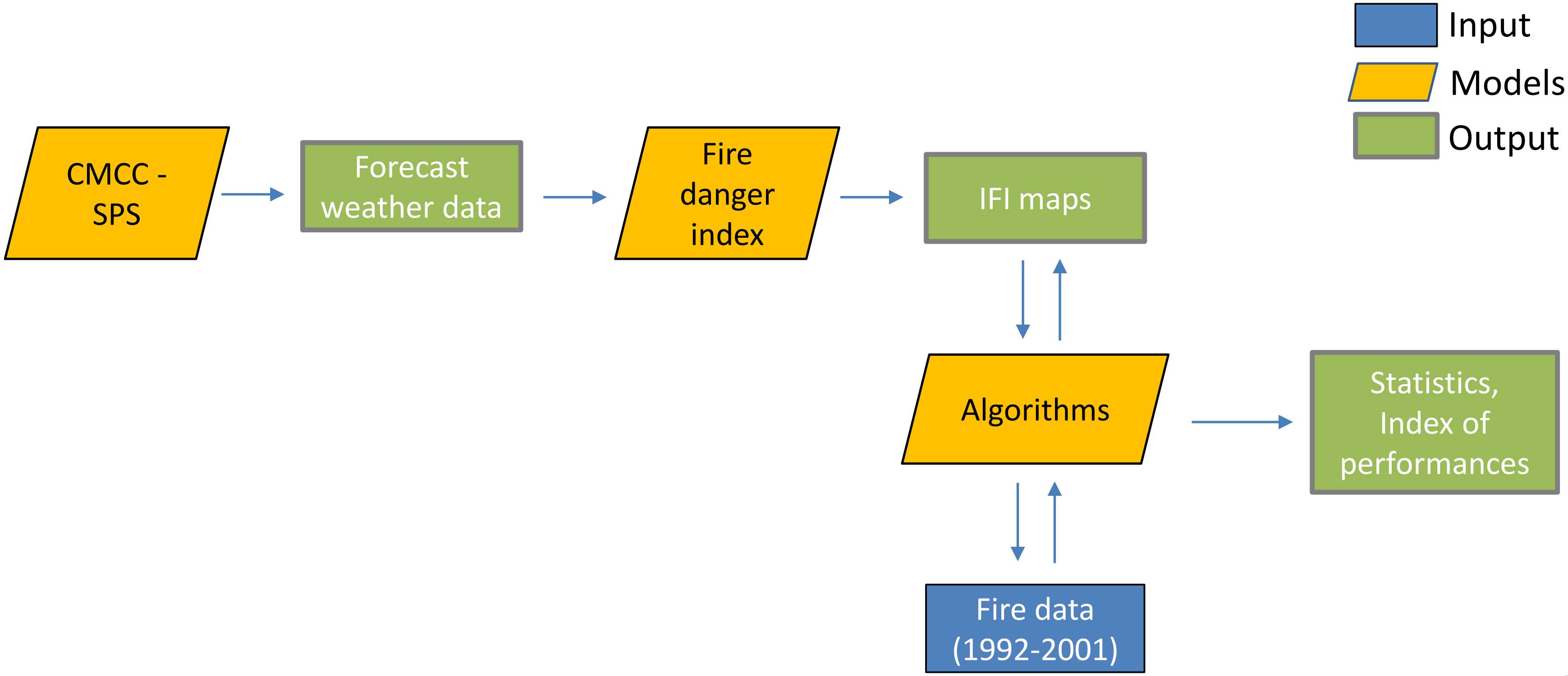




Seasonal forecast of temperature and rainfall anomalies

Seasonal fire danger forecast @ CMCC

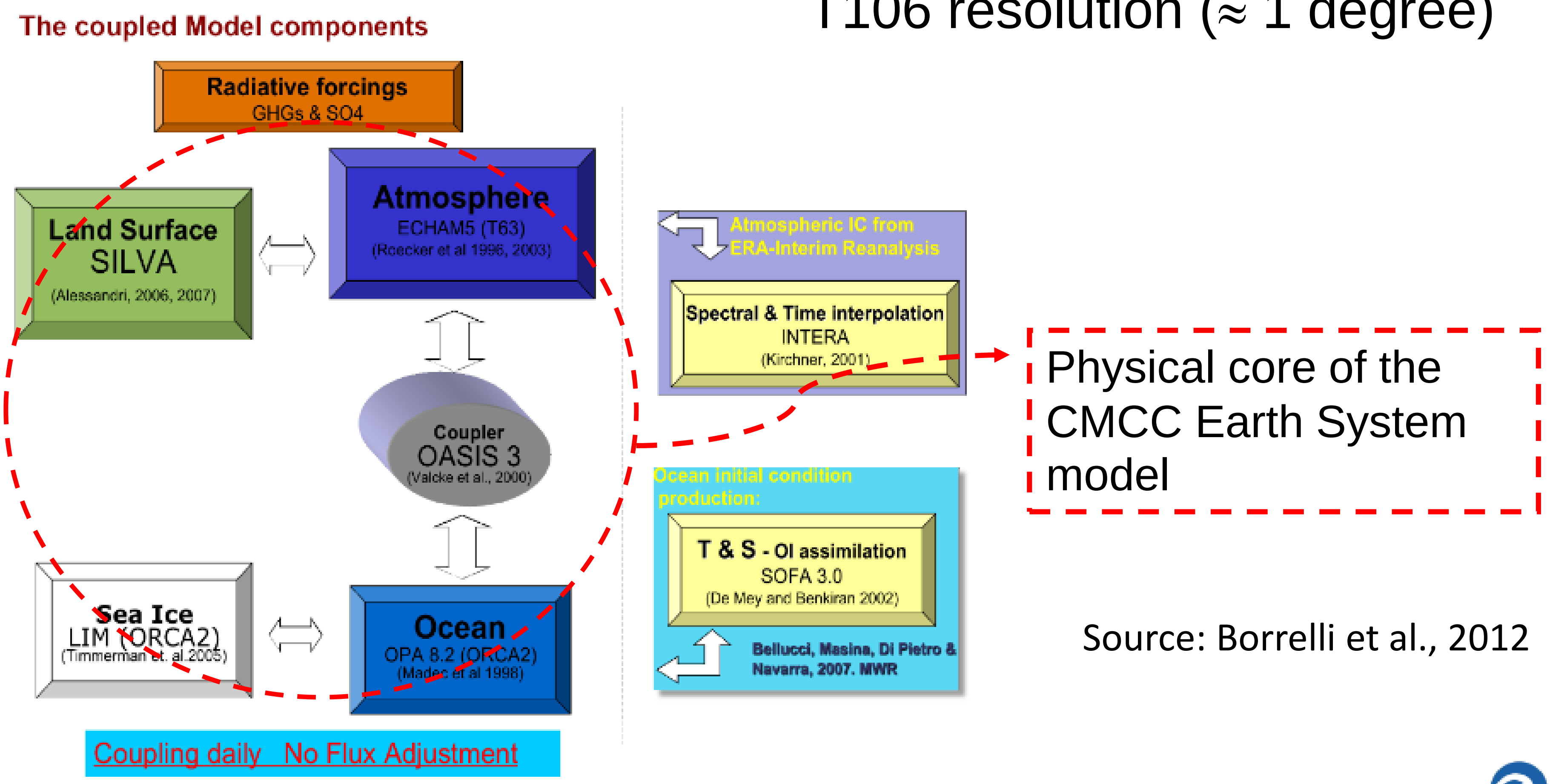
Evaluation of the CMCC Integrated Fire Danger Index (IFI) for estimating the seasonal fire danger forecast in the Euro-Mediterranean area starting from the CMCC seasonal climatic forecast system



CMCC-SPS: CMCC Seasonal Prediction System

Evolution of the system described in Alessandri et al. (2010)

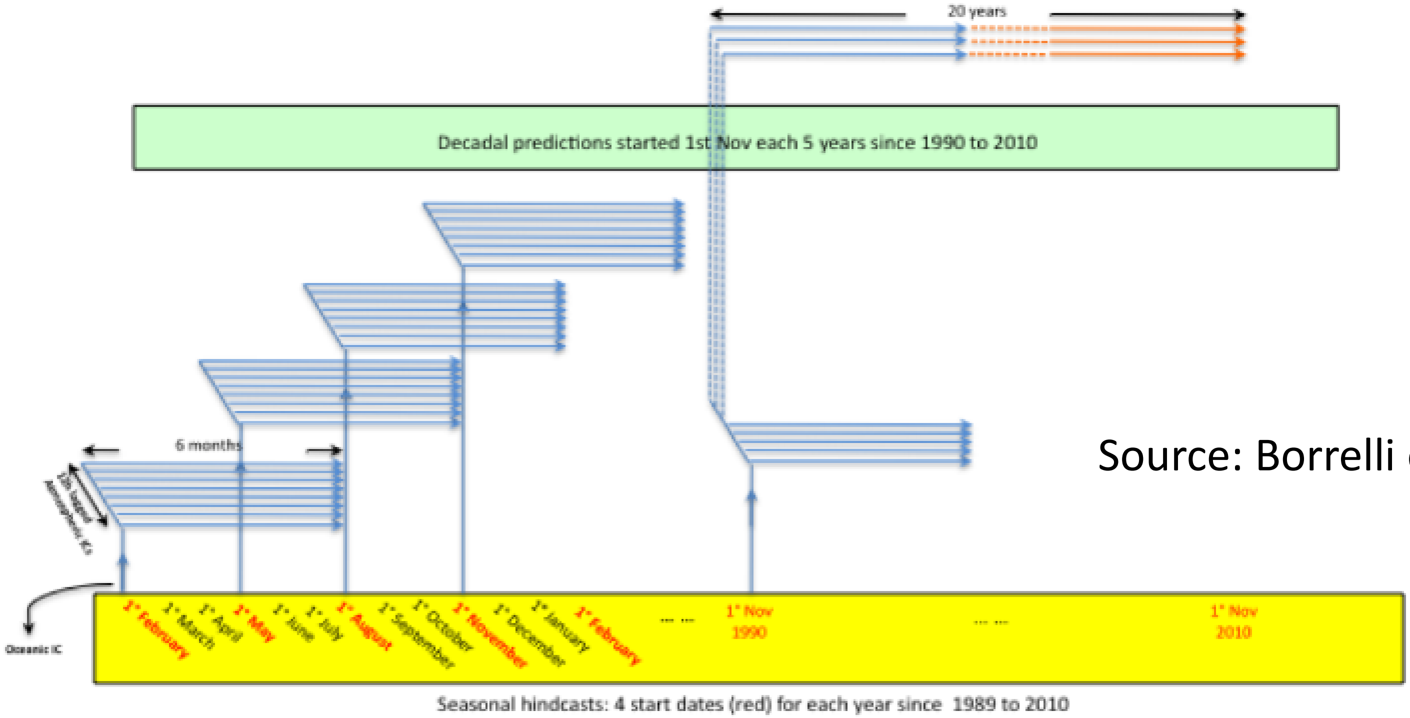
T106 resolution (≈ 1 degree)



Source: Borrelli et al., 2012

CMCC-SPS: Experimental setup

- A set of retrospective forecasts (hindcasts) from 1989 through 2010.
- Every year, the model is initialized at 4 different startdates (February 1st, May 1st, August 1st, November 1st) and then integrated for 6 months.
- For each start date, an ensemble of nine perturbed atmospheric initial conditions (ICs) was prepared

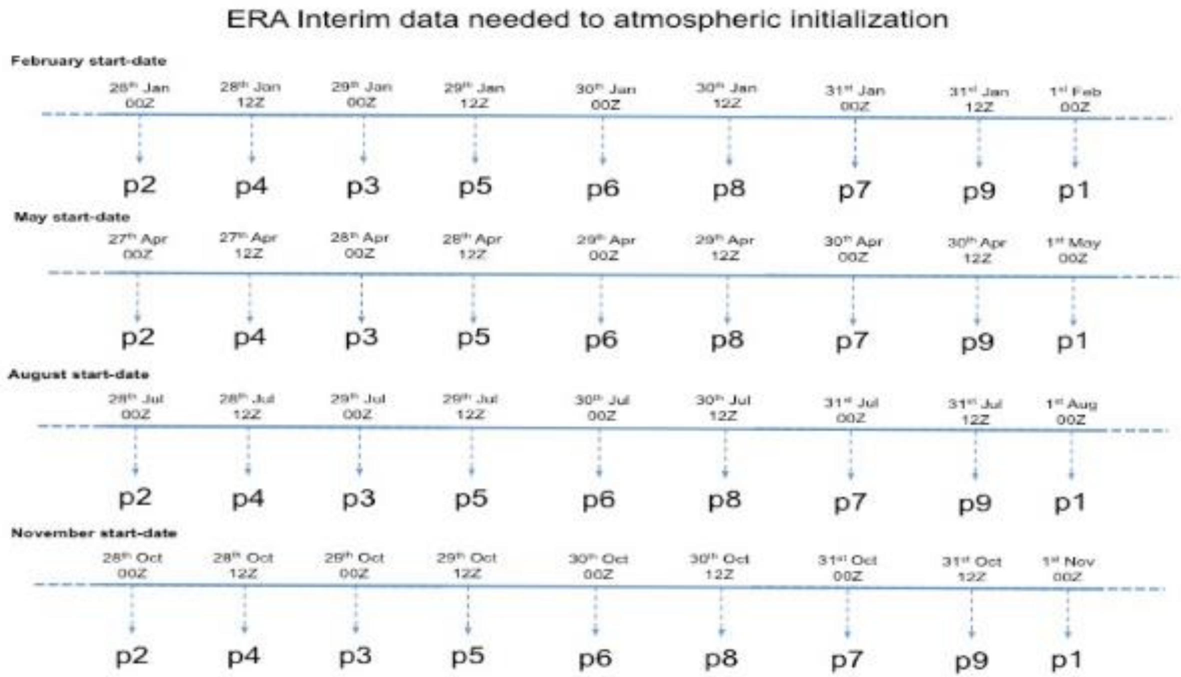


Source: Borrelli et al., 2012

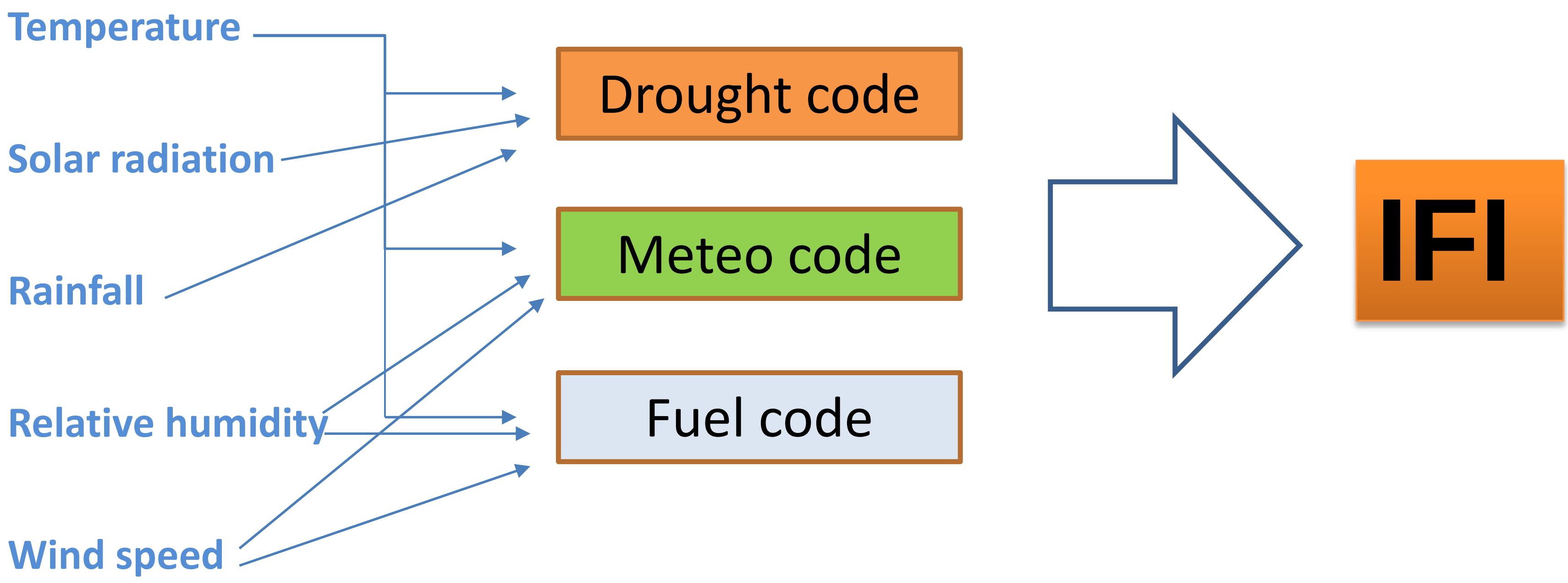
CMCC-SPS: Experimental setup

Source: Borrelli et al., 2012

- The atmospheric conditions are perturbed by imposing restart files saved every 12 hours during the 4 days preceding the start date
- 9 different initial states from which the SPS evolves are obtained, producing a probability distribution of the forecast

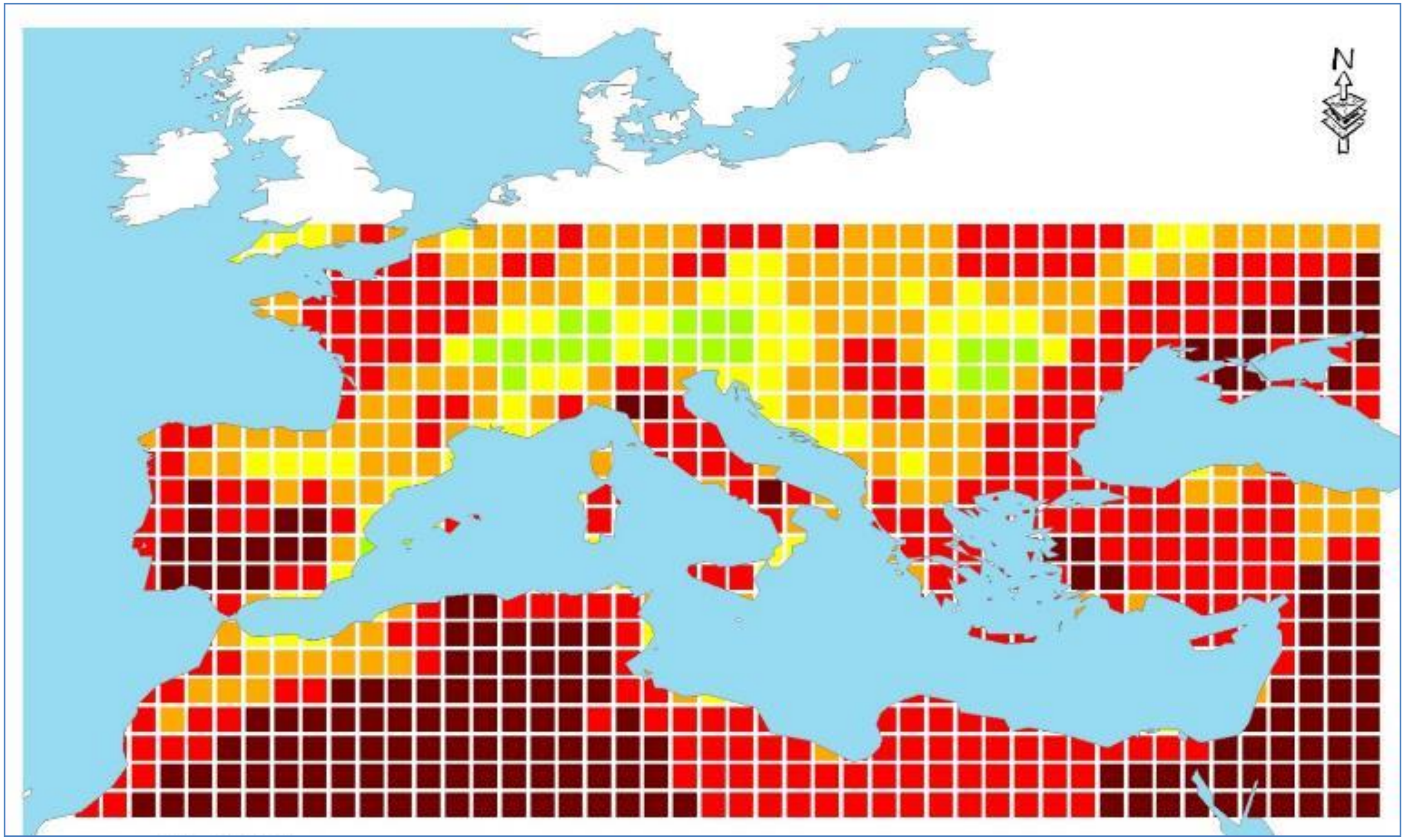


Integrated Fire Danger Index (IFI)



Source: Sirca et al., in preparation

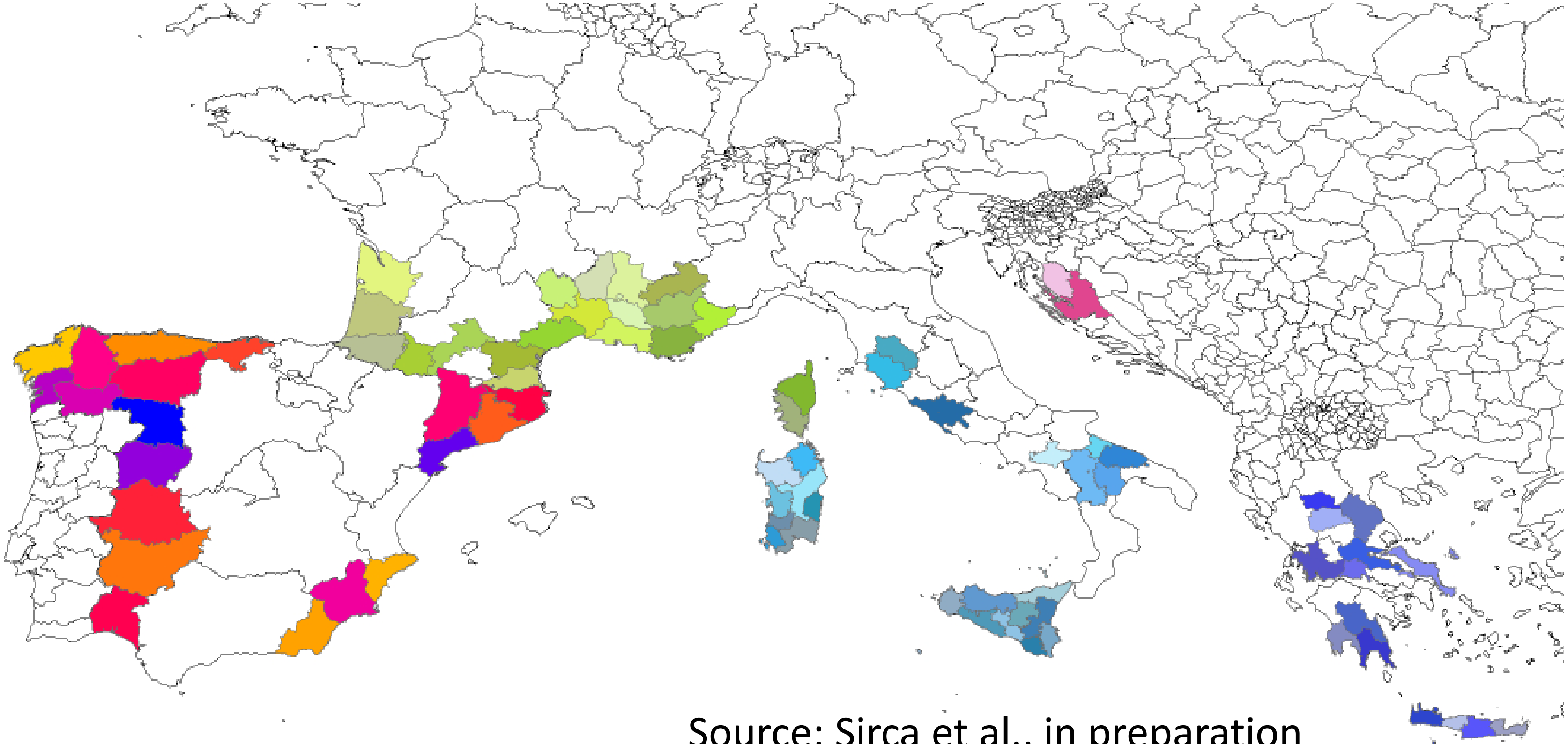
IFI – SPS OUTPUT



Source: Sirca et al., in preparation

Fire data for the validating analysis

67 hot spot areas (fire number and burned area data) (*source: JRC, Sardinia CFVA, Database Promethée, Generalitat de Catalunya*)

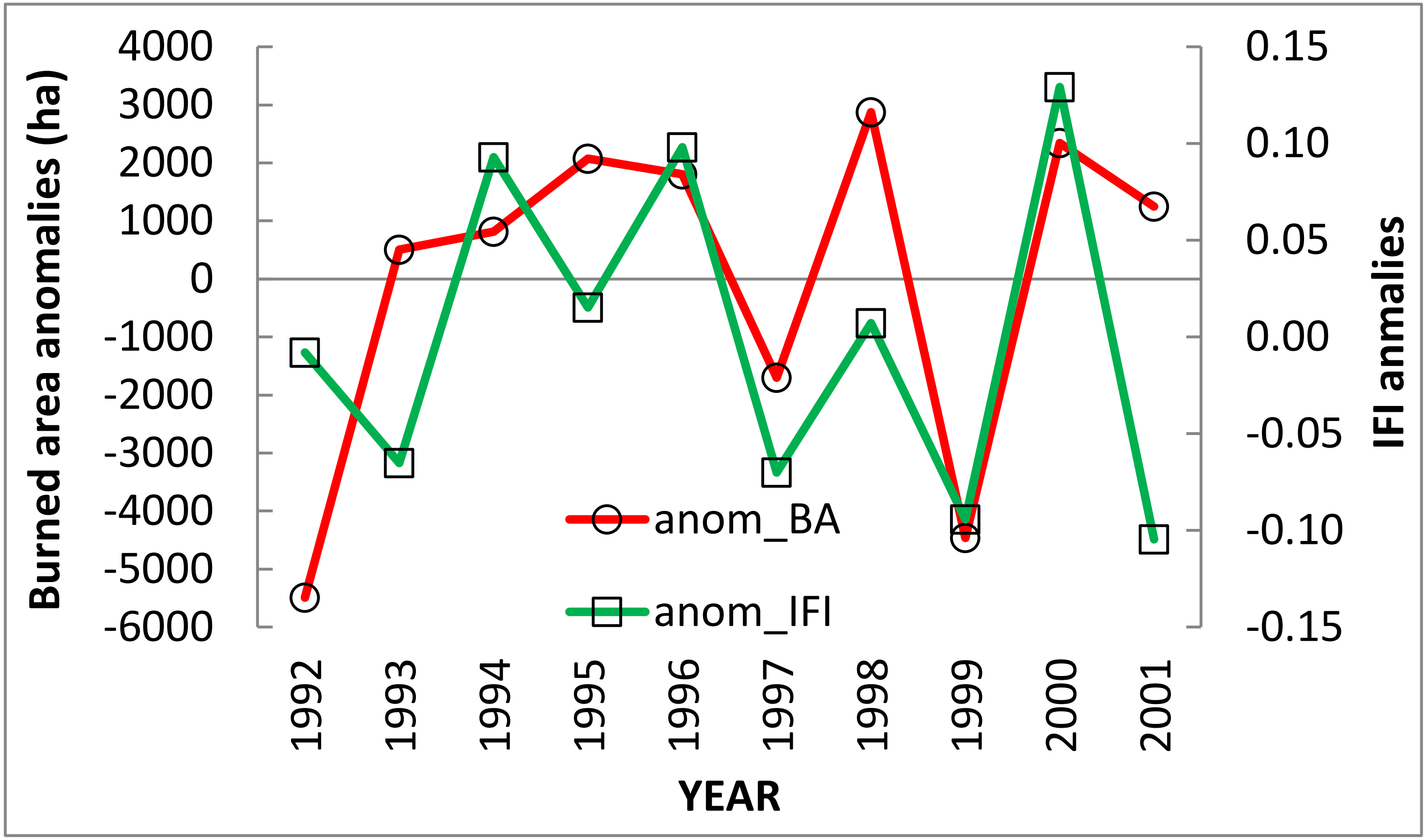


Source: Sirca et al., in preparation

Predictability of interannual fire occurrence

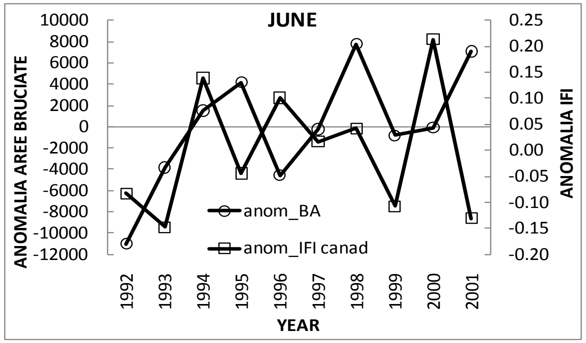
IFI and burned area anomalies

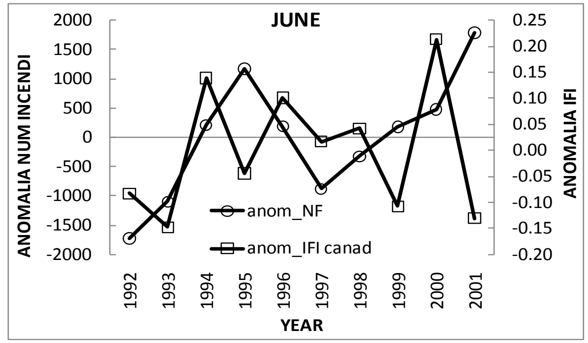
Spearman's rho = 0.56

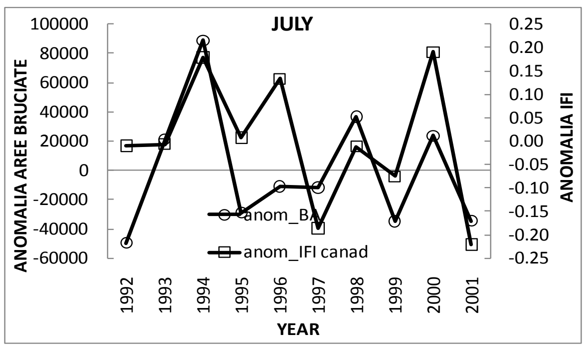


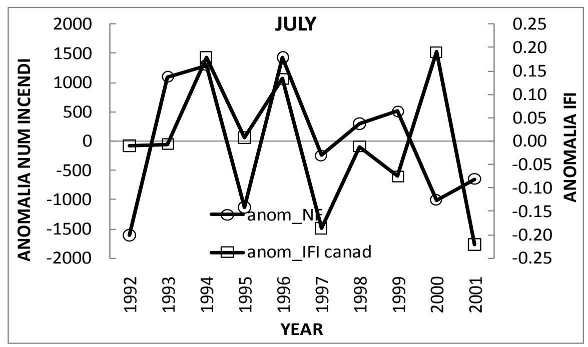
Source: Sirca et al., in preparation

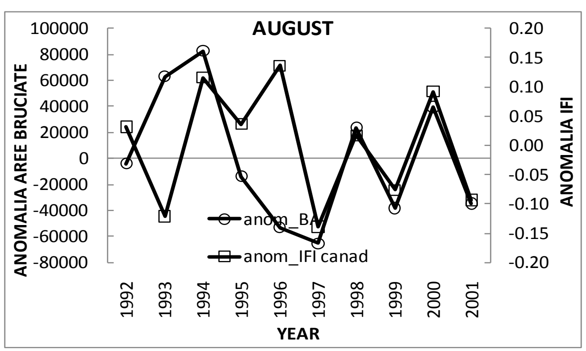
Inter-annual monthly anomalies of fire occurrence and IFI

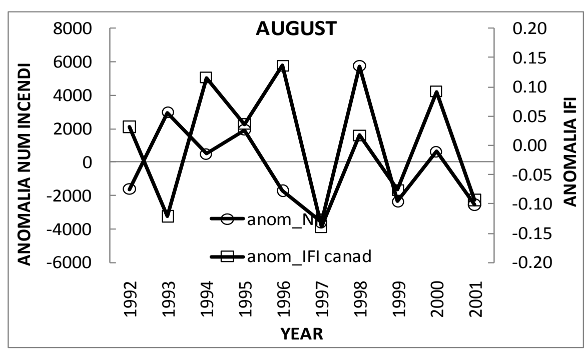












Spearman correlation coefficients at monthly scale

	BA
MAY	0.03
JUN	0.08
JUL	0.58
AUG	0.29
SEP	0.68
OCT	-0.14

Modèles pour prévenir, gérer et atténuer les risques d'incendie dans un climat changeant

Tools

Fire danger

IFI (Integrated Fire danger Index)

(Sirca et al., 2006)

→

- daily/seasonal fire danger forecast
- fire danger projections with future scenarios

Fire spread and behaviour

FARSITE, FlamMap, RANDIG

(Finney, 2003)

→

- fire behaviour and spread simulation
- fire spread and behaviour projections using future scenarios
- **assessing fire risk mitigation strategies** (prescribed fires, fuel reduction, etc.)

Fire emissions

FOFEM (Reinhardt, 1997)

→

- analysis of fuel consumption
-smoke characterization
-Fire emission mitigation

Main Applications

Overview of risk

- Risk is the chance that “something bad will happen”
- Combines likelihood with effects
- It is an expectation
- Developed for disaster management and insurance where uncertainty is high (large wildfires)
- Units are expectations ($, area, things, people, etc)

Source: Ager 2013, Master PIROS - UNISS

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"

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

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

Risk Assessment versus Mitigation

Assessment:

– Map risk factors and how they contribute to overall exposure risk

Mitigation

– Changing the expected outcome:

- Reduce wildfire probability $P(f_i)$
- Reduce fire intensity f_i
- Change the response function $R(f_i)$ to reduce suceptibility, minimizing the impact of fires

Source: Ager 2013, Master PIROS - UNISS

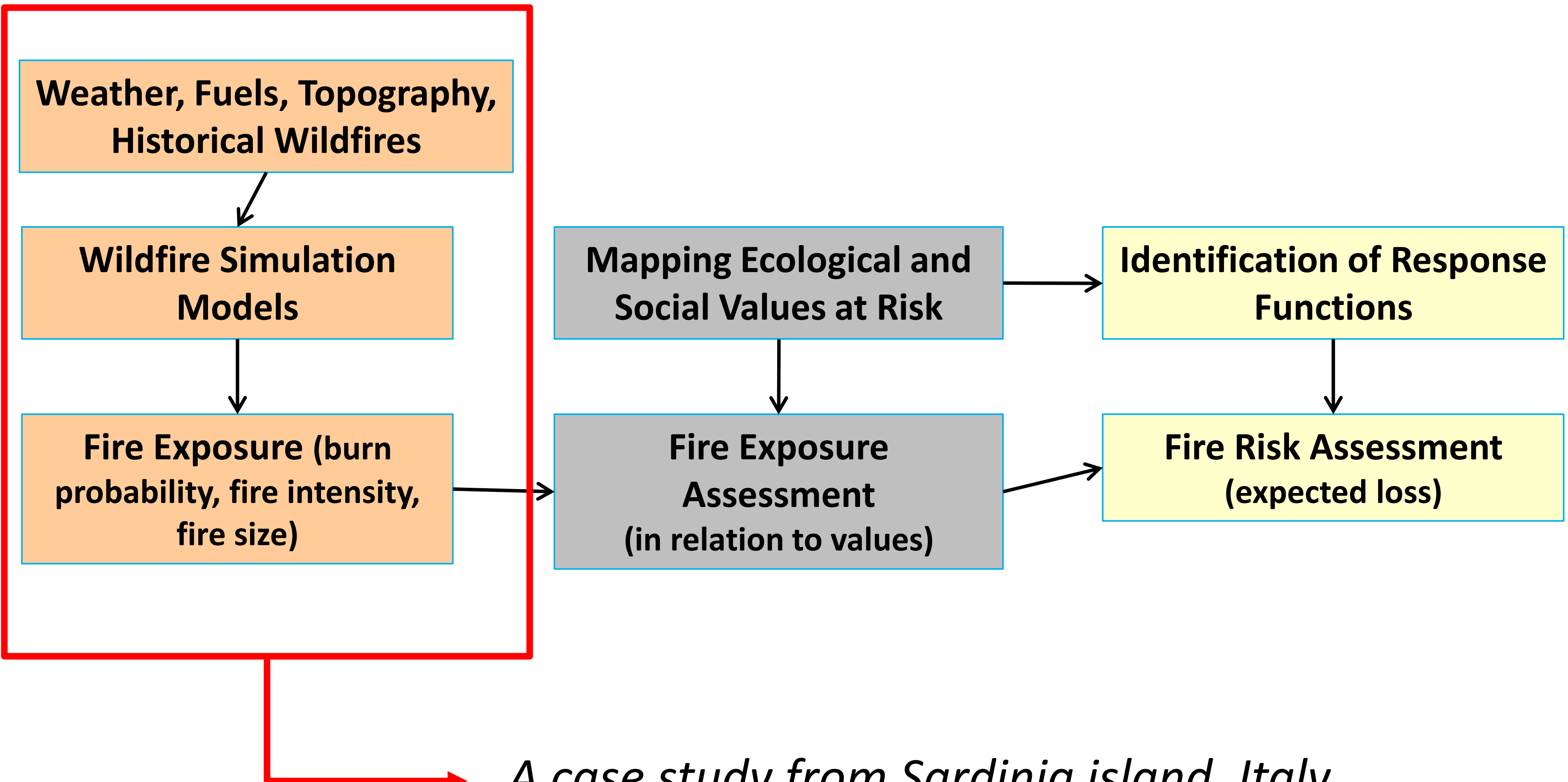
Why not just mitigate without an assessment?

Risk assessments help

- Identify the drivers of risk
- Identify leverage points
- Treatment strategies
- Cost effectiveness
- Prioritize activities

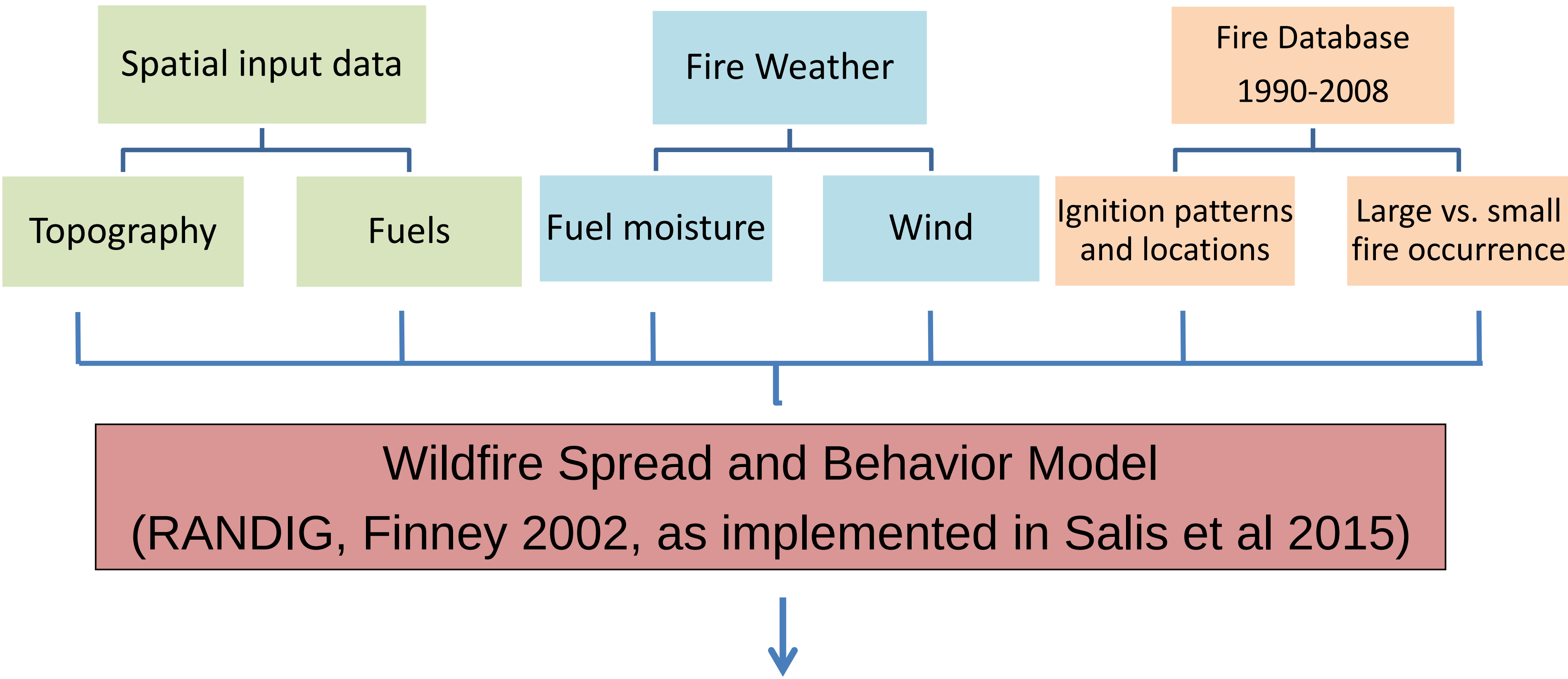
Source: Ager 2013, Master PIROS - UNISS

Wildfire Risk Assessment Framework



A case study from Sardinia island, Italy

"Assessing exposure of human and ecological values to wildfire in Sardinia, Italy"

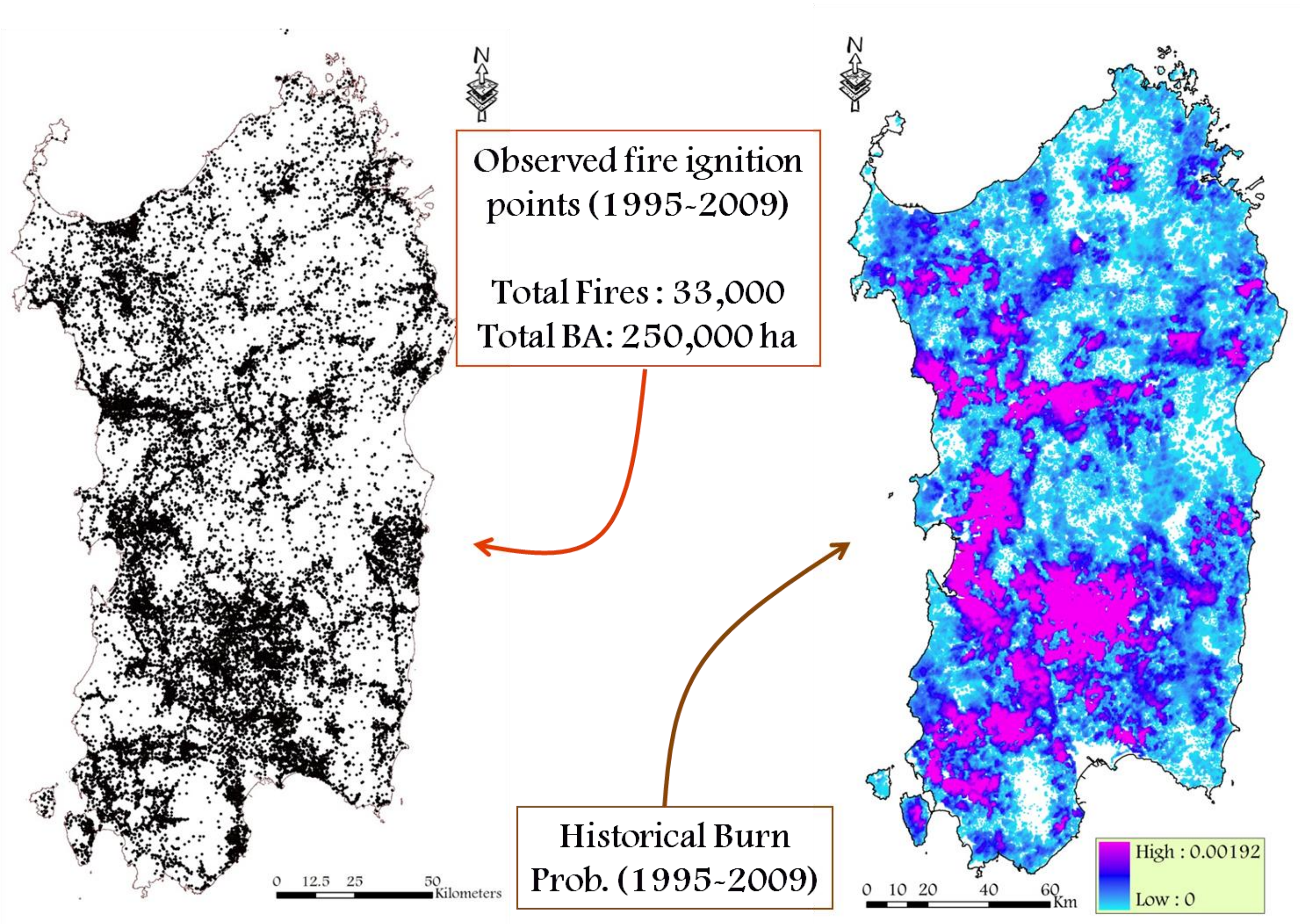


Burn probability (BP), Conditional flame length (CFL), Average fire size (FS), Fire potential index (FPI), etc.

Salis et al., 2013

"Assessing exposure of human and ecological values to wildfire in Sardinia, Italy"

Identification of areas characterized by high fire risk exposure



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Identification of areas characterized by high fire risk exposure

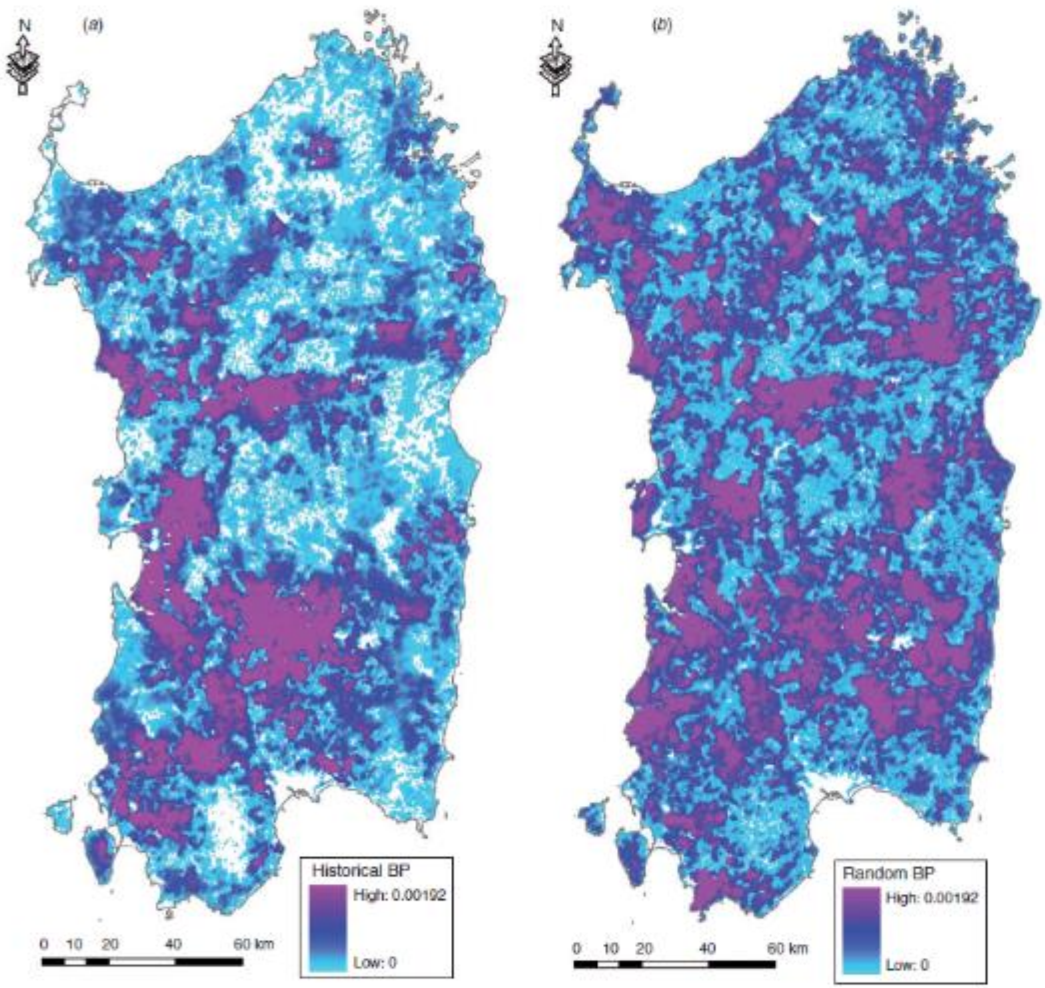
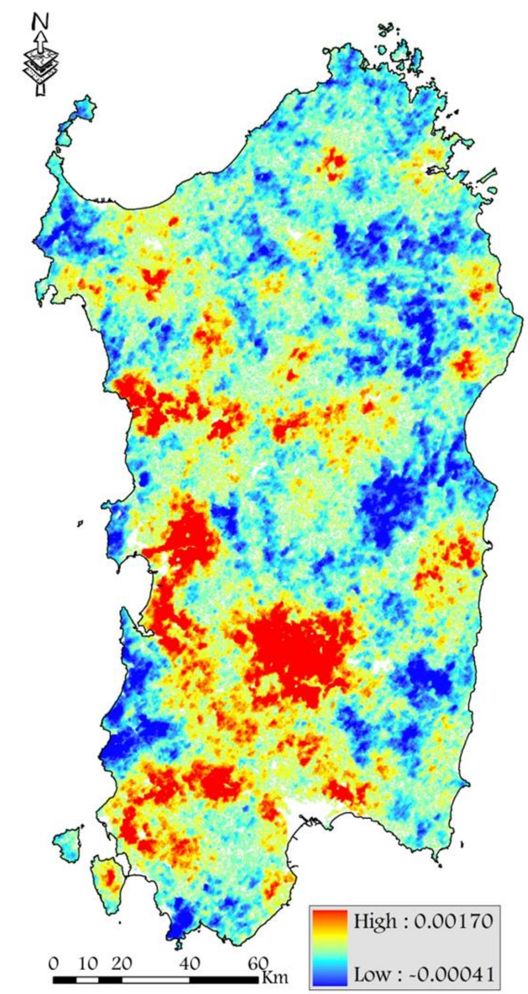
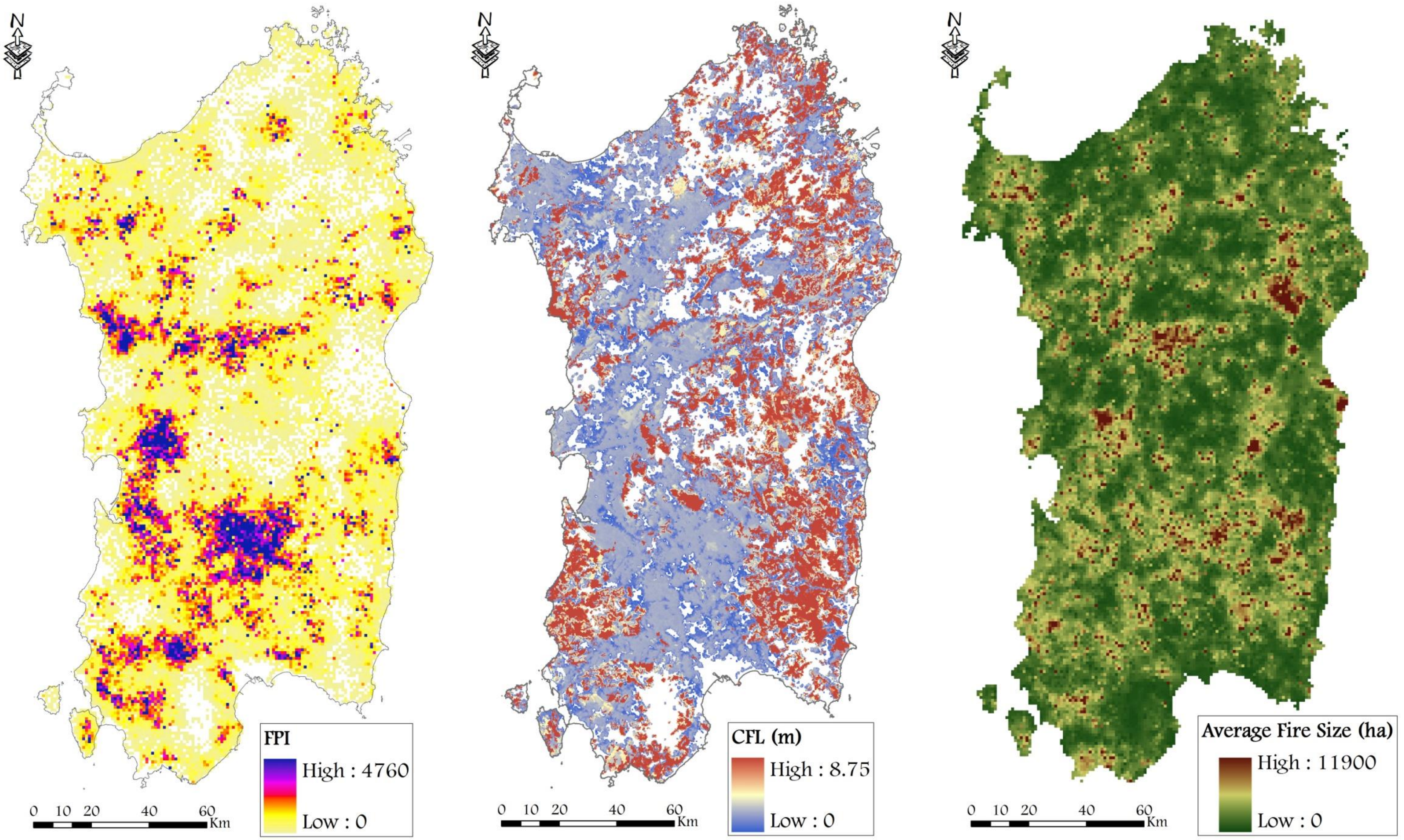


Fig. 9. Burn probability maps with ignition locations sampled from the historical grid (*a*) and randomly selected (*b*).



Salis et al., 2013

"*Assessing exposure of human and ecological values to wildfire in Sardinia, Italy*"



Salis et al., 2013

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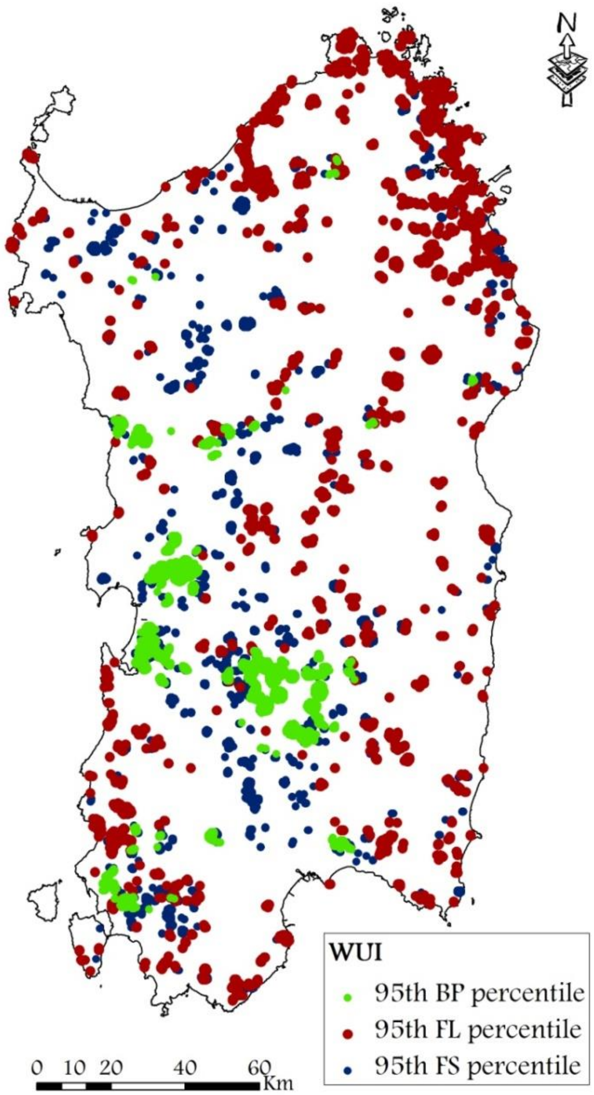
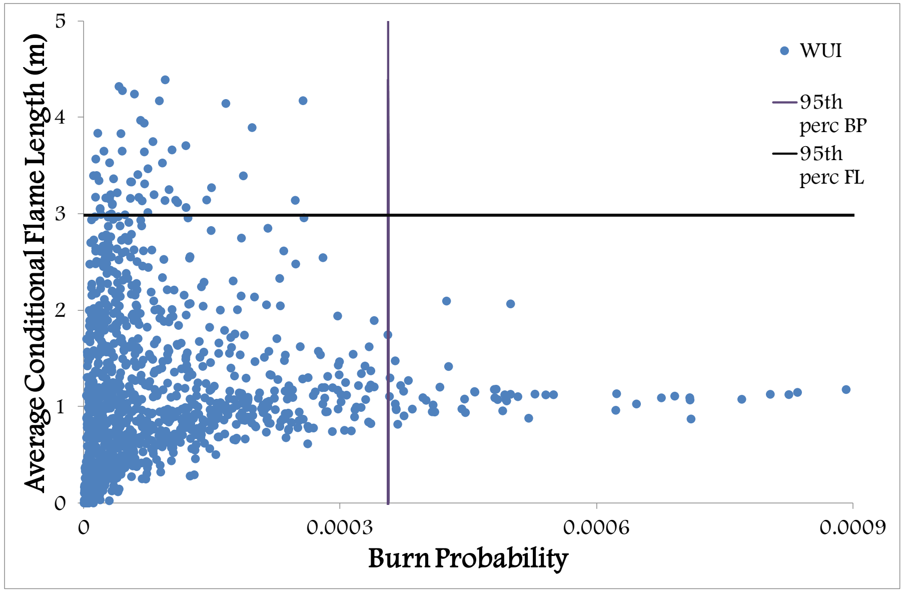
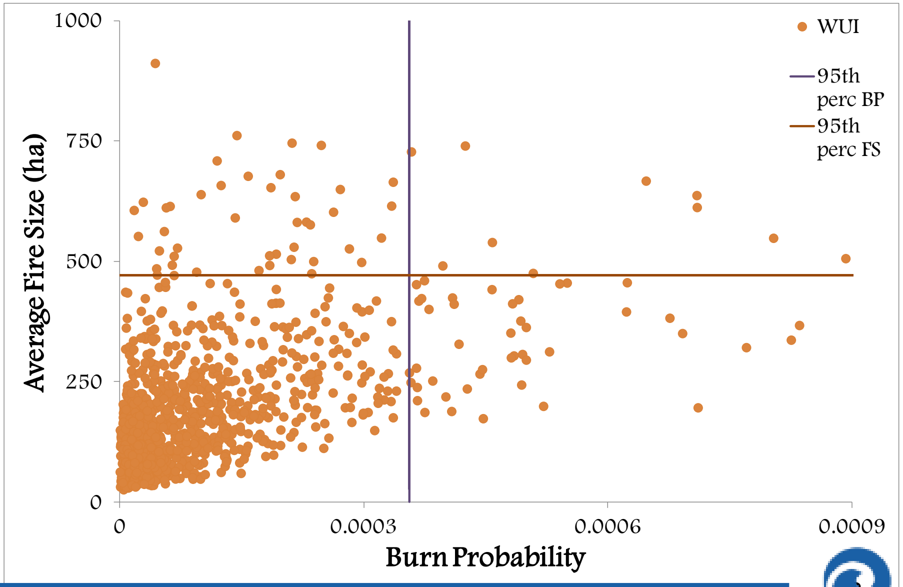


WUIs





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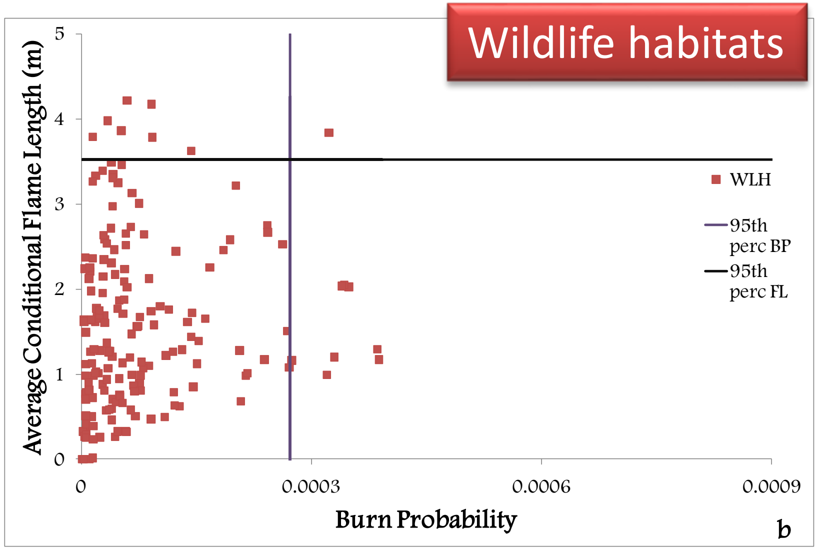
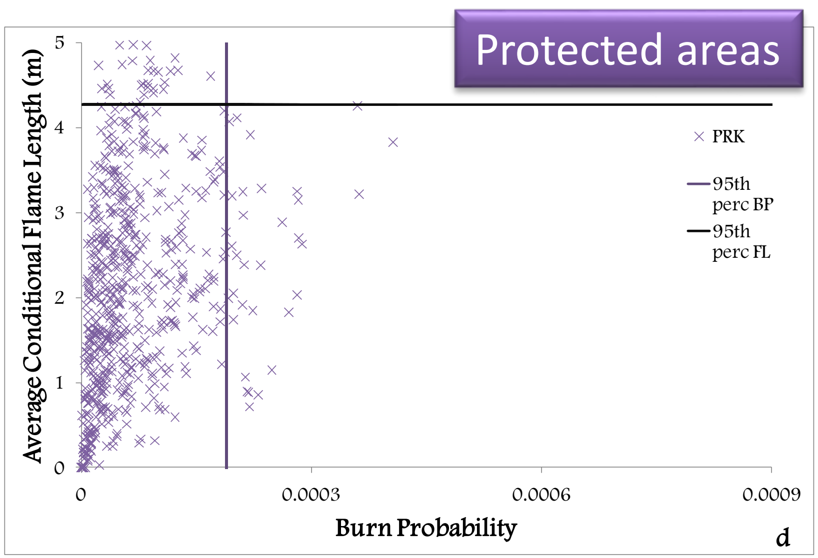
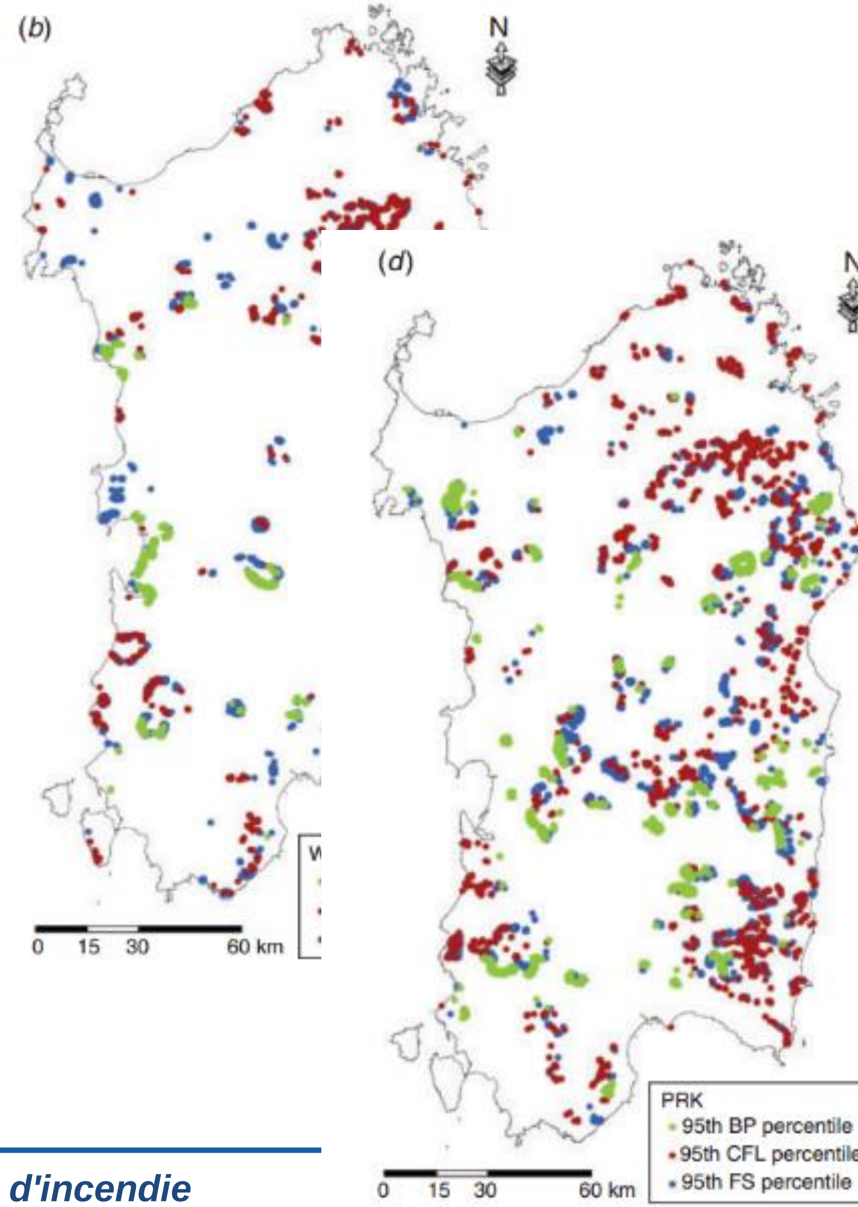
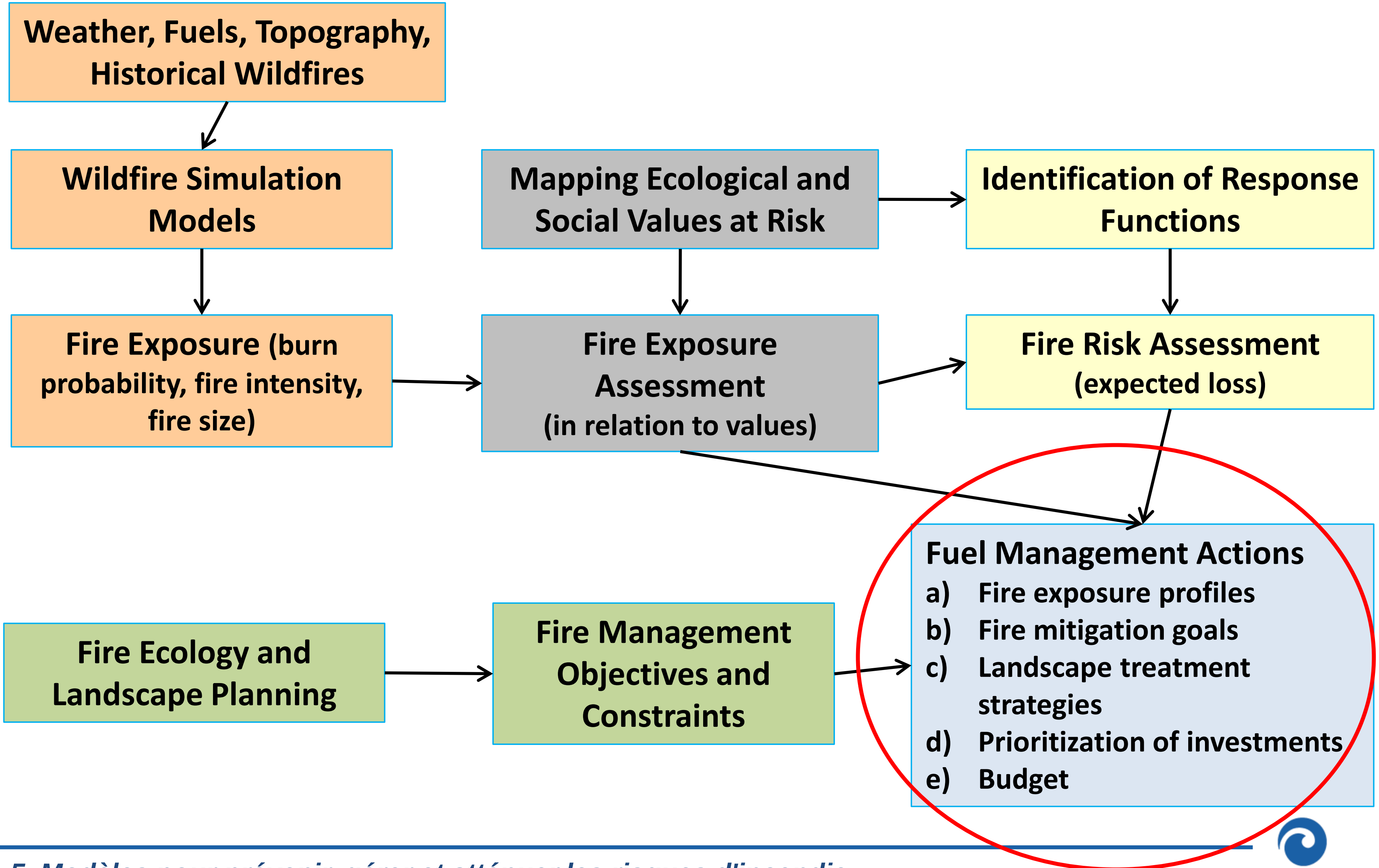






Wildfire Risk Assessment and Fuel Management Framework

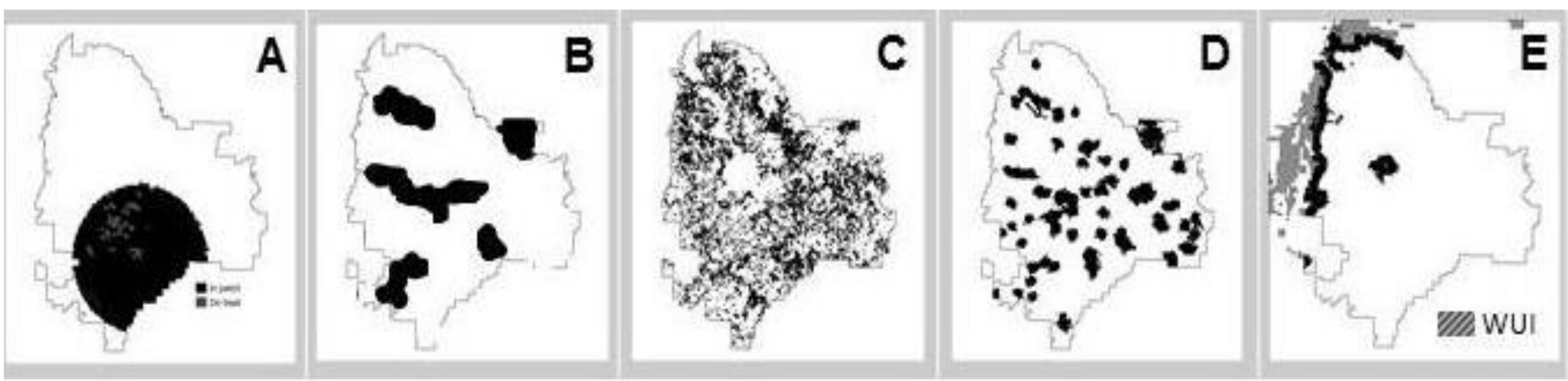


Fuel Management Strategies

There are many fuel management strategies

Restoration of fire adapted forests → **Protection from fire**

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



Black areas represent treatment units

Source: Ager 2013

Fuel Management Strategies

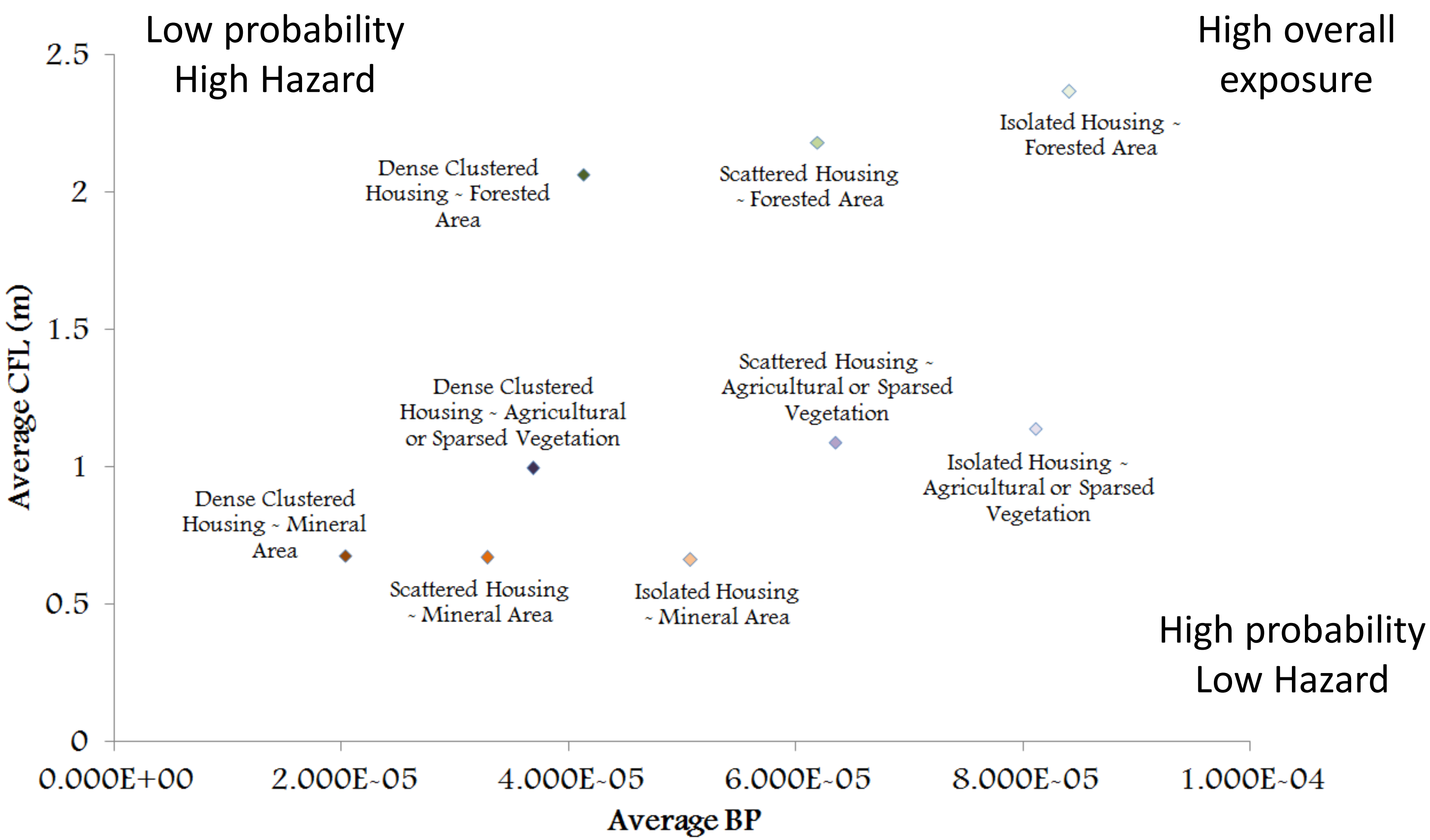
Fuel management techniques

- Prescribed burning
  - **Intentional ignition of fuels for specific management purposes**
- Mechanical treatments
  - **Pruning, thinning**
- Controlled grazing
  - **allowing farm animals to graze a field for a brief period of time**

- Reduces spread rate and intensity
- Facilitate suppression and containment
- Reduces escape rate

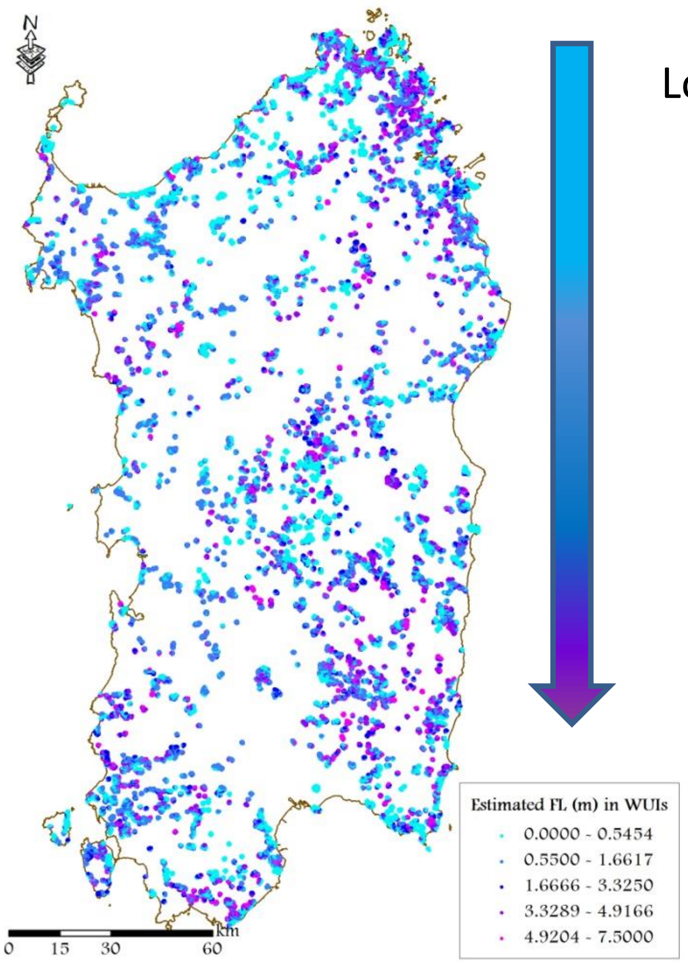
Wildfire Risk Assessment and Fuel Management Framework

Prioritize fuel management based on exposure plots



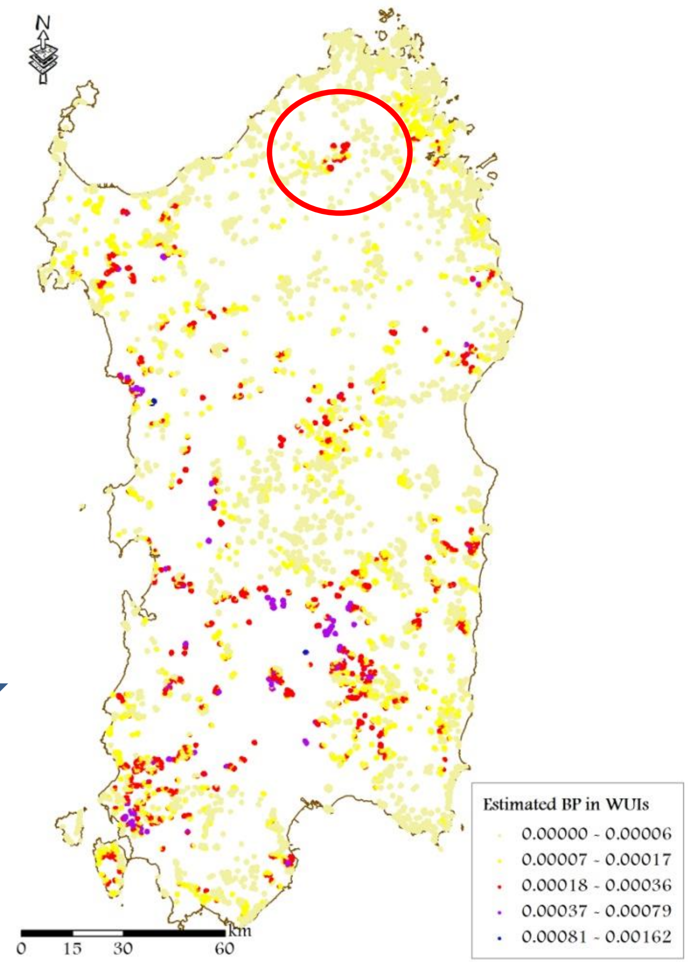
Wildfire Risk Assessment and Fuel Management Framework

Prioritize fuel management based on exposure plots



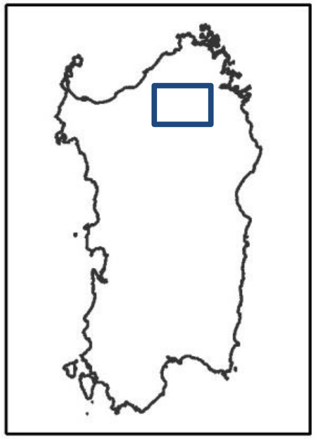
Low probability
Low Hazard

High overall
exposure



Fire Risk Management in Sardinia

(Salis et al., in prep.)



SIMULATIONS

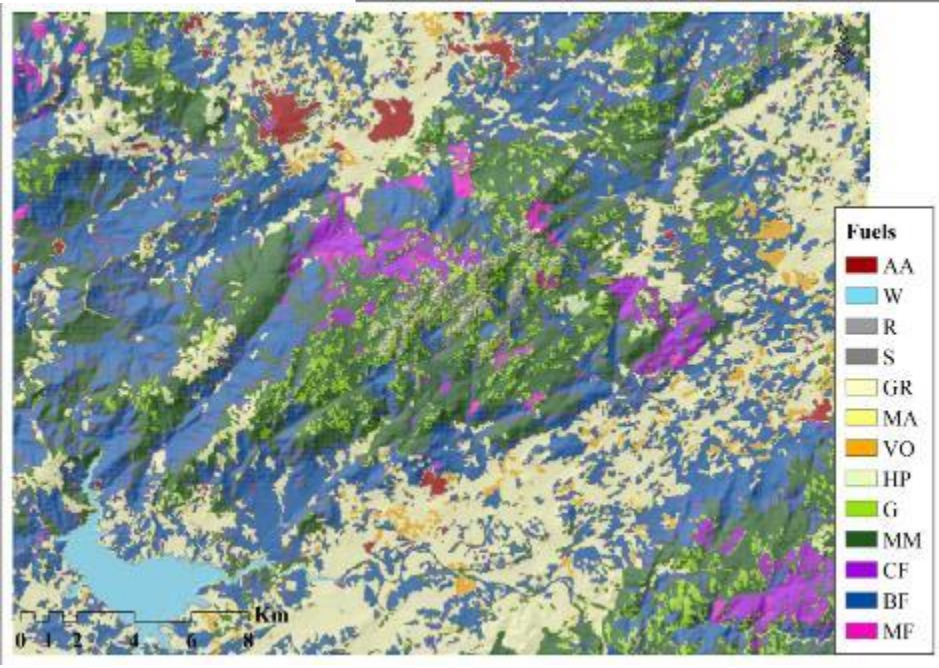
Randig, MTT algorithm (Finney 2002)

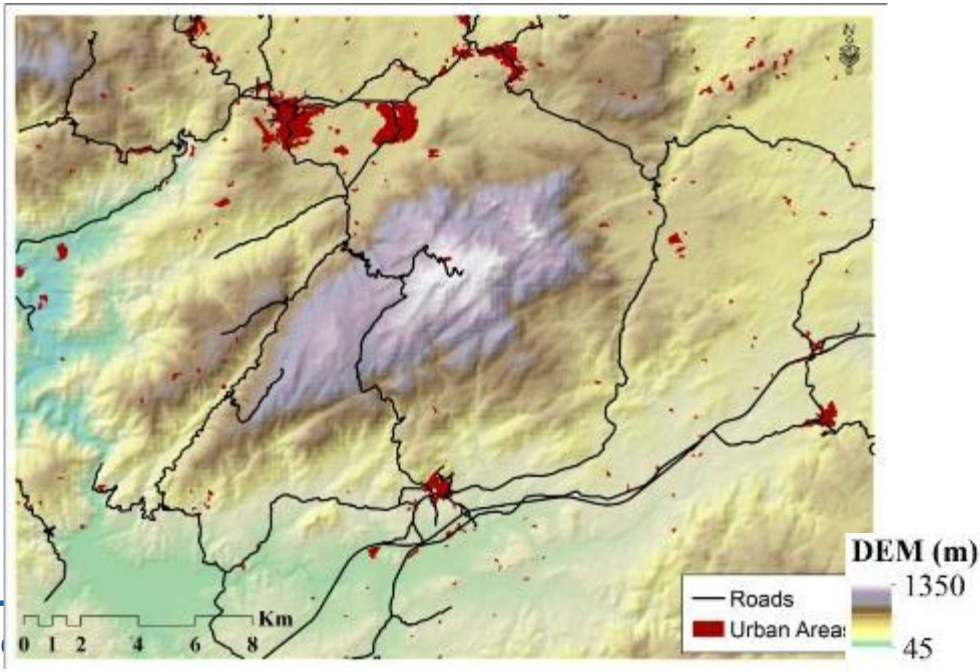
Data resolution: 50 m over 700 km2 (North Sardinia)

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

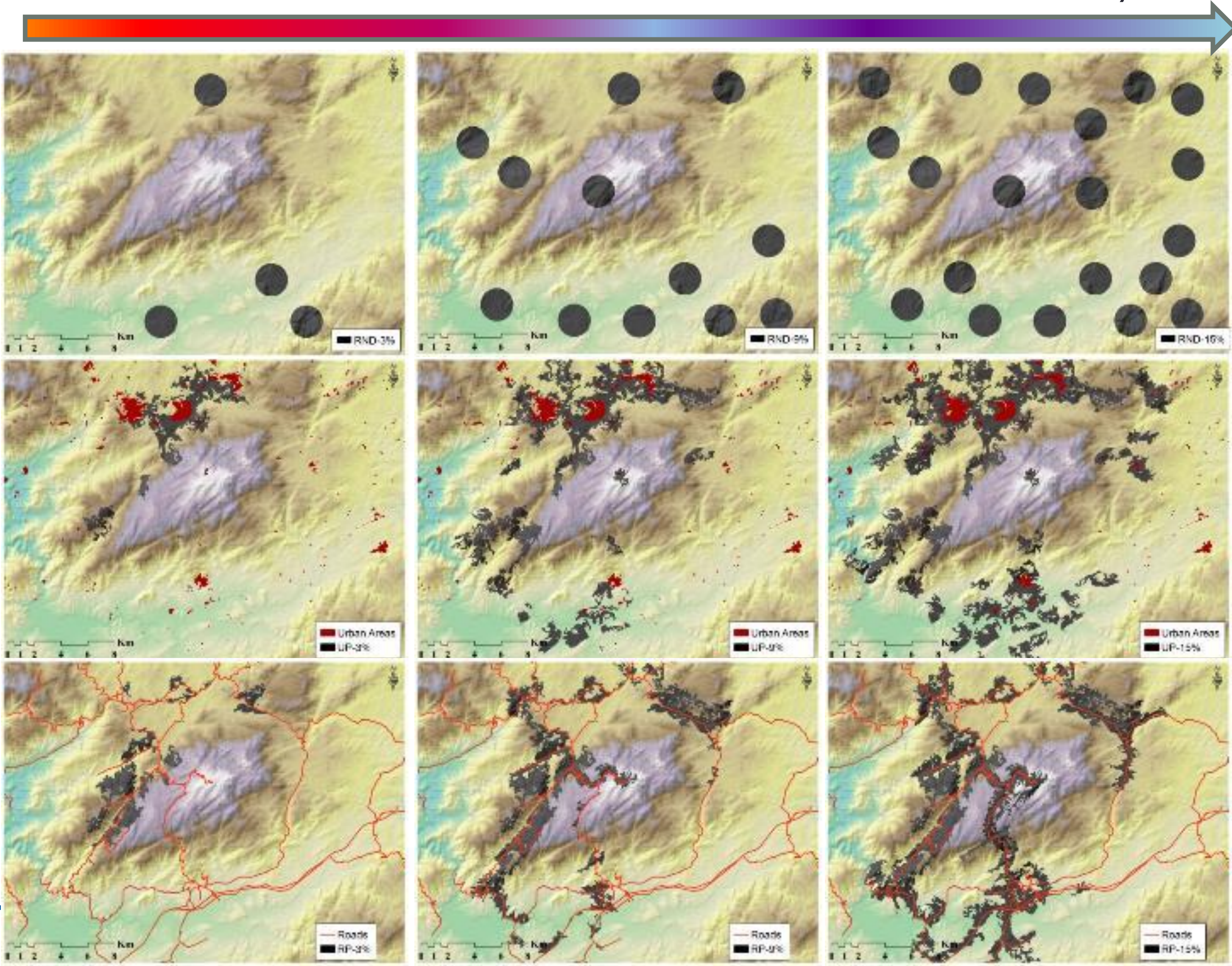




Fire Risk Management in Sardinia

(Salis et al., in prep.)

Area Treated, Cost, Risk reduction,
Teams, Time , Work



No Priorities: Random Areas

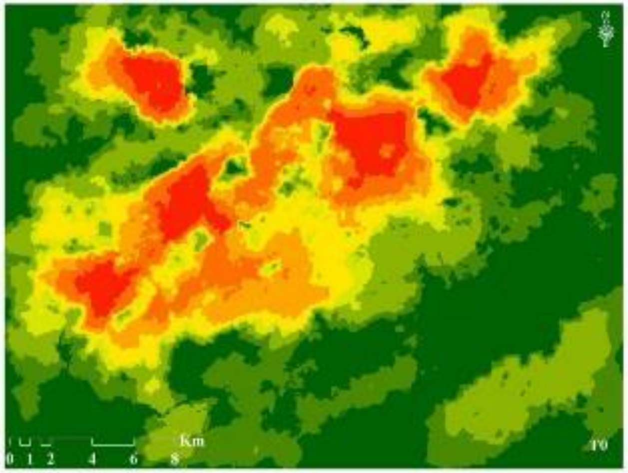
Priority: Urban Protection

Priority: Road Protection

Fire Risk Management in Sardinia

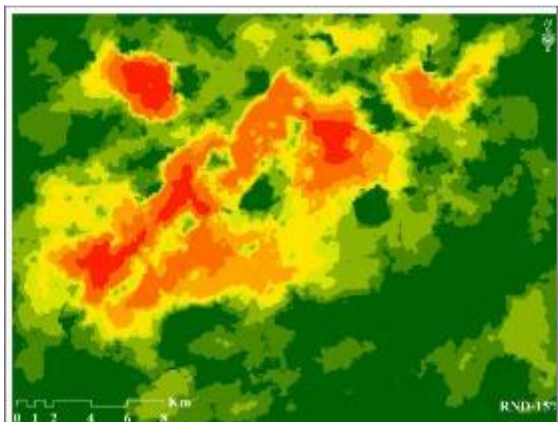
No Treatment

(Salis et al., in prep.)

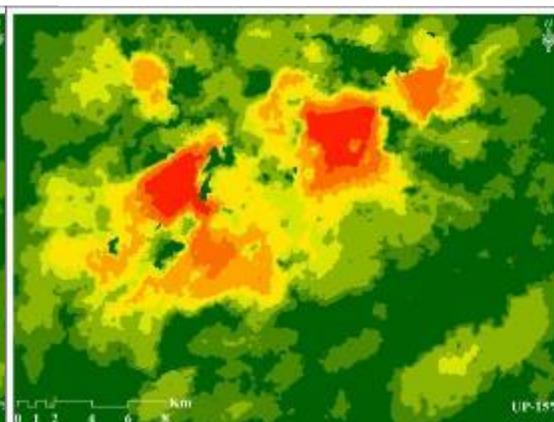


Spatial variation in burn probability (BP) with the diverse fuel treatment strategies

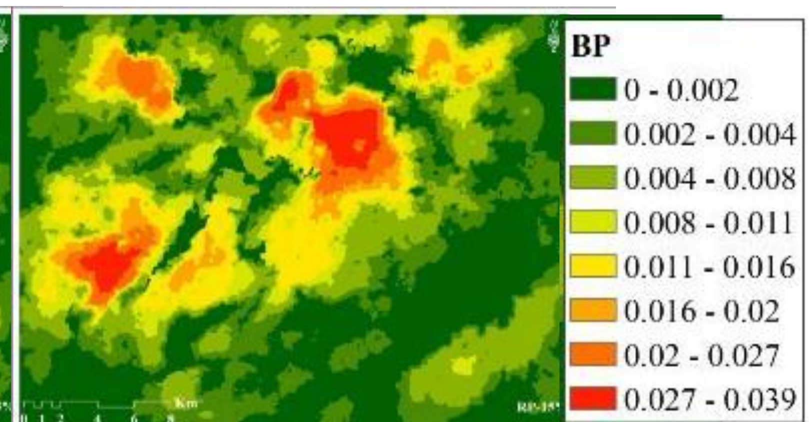
Random



Urban Protection



Road Protection

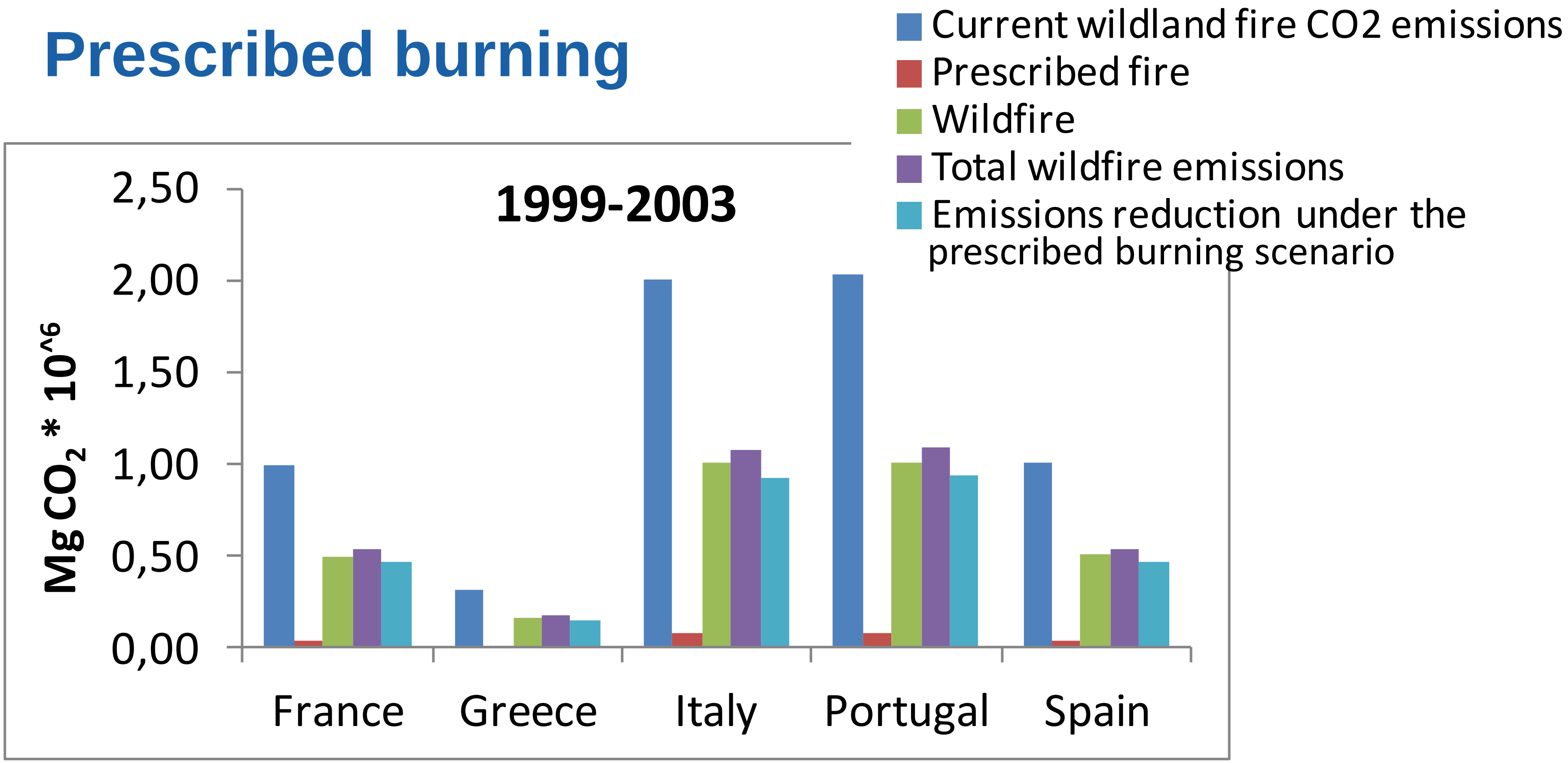


Modèles pour prévenir, gérer et atténuer les risques d'incendie dans un climat changeant

Tools		Main Applications
Fire danger IFI (Integrated Fire danger Index) (Sirca et al., 2006)	→	- daily/seasonal fire danger forecast - fire danger projections with future scenarios
Fire spread and behaviour FARSITE, FlamMap, RANDIG (Finney, 2003)	→	- fire behaviour and spread simulation - fire spread and behaviour projections using future scenarios - assessing fire risk mitigation strategies (prescribed fires, fuel reduction, etc.)
Fire emissions FOFEM (Reinhardt, 1997)	→	- analysis of fuel consumption -smoke characterization -Fire emission mitigation

Fire Emission Mitigation Strategies

Prescribed burning



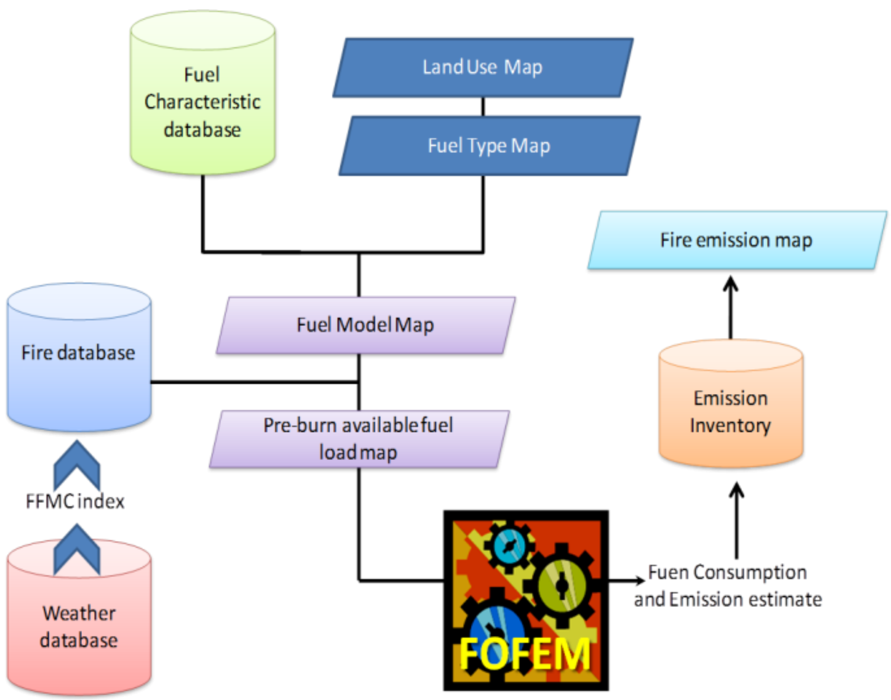
46% Emissions reduction

Source: Narayan et al., 2007

Fire Emission Mitigation Strategies

(Bacciu et al., in prep.)

Potential of fuel management practices evaluation in mitigating emissions from forest fires, also taking into account the carbon loss by treatments and fires under the treatments



Fire Emission Mitigation Strategies

(Bacciu et al., in prep.)

Pre

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and her
-30% re

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60% reductio

Shrub fu

It is assumed
30% reductio

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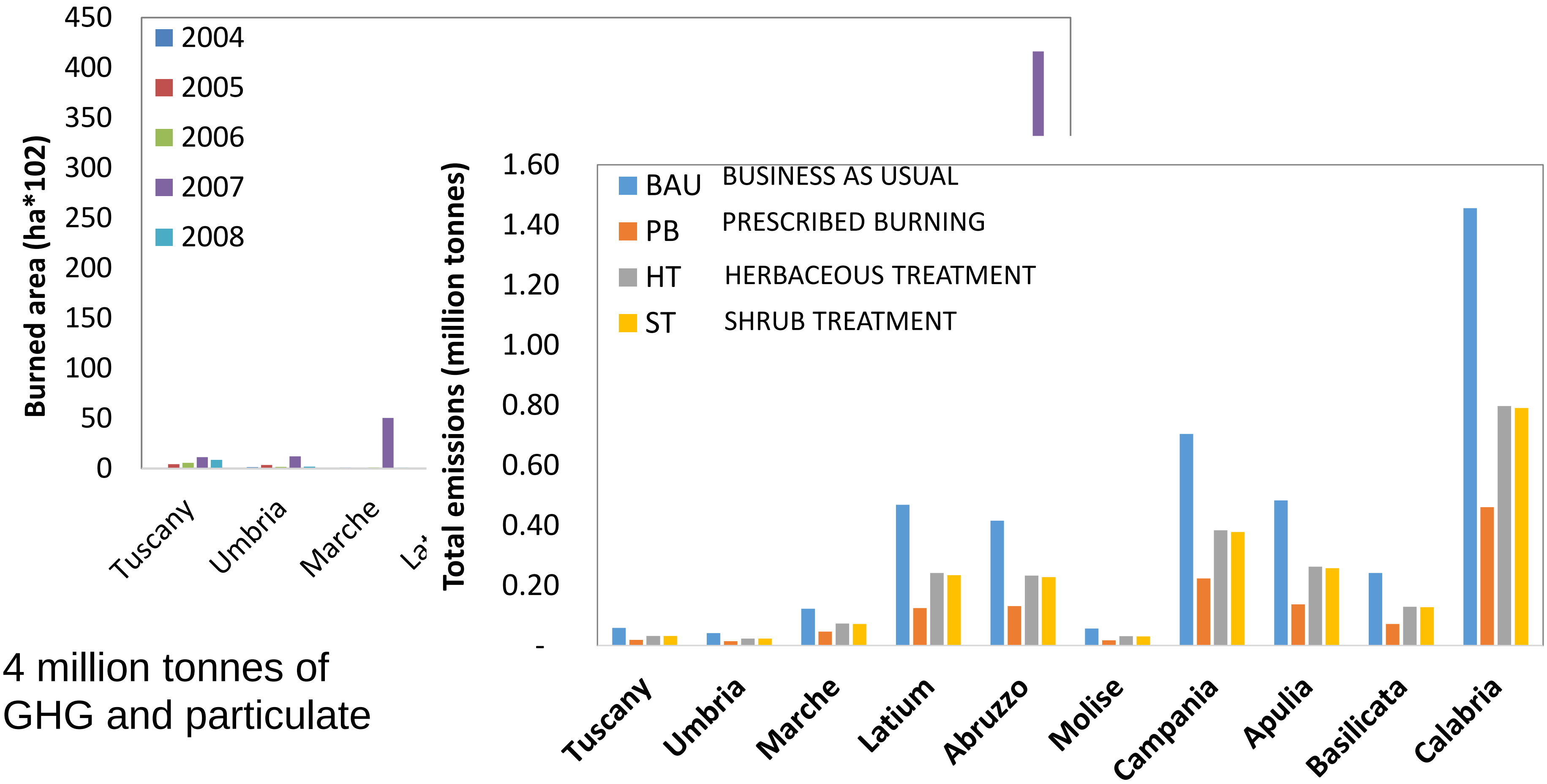
fire of 5

Duff and crown fuel consumption

It is assumed that the comsumption of duff, live tree foliage and branches depends on the burn severity: the % of combusted fuel is determined according to the fuel moisture group.

Fire Emission Mitigation Strategies

(Bacciu et al., in prep.)



4 million tonnes of GHG and particulate

PB reduction -> 2.8 million tonnes

HT/ST reduction -> 1.8 million tonnes

Final remarks

1. Impacts of climate change are **extremely varied** between and within regions

2. **Regional risk** as**sessment** is essential and needs the contribution of the different sectors

3. Adaptation options need to be developed at **regional/local scale** based on detailed *Climate Resilience Studies*

شكرا Merçi **Thanks**

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Costantino Sirca, Alan Ager, Mark Finney, Bachisio Arca

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici