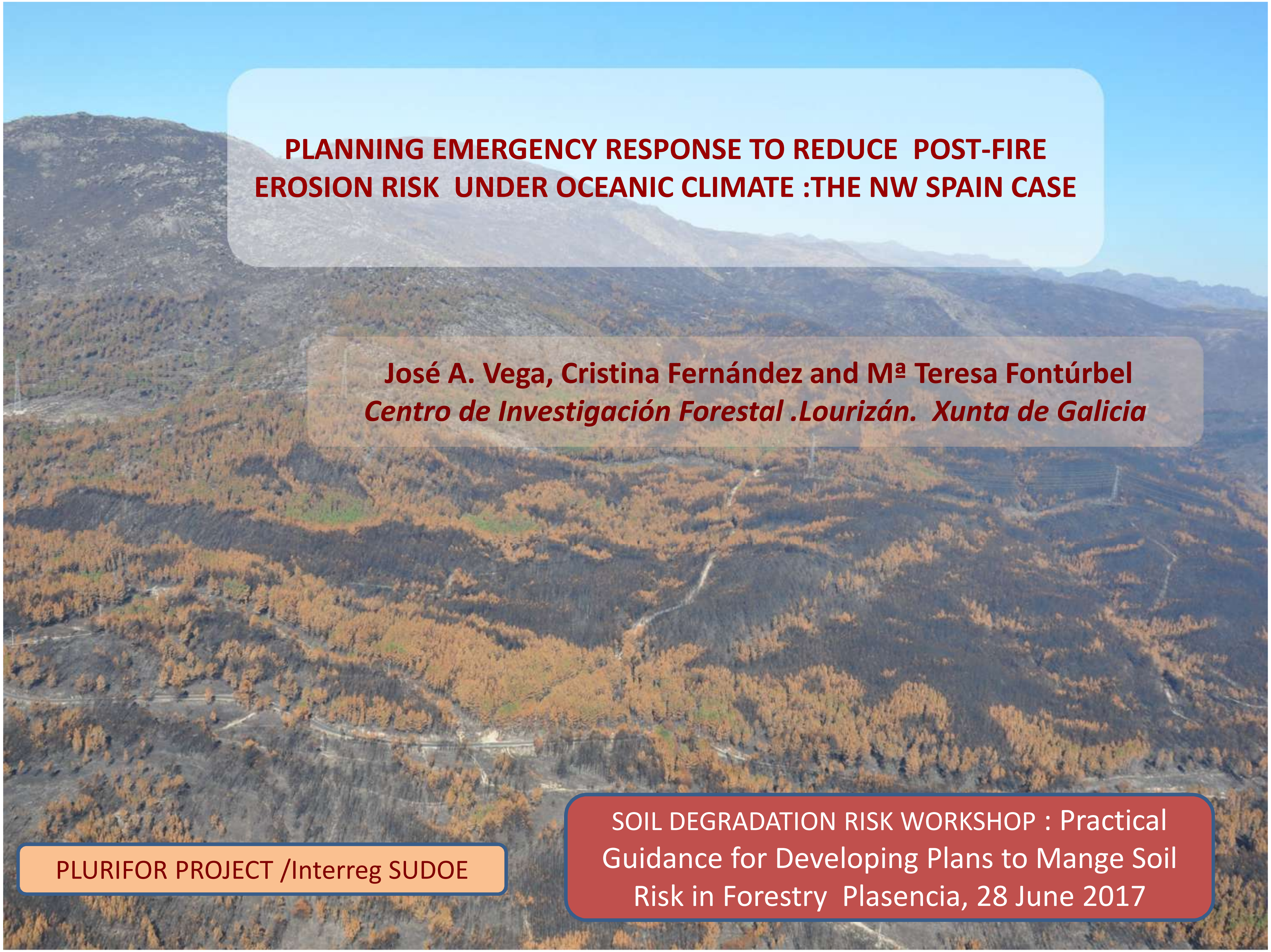


PLANNING EMERGENCY RESPONSE TO REDUCE POST-FIRE EROSION RISK UNDER OCEANIC CLIMATE :THE NW SPAIN CASE

José A. Vega, Cristina Fernández and Mª Teresa Fontúrbel
Centro de Investigación Forestal .Lourizán. Xunta de Galicia

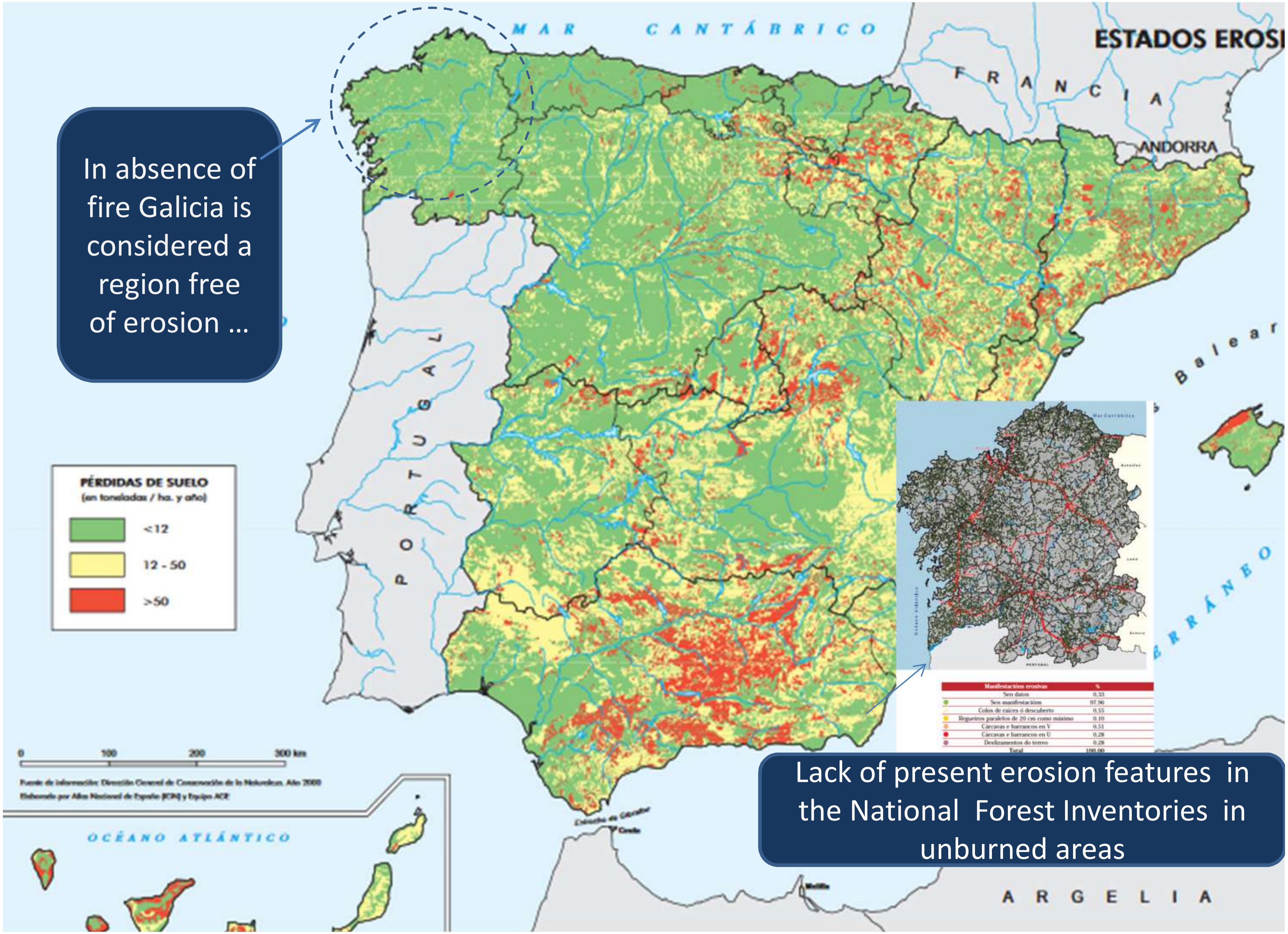
PLURIFOR PROJECT /Interreg SUDOE

SOIL DEGRADATION RISK WORKSHOP : Practical Guidance for Developing Plans to Mange Soil Risk in Forestry Plasencia, 28 June 2017

Outline

- The scenario
- Post -fire rehabilitation protocols: a meeting point between researchers and managers.
- Coping with fire severity evaluation issue
- Going from research to operational scale: The Galicia case.
- Post-fire risk management needs

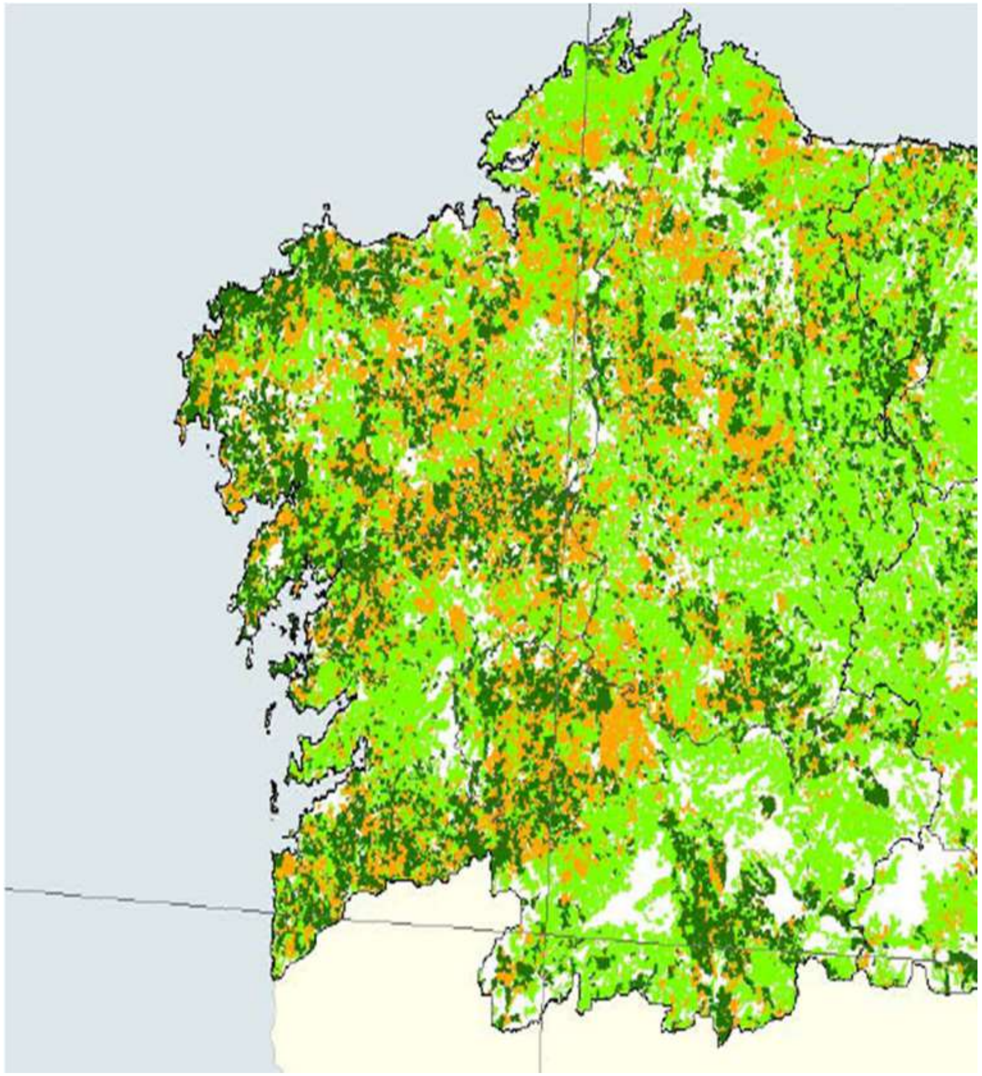

Which are the main distinctive features of NW Iberia in terms of post-fire erosive risk?



Manifestacións erosivas	%
Sen datos	0.33
Sen manifestacións	97.96
Colos de raíces ó descuberto	0.55
Regueiros paralelos de 20 cm como máximo	0.10
Cárcavas e barrancos en V	0.51
Cárcavas e barrancos en U	0.28
Deslizamentos do terreo	0.28
Total	100.00

In absence of fire Galicia is considered a region free of erosion ...

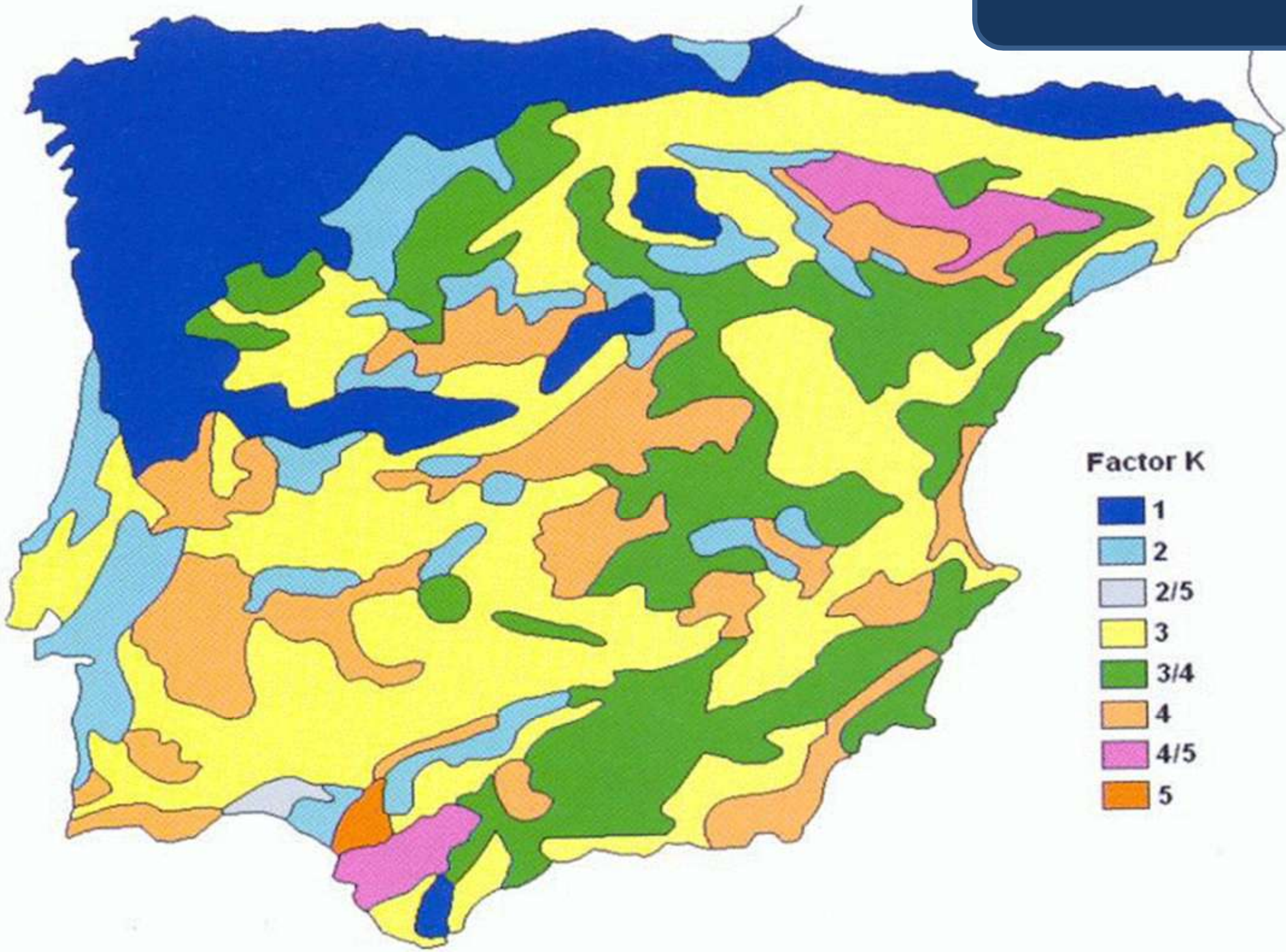
Lack of present erosion features in the National Forest Inventories in unburned areas



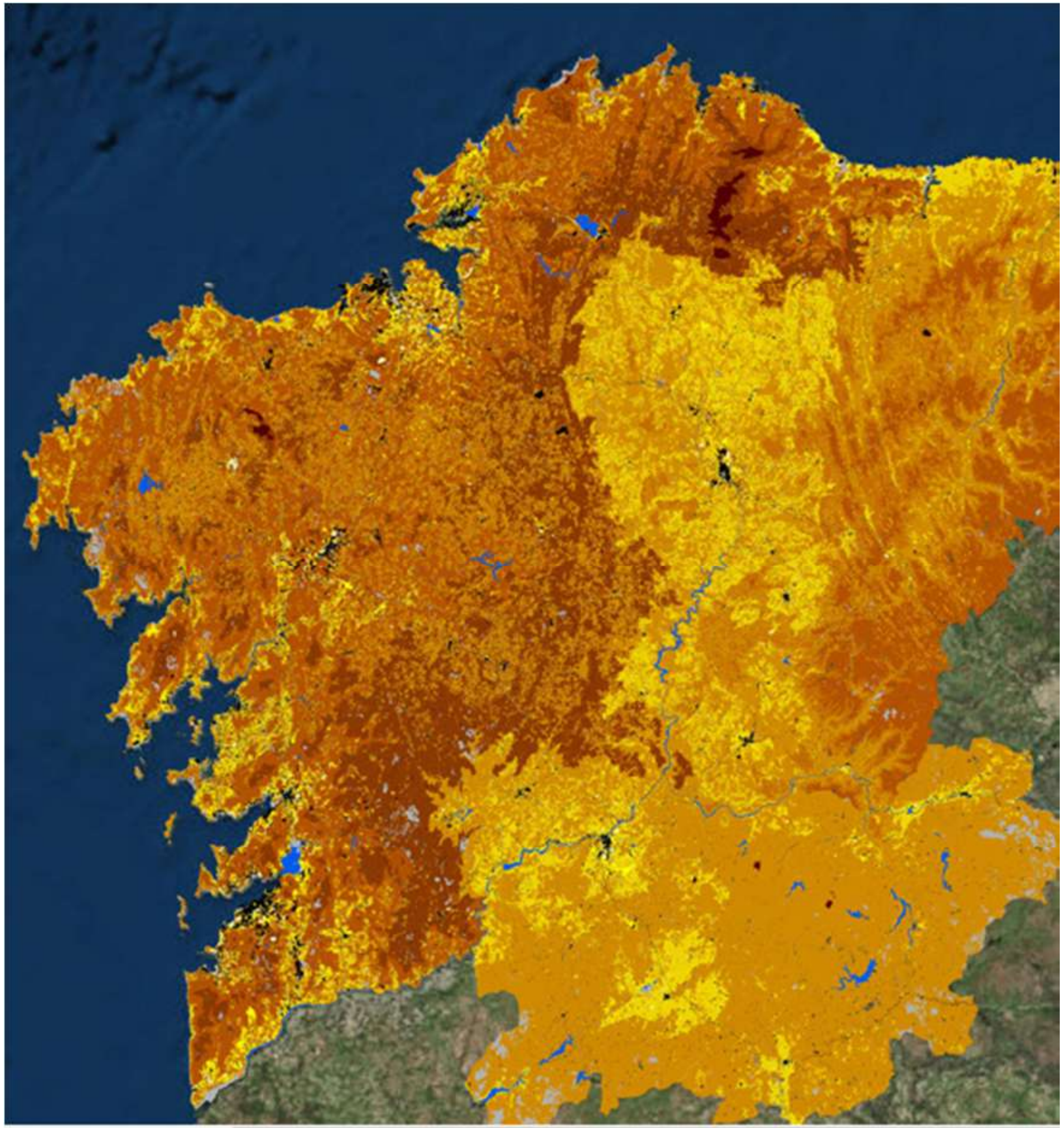
About 2/3 of its territory is covered by forest vegetation:plantations, (mainly *E.globulus* and *P.pinaster*), native forest (largely *Q.robur* and *Q.pyrenaica),* totalizing about 1,5 .10^6 ha and shrublands (*Ulex* spp. and *Erica* spp.) occupying around 600,000 ha

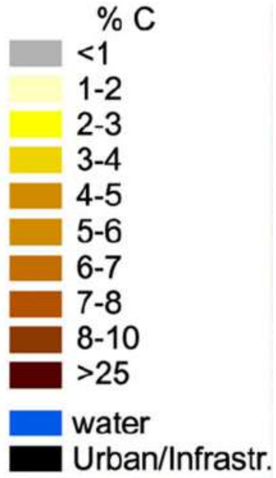
The Galician forest makes up 7,5 % of the Spain forested area and shrubland 6,5% of the corresponding area in Spain

Soils with low erodibility,



Undisturbed soil erodibility classes in Iberia (k factor of the USLE, Mg m^2 h ha^{-1}J cm^{-1}) according soil properties (Diaz-Fierros and Benito, 1996) in unburned soils

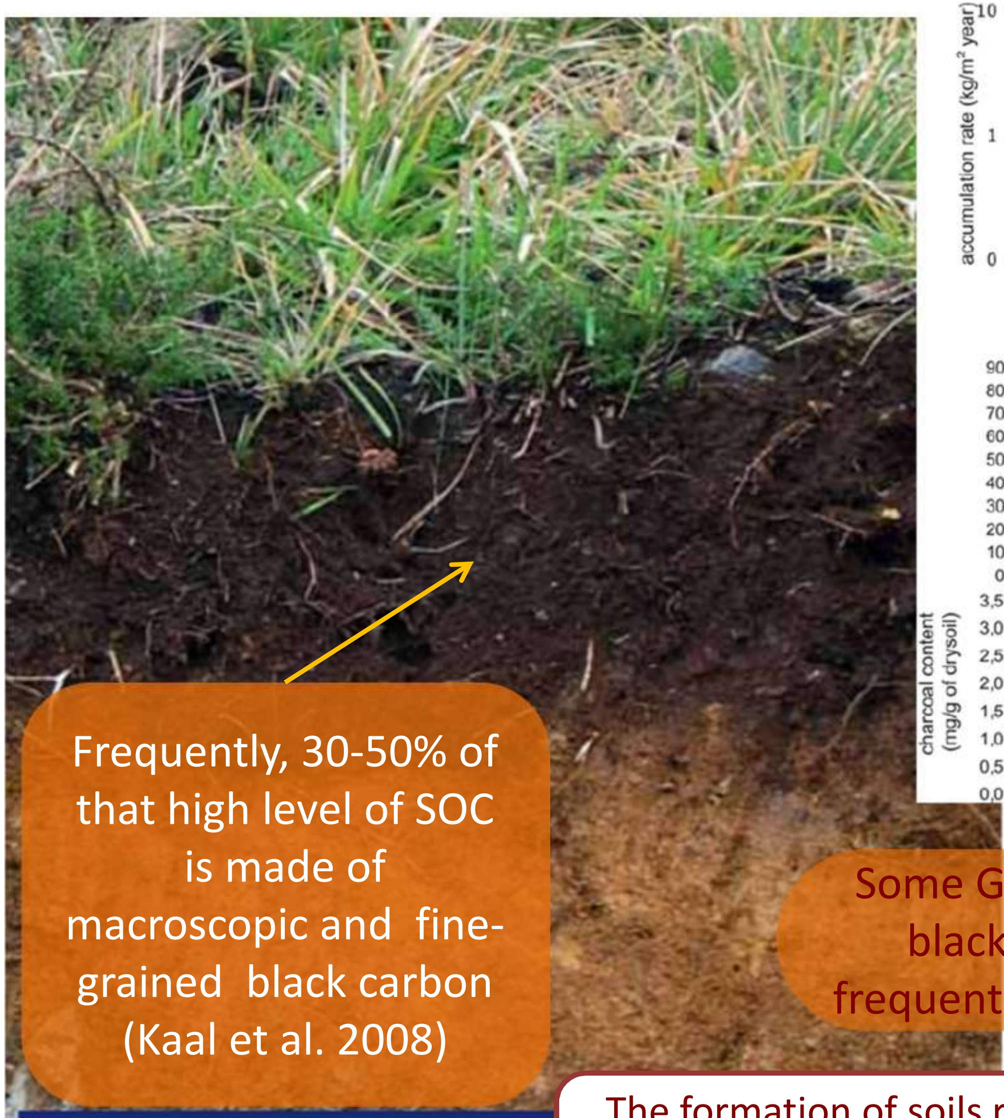


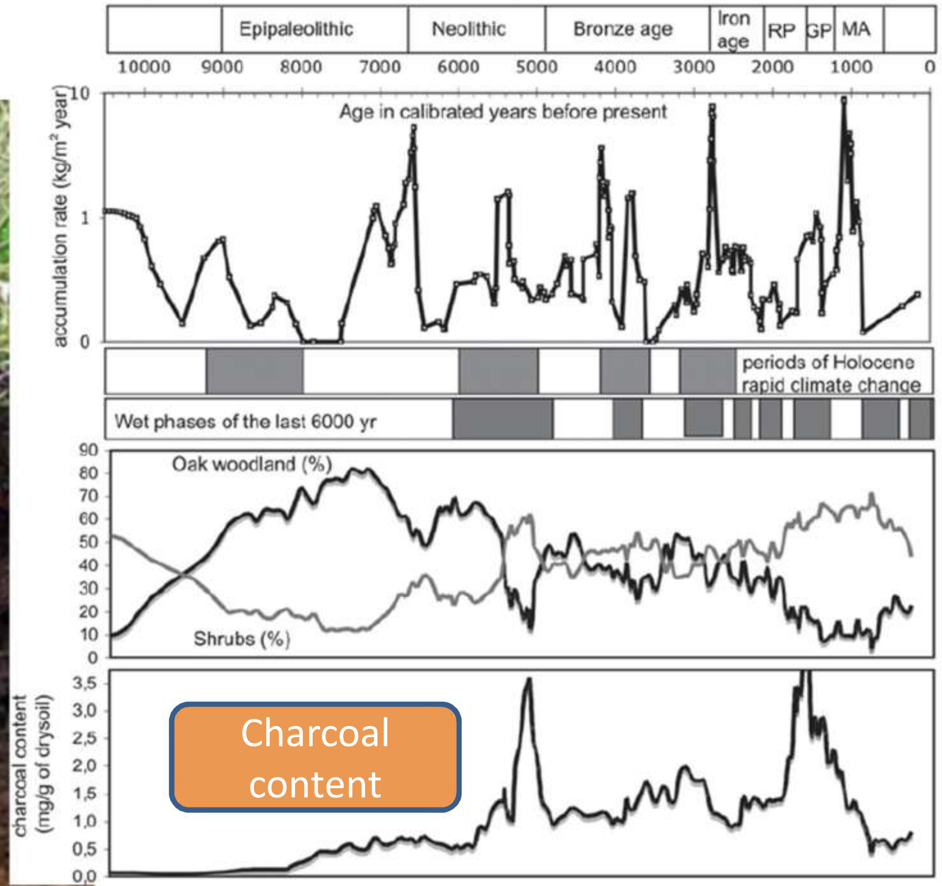


Relatively high organic C content (SOC) , compared to other forest areas

That favours:

•Good structure
*High aggregate stabil ity.
*combined with coarse texture , elevated infiltation rate.

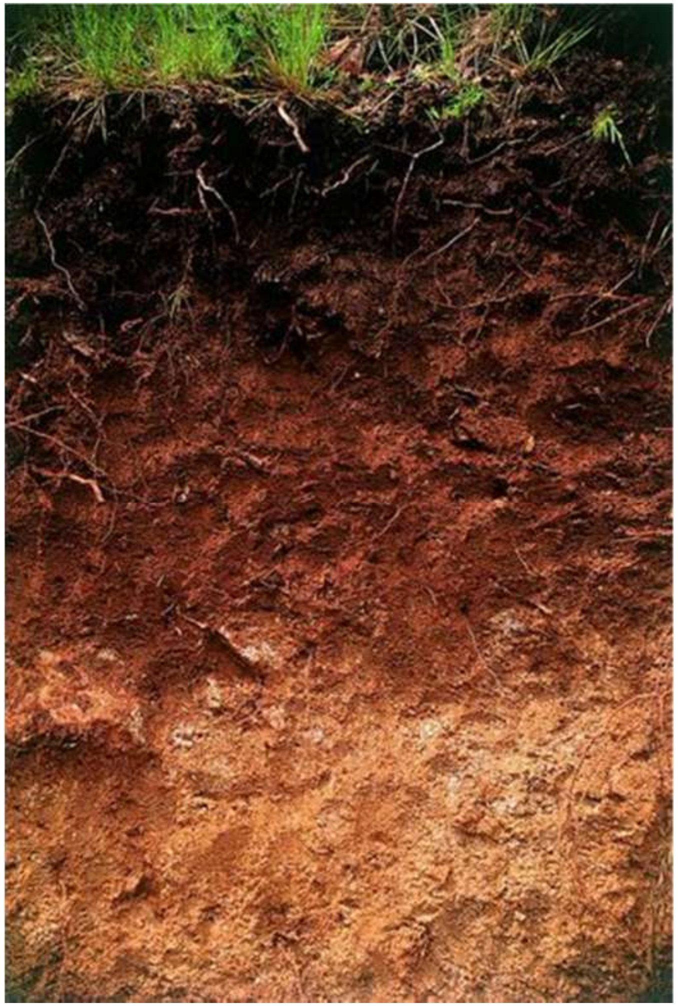




Frequently, 30-50% of that high level of SOC is made of macroscopic and fine-grained black carbon (Kaal et al. 2008)

Some Galician umbrisols should be considered black colored soils, possibly formed upon frequent anthropogenic fires from the Neolithic

The formation of soils rich in organic matter is often the result of black carbon accumulation due to a recurrent fires dgurin thousands of years (Martinez Cortizas 2009)



The well developed vegation under a mild and rainy oceanic climate gives rise abundant   surface roots mats, incresing soil agregate stability and shear stress strength

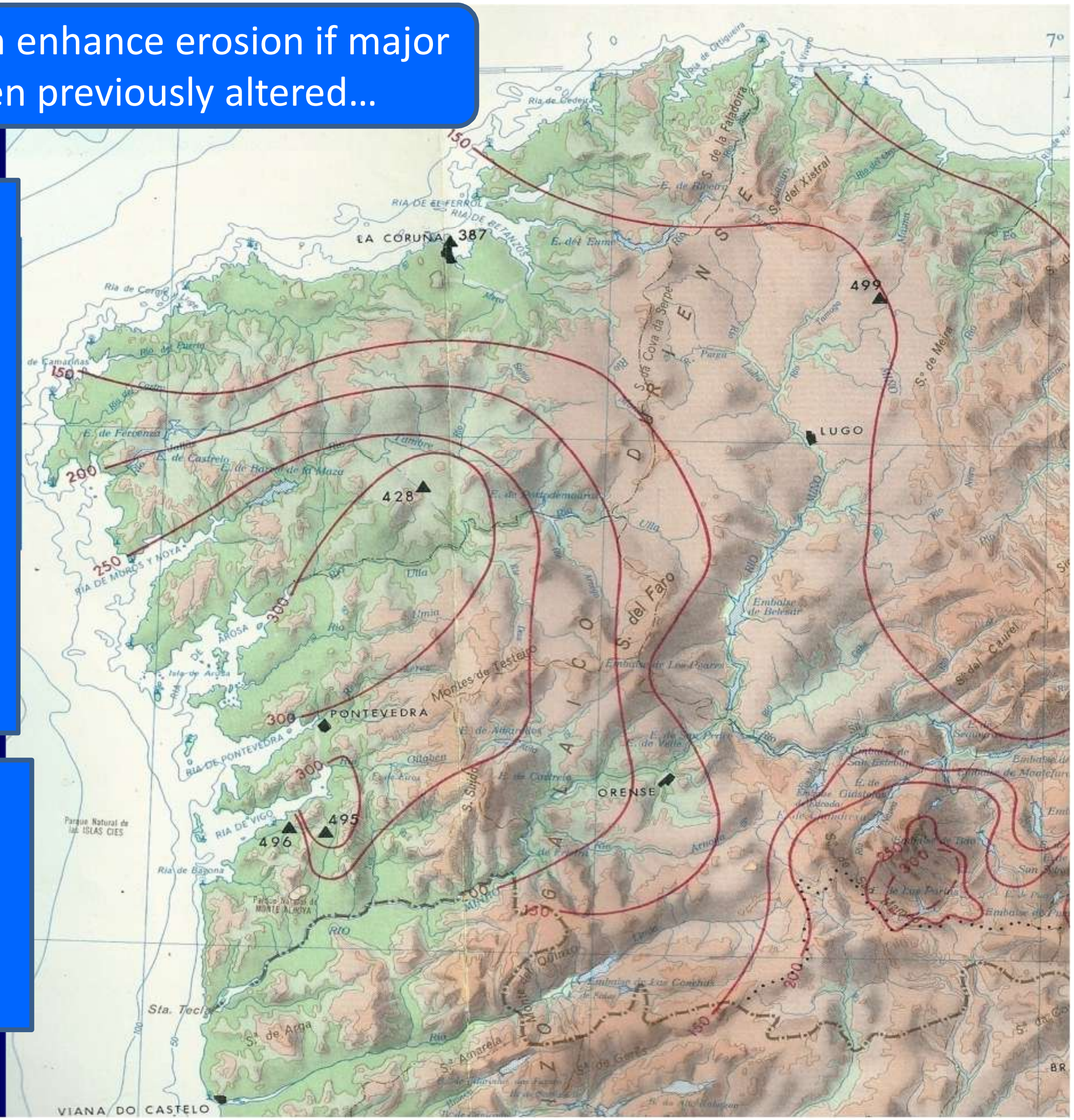
Foto: Pérez-Moreira

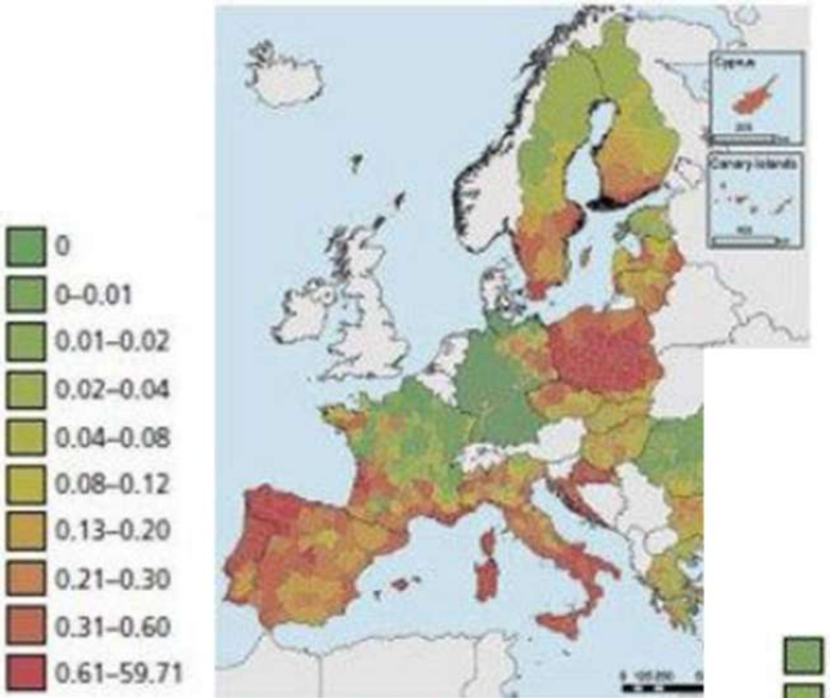
Most of NW Iberia vegetation species are fire-adapted and post-fire regeneration is usually assured through resprouting and seedling mechanisms

....However other factors can enhance erosion if major soil properties have been previously altered...

High rainfall erosivity .
In the western area oceanic climate with heavy rain (1500-3000 mm/year).
In the eastern one Mediterranean climate influence is high (around 750-1200mm of rainfall) with convective rainfall episodes

Mountaneous rugged terrain

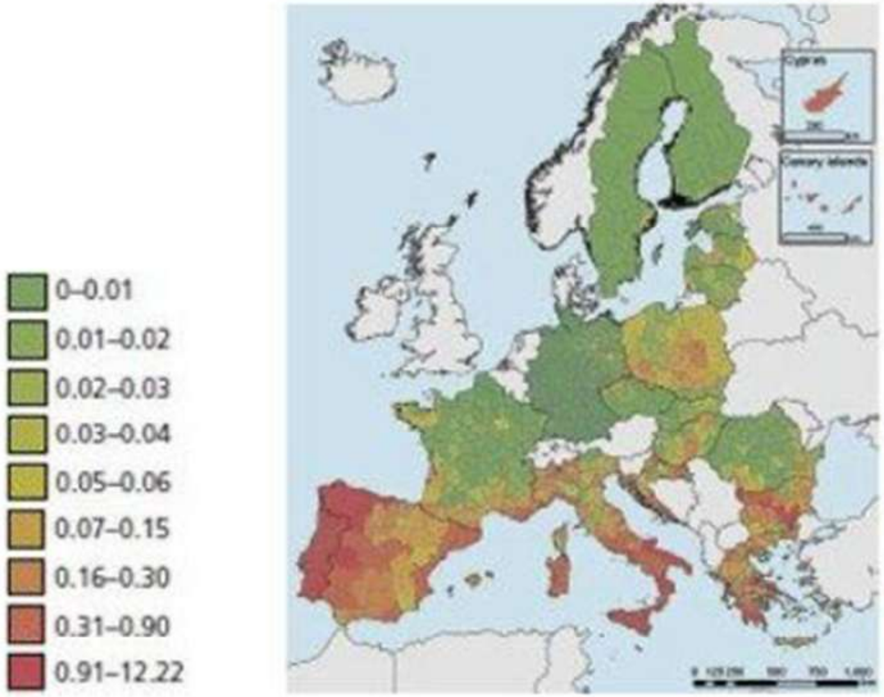




Fuente: FAOSTAT (2012)

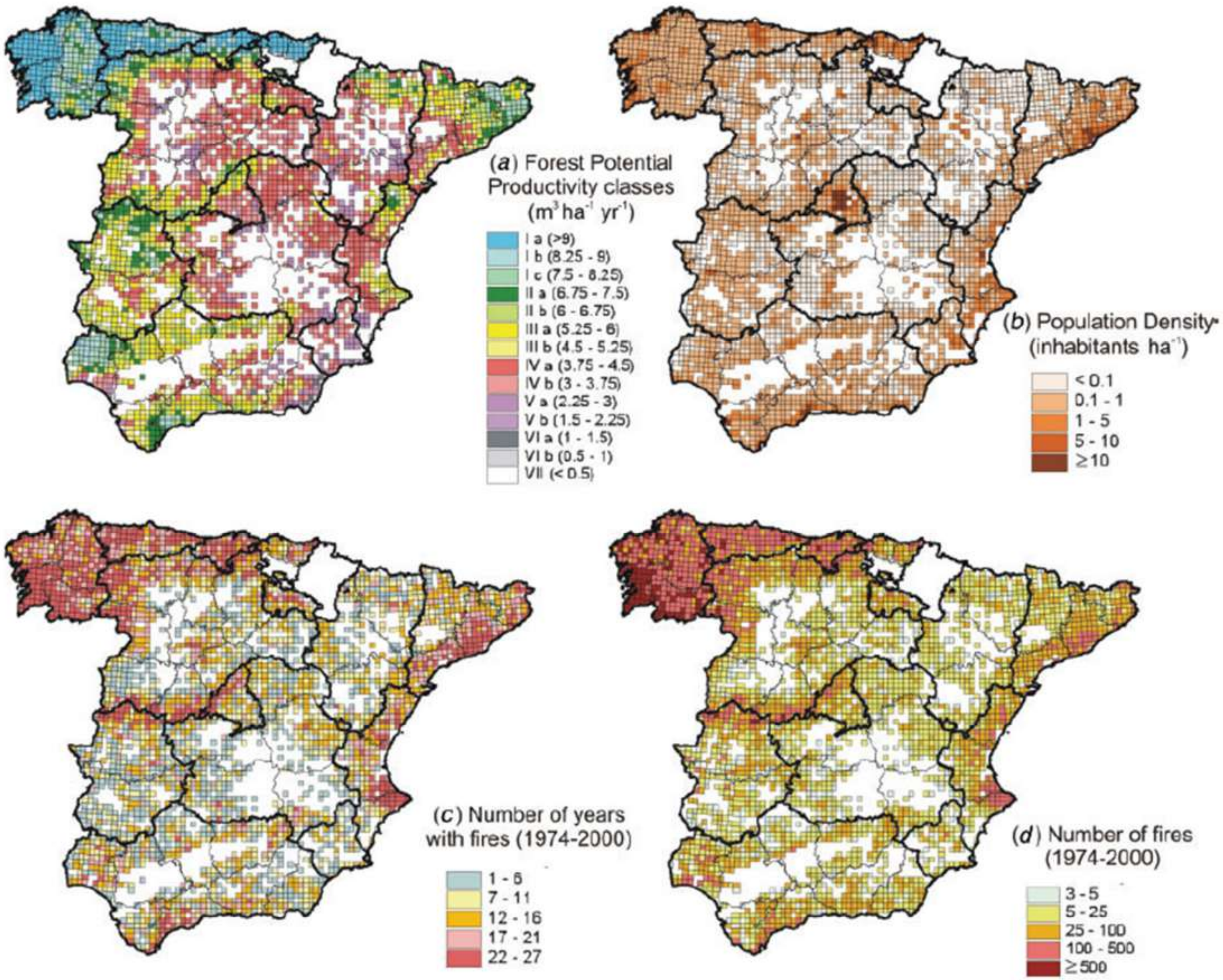
Figura 24: Número de incendios por año y por cada 10 Km² en
Valores promedio del intervalo 1998-2007.

NW Iberia is subjected to a high wildfire pressure



Fuente: FAOSTAT (2012)

gura 23: Área de bosque quemada anual (% sobre el total de superficie forestal).
Valores promedio del intervalo 1998-2007

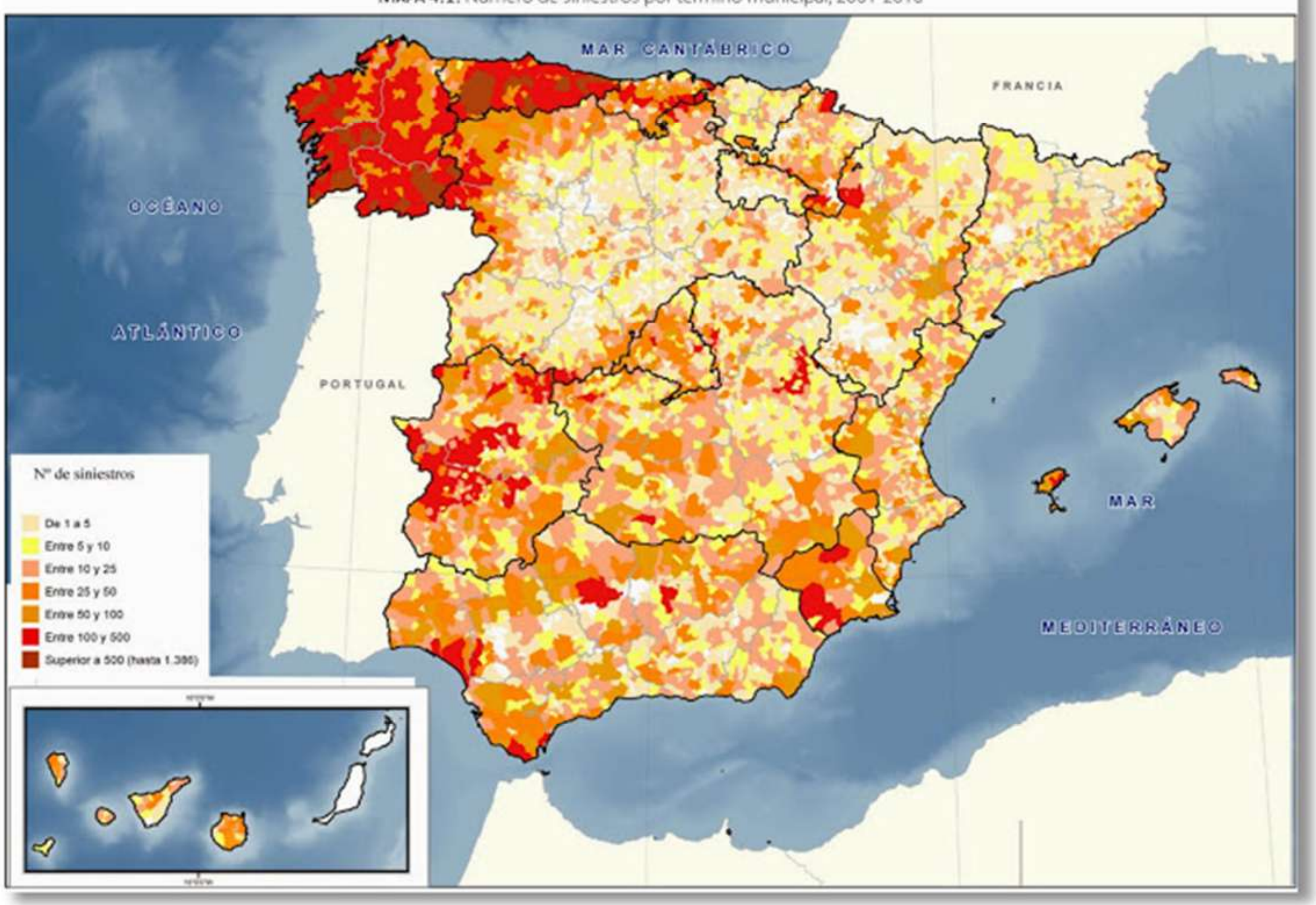


6º CONGRESO FORESTAL ESPAÑOL

Vázquez et al (2006)

Between 1974-2010 the fires occurred in Galicia were 48% of the wildfires In Spain

The burned area in Galicia made up 26% of the total burned area in Spain



Número medio anual de siniestros en el decenio 2001-2010

The forested area burned in Galicia in that period was 27%of the total forested burned area in Spain.

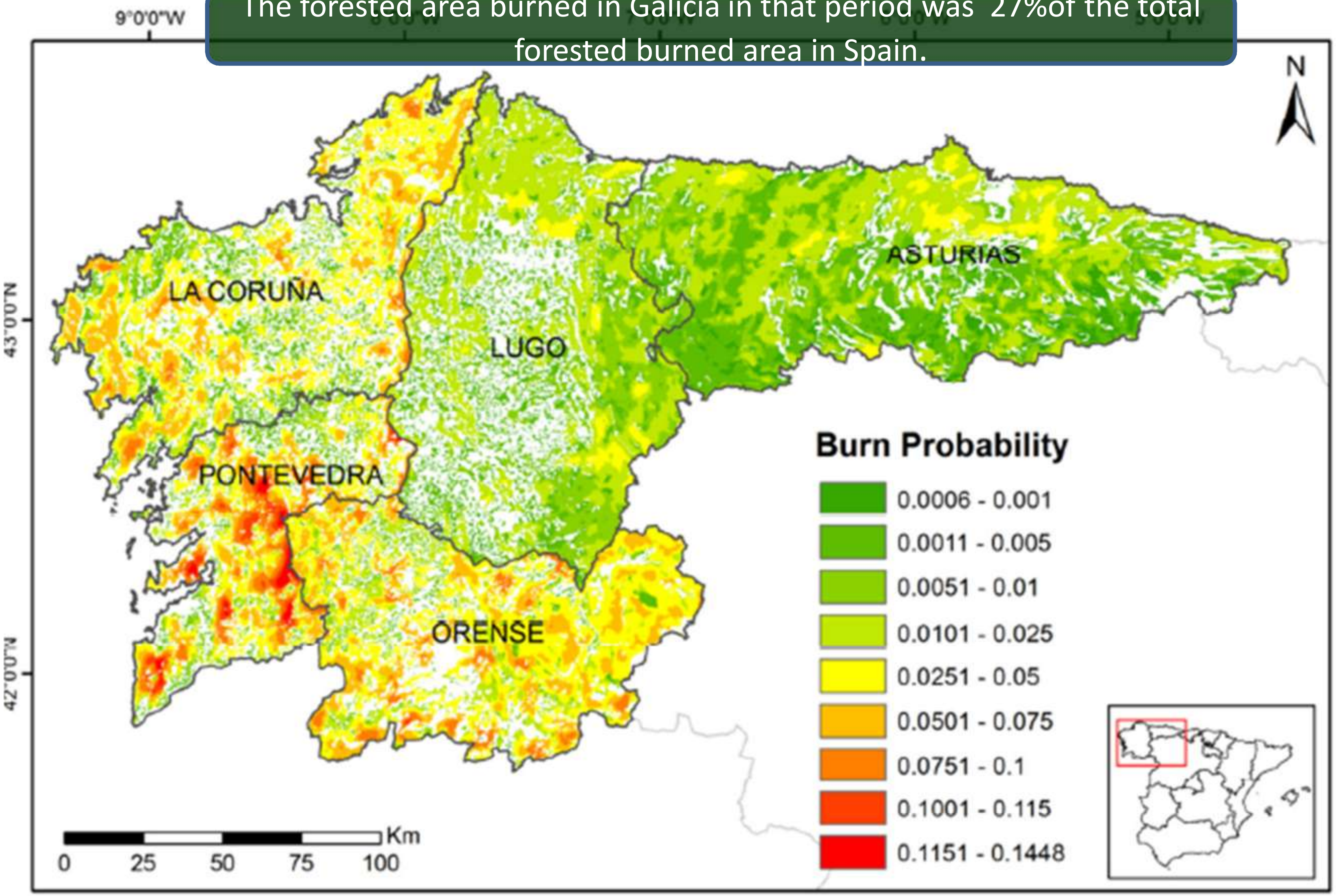
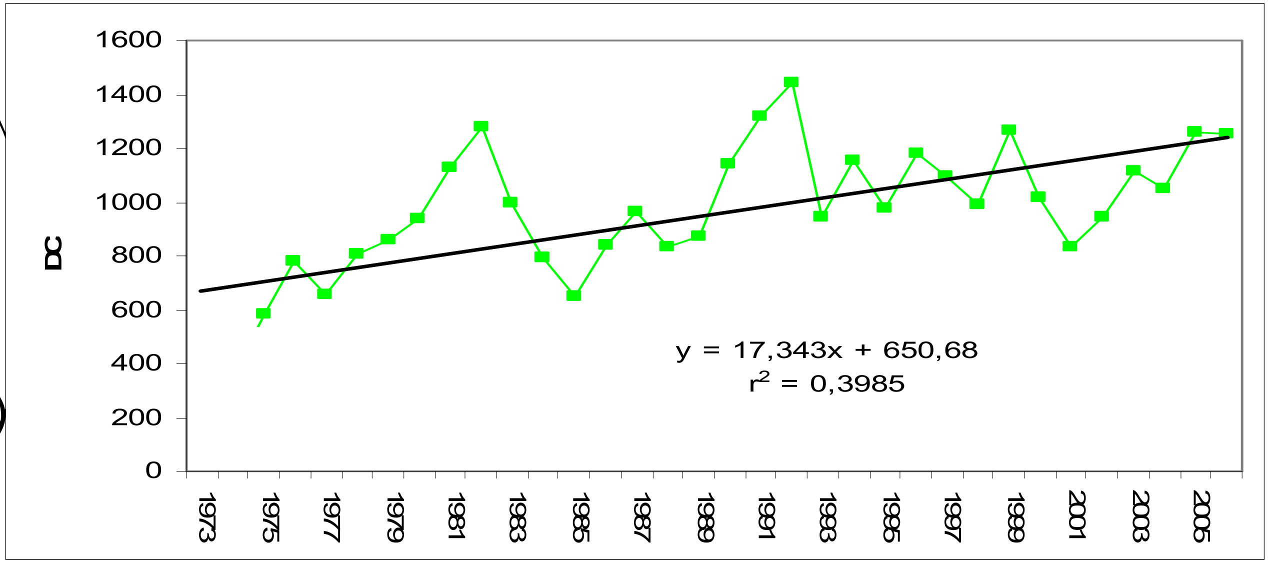


Figure 2. Map of the Simulated Burn Probabilities

Chuvieco et al. 2012

Example of climate change influence on fire hazard (Ourense ; Spain)

Trend of Duff code DC index (CFFDRS), a duff mositure proxy (period 1975-2006)



Canadian forest fire danger indexes show a worsening in the last decades and they were significantly related to fire activty in NW Spain

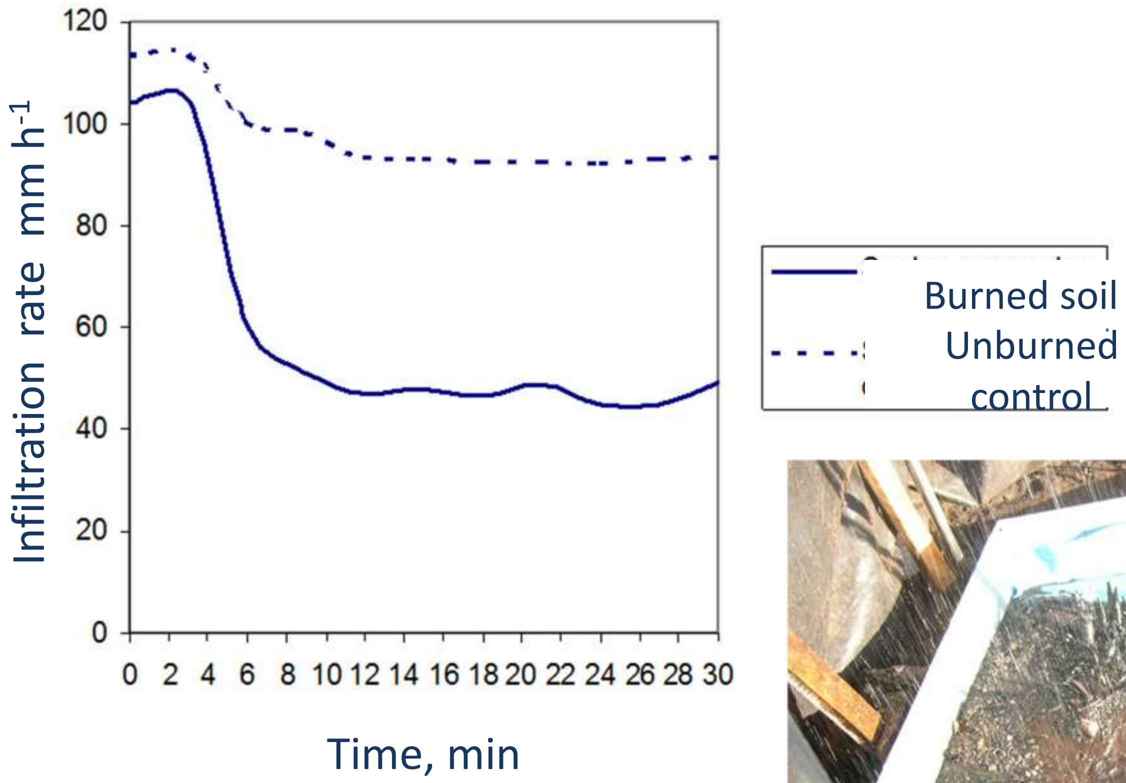
CLIGAL Project Xunta de Galicia (2009)


When a wildfire arises, some of those factors providing good conditions for vegetation growth can also favor fire intensity
Large biomass accumulations can promote high severity fires

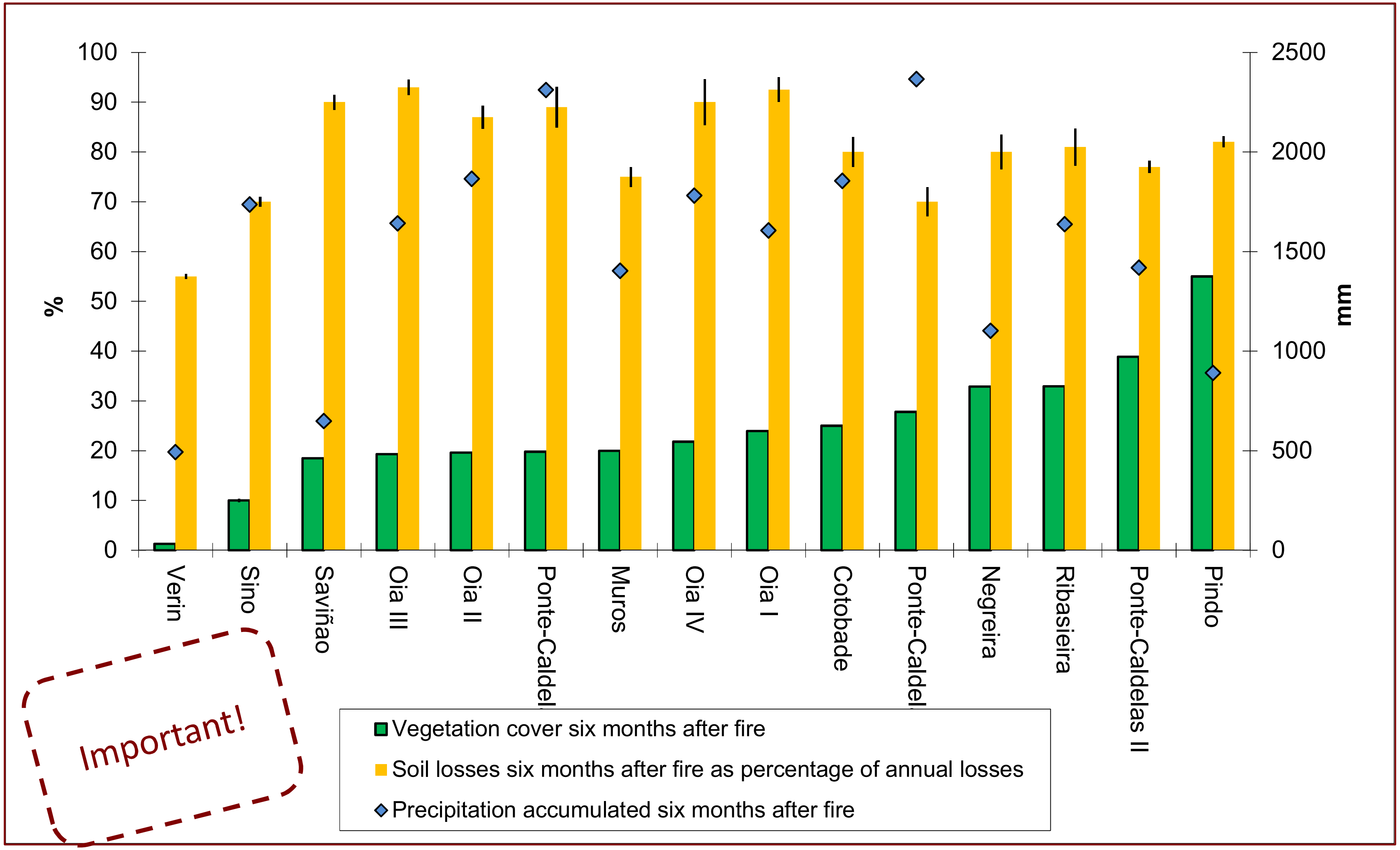
Thick forest floor (typically more than 20Mg/ha) can generate high levels of soil heating and burn severity with dramatic changes in relevant soil properties

Soil heating gives rise to the formation of a hydrophobic layer ,reducing water inflitration . Its thickness and water repellency degree is enhanced in coarse textured soils rich in organic C like those of Galicia.

When soil burn severity is high ,that hydrophobic layer is located deeper into the surface soil, facilitating rill formation and soil detachment from the underlying non repellent soil surface



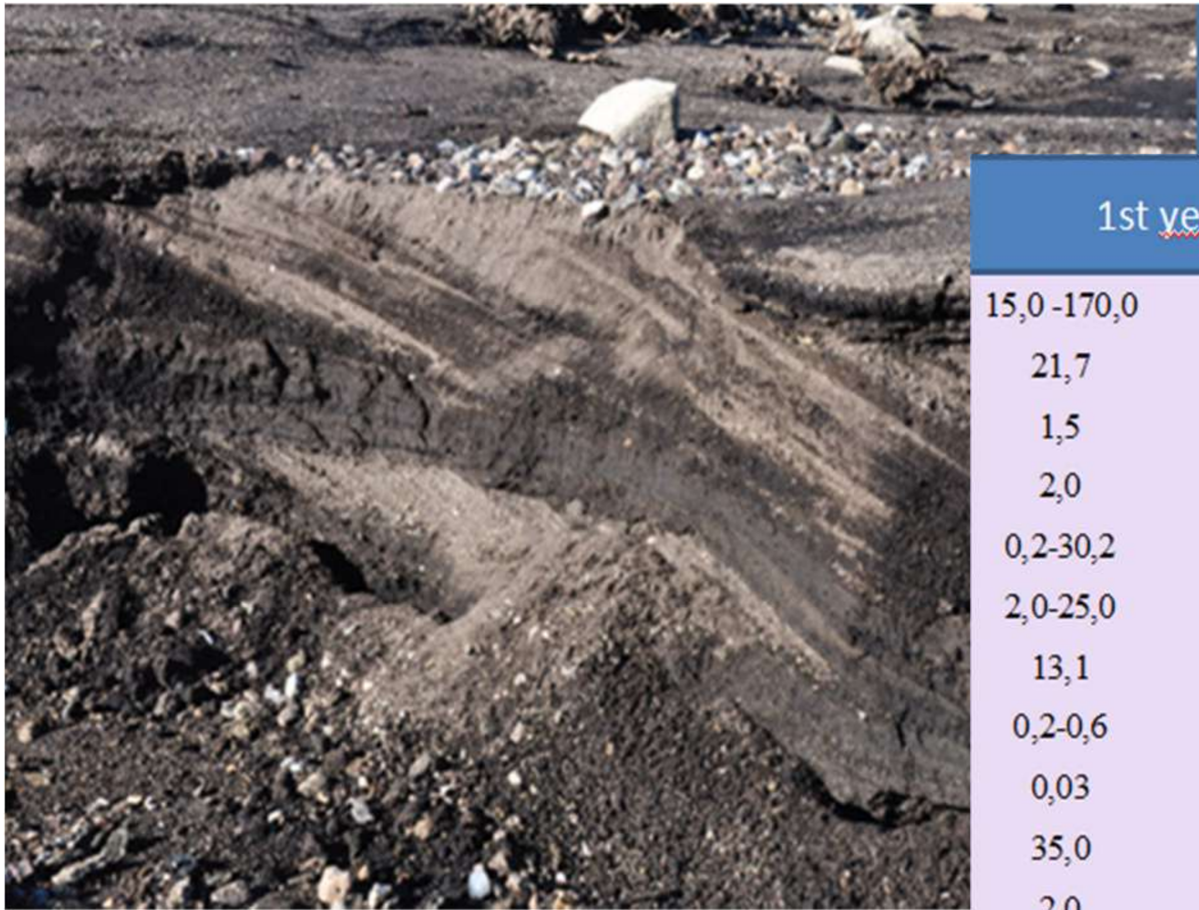
Fernández et al. (2006)



In NW Iberia , soil losses are concentrated in the first months after fire (> 80% in the first 6 post-fire months).

In that period vegetation cover is ineffective for soil protection.

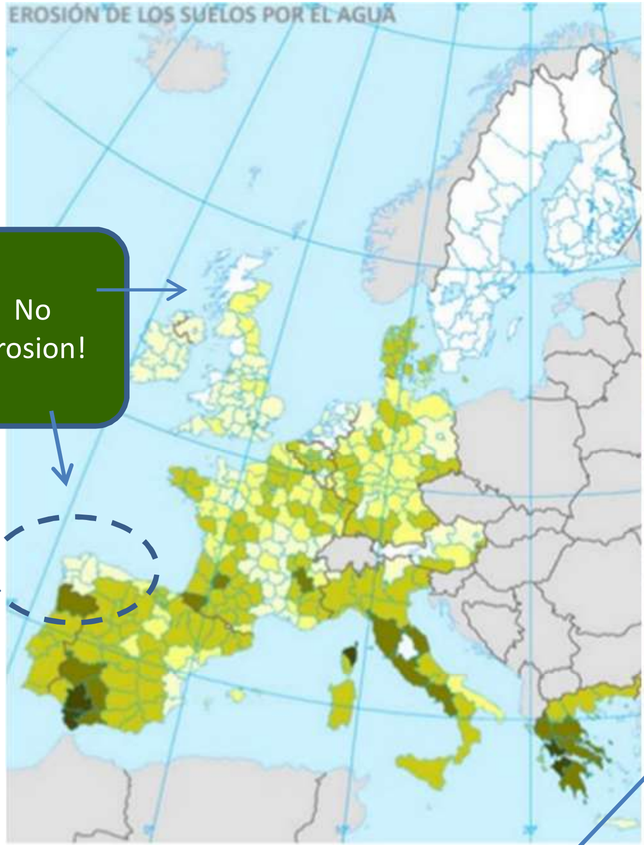

In the first six months following wildfire ground cover by vegetation is generally low



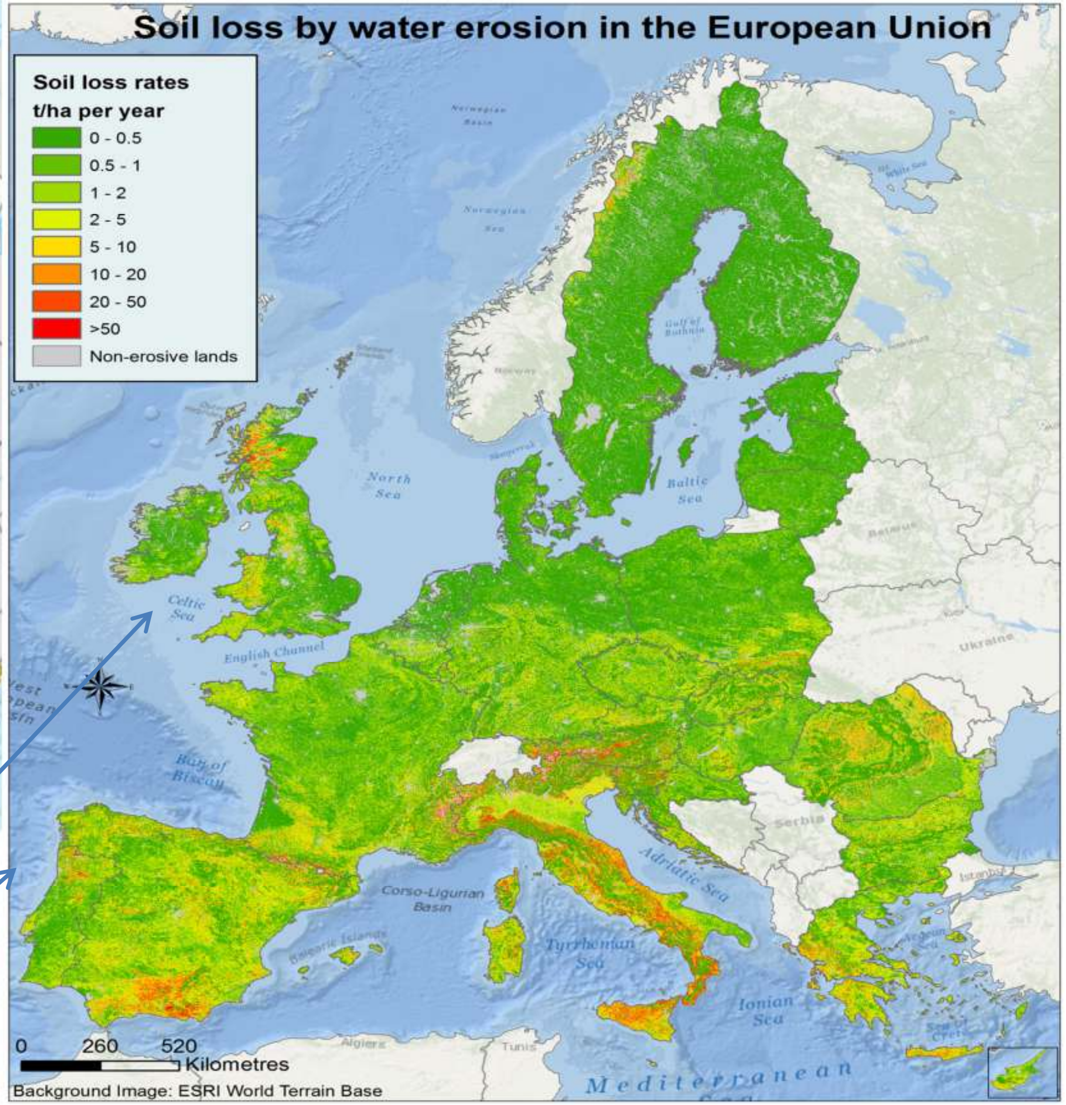
1st year Post-fire erosion(Mg/ha)	
15,0 -170,0	Díaz-Fierros et al. (1982)
21,7	Vega et al. (1982)
1,5	Vega et al. (1986)
2,0	Díaz-Fierros et al. (1990)
0,2-30,2	Díaz-Fierros et al. (1991)
2,0-25,0	Benito et al. (1991)
13,1	Soto y Díaz-Fierros (1998)
0,2-0,6	Vega et al. (2005 a)
0,03	Fernández et al. (2007)
35,0	Fernández et al. (2011)
2,0	Díaz-Raviña et al. (2012)
20,4	Vega et al. (2013)

..... and more

No erosion!



Let´s see: there is erosion !



So the soil erosion maps in Europe are changing!


Managing post-fire impacts

The emergency stabilization is the urgent response developed for post-fire risk management.

Main objectives:

- Mitigation of the threats to the human life and resources
- Reduction of soil erosion
- Limitation of soil degradation and water quality decrease
- Reduction of flood, debris flow and mudflow risk.
- Accelerate natural regeneration of the ecosystem

BASIC PRINCIPLES

*The highest priority for human life and safety
* Short response time
*Fast treatments implementation
*Treatments application according to a priority

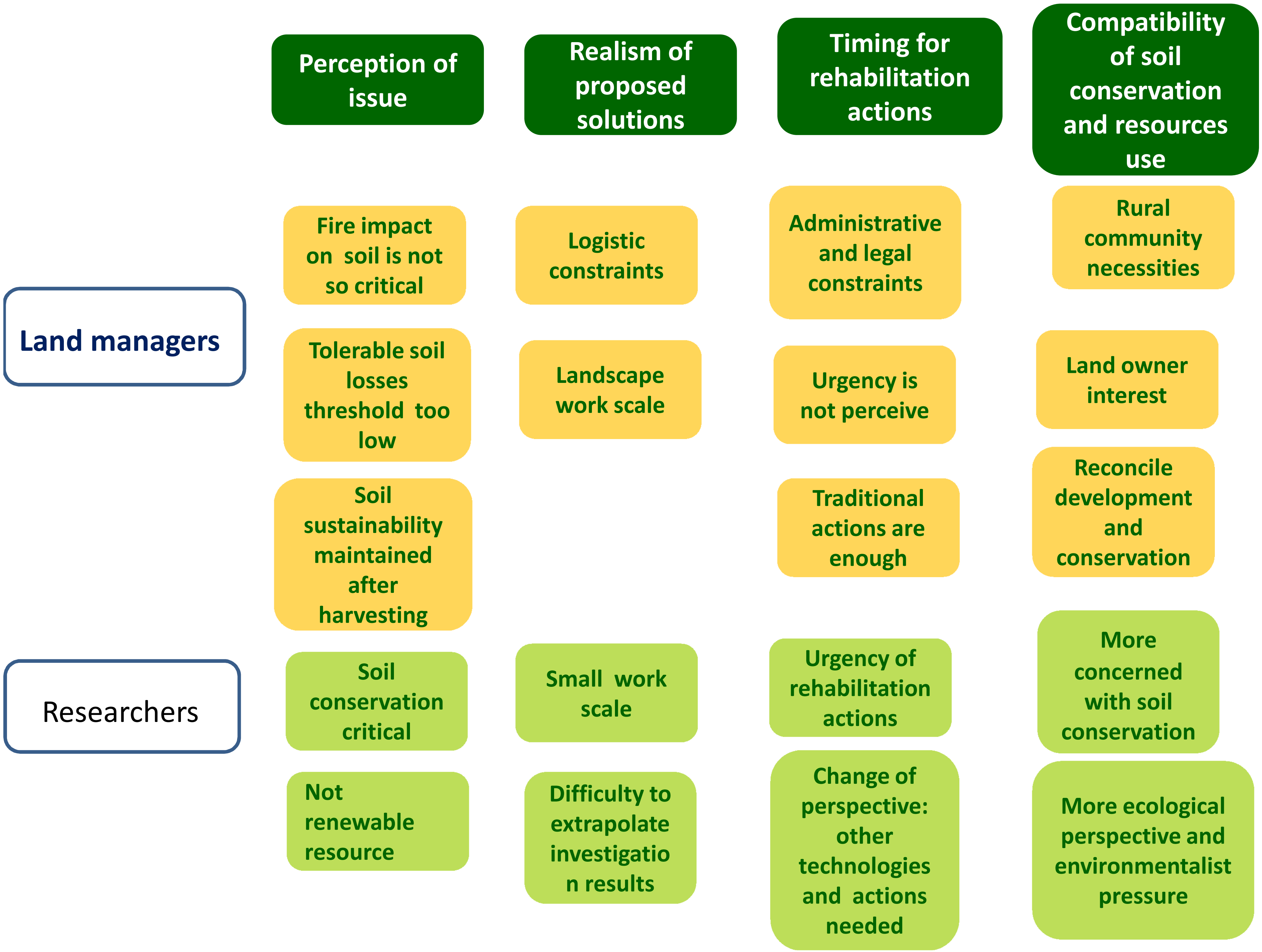
*Cooperation and coordination with other agencies, entities and owners is critical

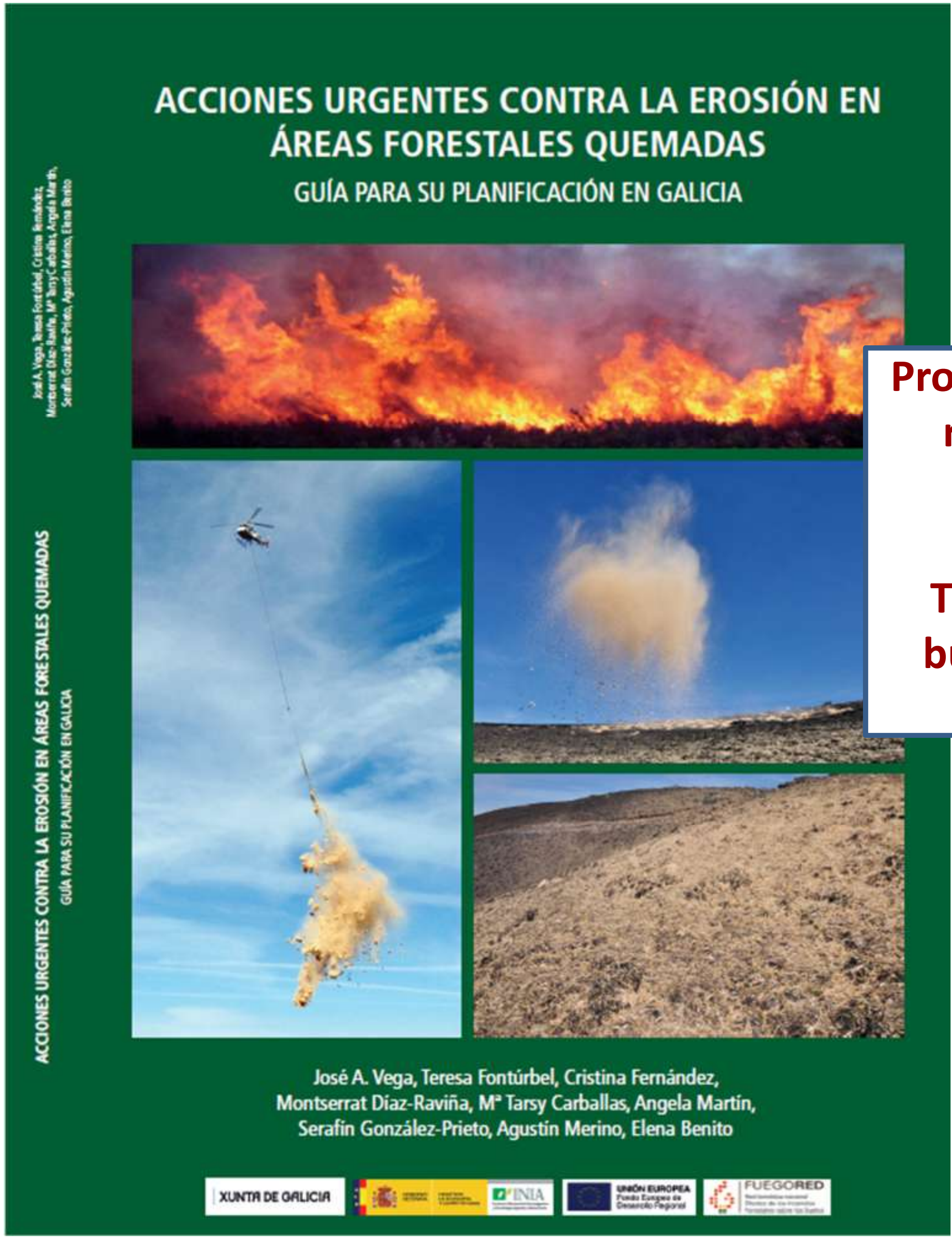
*Actions compatible with local resources management plans

*Adequacy to value or resources to protect

*Simple and flexible planning

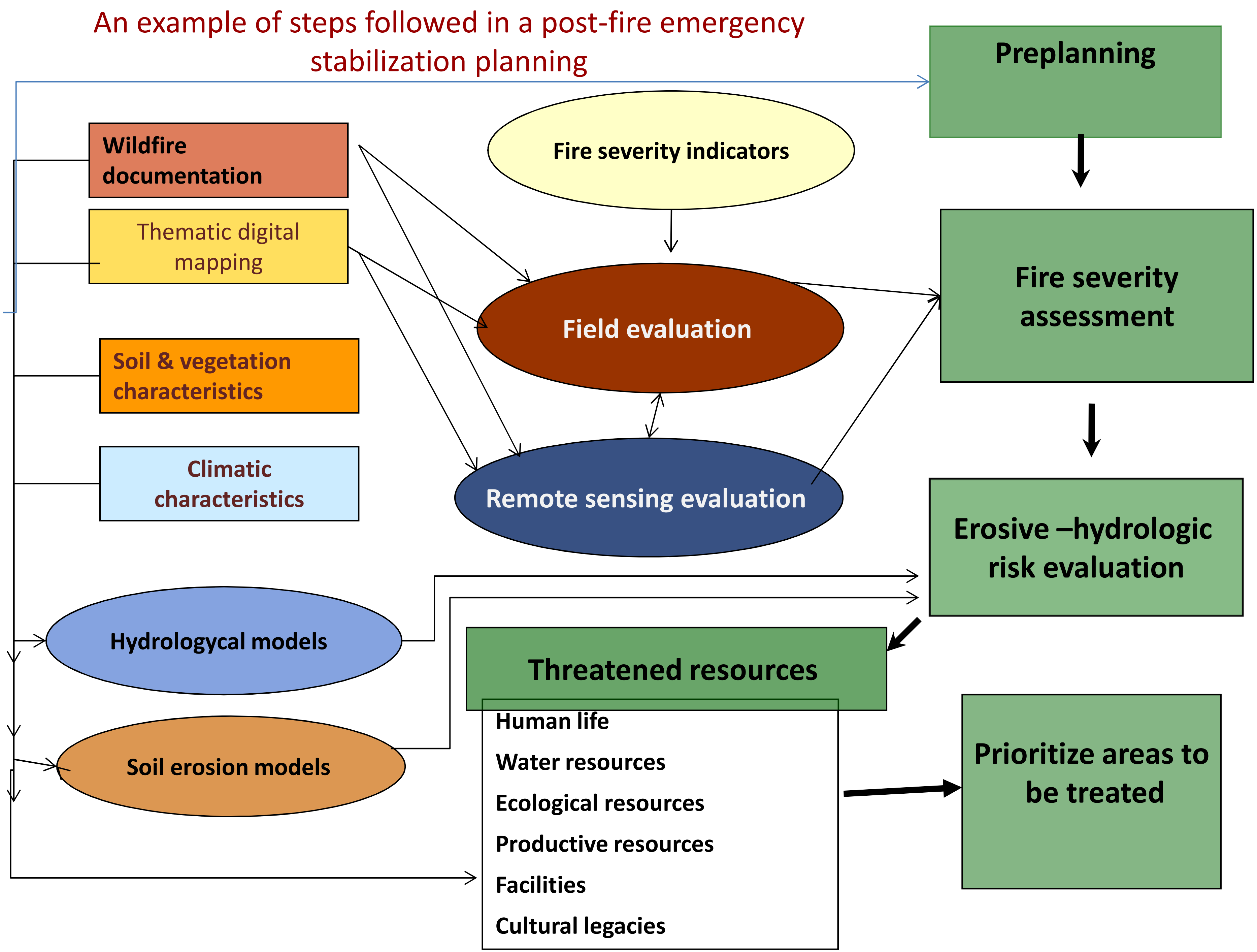
* Good communication with groups affected and media


Perception of issue
Realism of proposed solutions
Timing for rehabilitation actions
Compatibility of soil conservation and resources use
Land managers
Fire impact on soil is not so critical
Tolerable soil losses threshold too low
Soil sustainability maintained after harvesting
Logistic constraints
Landscape work scale
Administrative and legal constraints
Urgency is not perceive
Traditional actions are enough
Rural community necessities
Land owner interest
Reconcile development and conservation
Researchers
Soil conservation critical
Not renewable resource
Small work scale
Difficulty to extrapolate investigation results
Urgency of rehabilitation actions
Change of perspective: other technologies and actions needed
More concerned with soil conservation
More ecological perspective and environmentalist pressure



Protocols agreed between managers and researchers can be a useful tool to manage post-fire risks

This guide is currently being used for burned areas emergency stabilization response in NW Spain


An example of steps followed in a post-fire emergency stabilization planning
Preplanning
Wildfire documentation
Thematic digital mapping
Fire severity indicators
Field evaluation
Fire severity assessment
Soil & vegetation characteristics
Climatic characteristics
Remote sensing evaluation
Erosive –hydrologic risk evaluation
Hydrologycal models
Threatened resources
Human life
Water resources
Ecological resources
Productive resources
Facilities
Cultural legacies
Soil erosion models
Prioritize areas to be treated

Change of paradigm!

To give priority to cover burned soil surface as soon as possible instead of:

To build check dams in channels to collect sediments

Too slow & not prevent soil removal

To install log barriers

Slow & low efficiency

Seeding

Slow & competition issue

Planning is even more critical under oceanic climate , like in NW Iberia because...

There is a short but effective “Perturbation window” soon after wildfire

Elevated rainfall comes usually soon after fire

Soil burn severity frequently high

There is no time enough for vegetation regrowth or seeded can be effective

Sloping terrain

Large potential for soil particle detachment

Elevated overland flow generation and flood

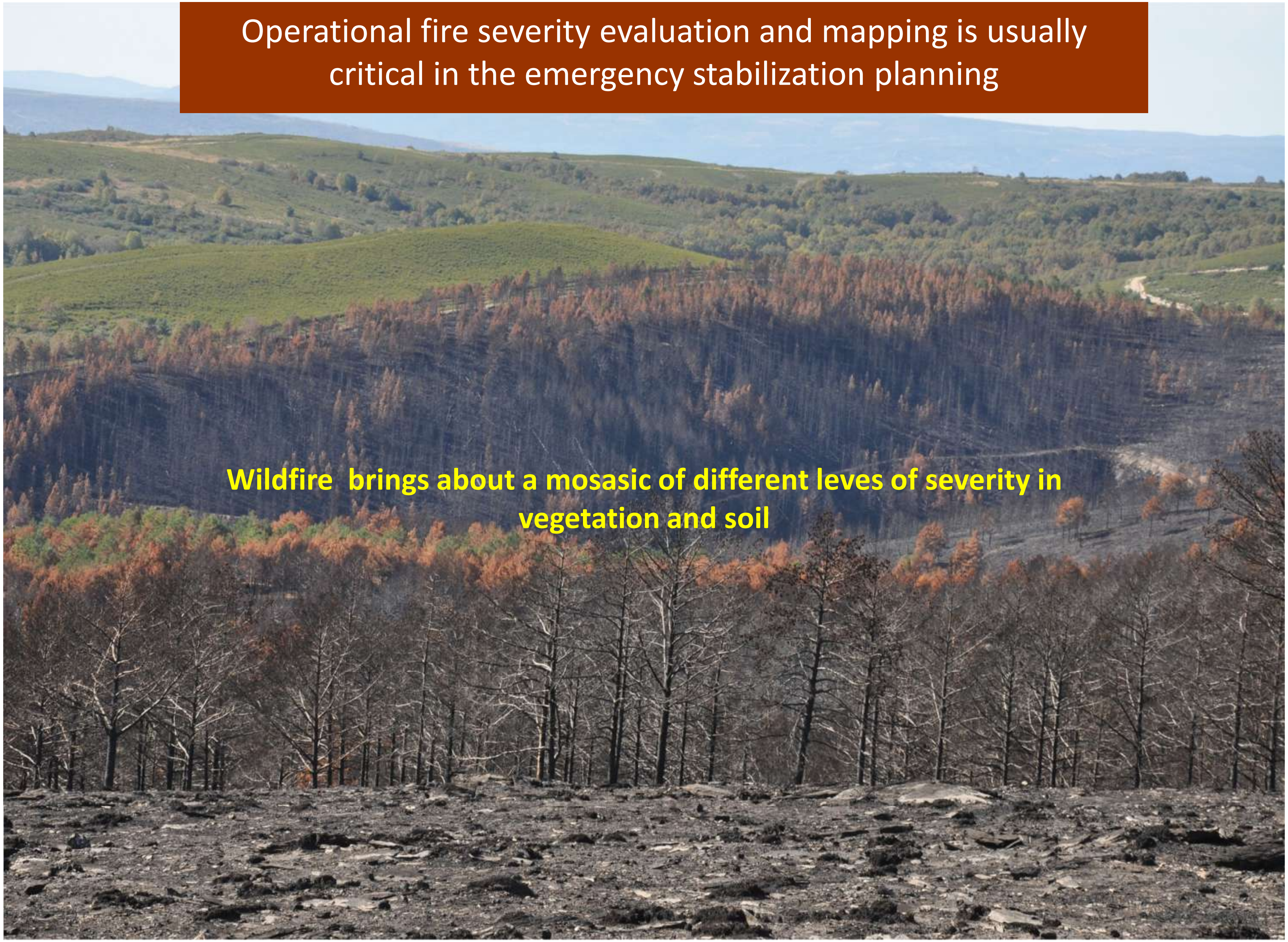
Threats to inhabitans resources and infrastructure

High probablity of drinking water quality impaired

Increased soil losses

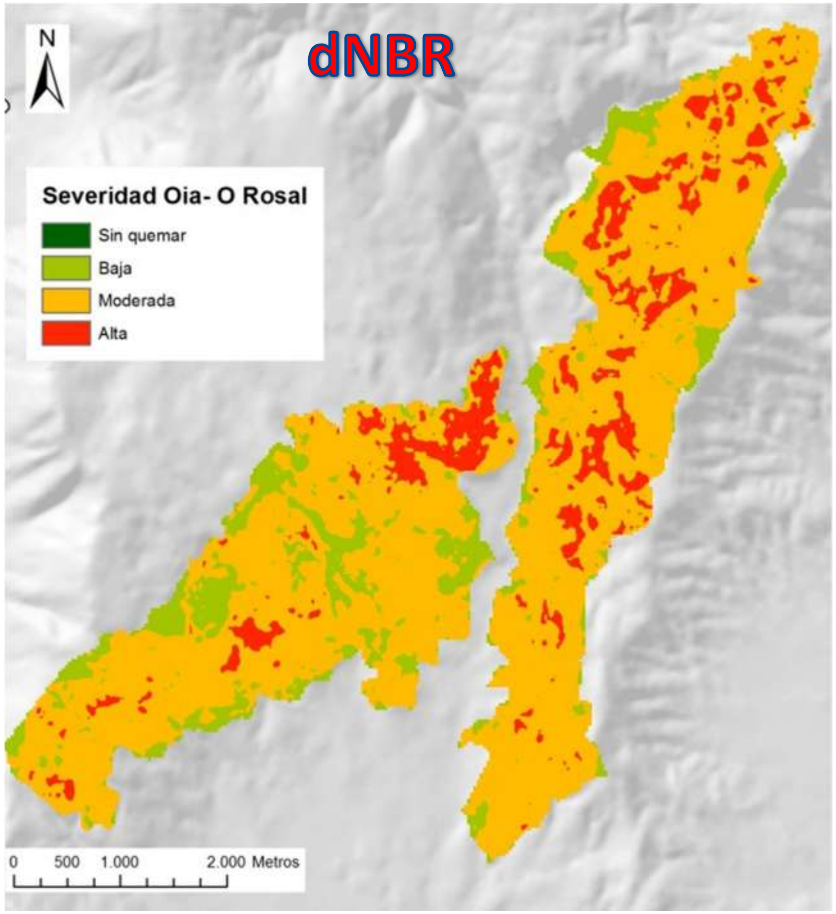
Ecosystem deterioration

Operational fire severity evaluation and mapping is usually critical in the emergency stabilization planning



Helicopter can be a very suitable equipment for the first survey of the burned areas

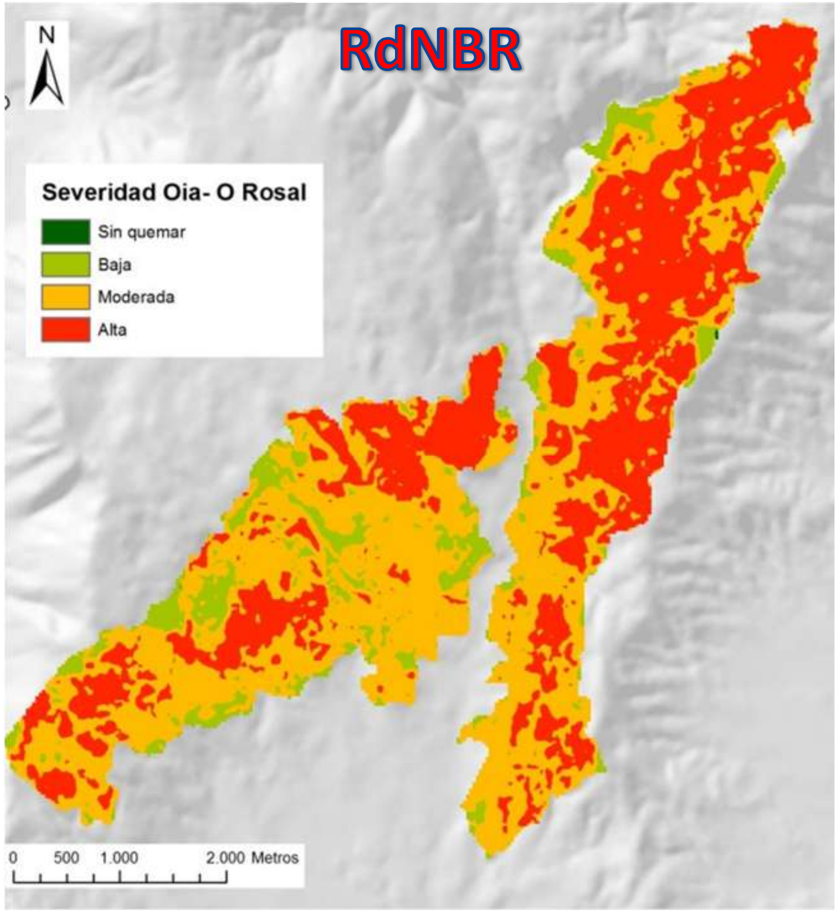
Comparing two fire remote sensed severity indexes



R^2 = **0,692** PG = **75%** Kappa = **0,560**

Sin quemar (< -281)
Baja (-281 – 161)
Moderada (161- 609)
Alta (> 609)

Sin quemar = **0%**
Baja = **14%**
Moderada = **74%**
Alta = **12%**

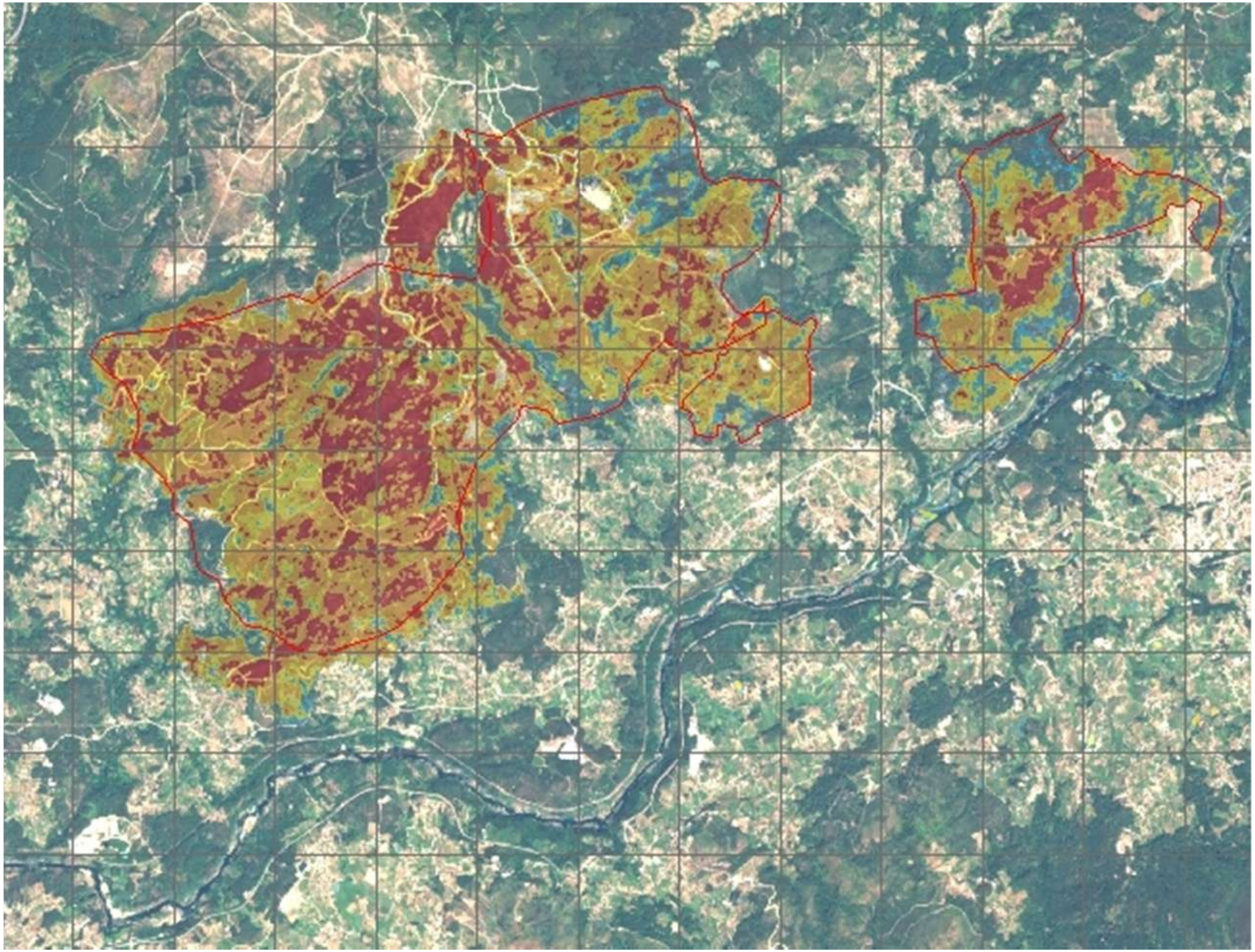


R^2 = **0,727** PG = **82,8%** Kappa = **0,699**

Sin quemar (< -358)
Baja (-358 – 189)
Moderada (189- 783)
Alta (> 783)

Sin quemar = **0%**
Baja = **12%**
Moderada = **67%**
Alta = **21%**

ARBO-CRECENTE WILDFIRE



dNBR obtained from the Sentinel-2 satellite

Evaluating soil burn severity in the field

* Five levels of soil burn severity

* Five attributes:

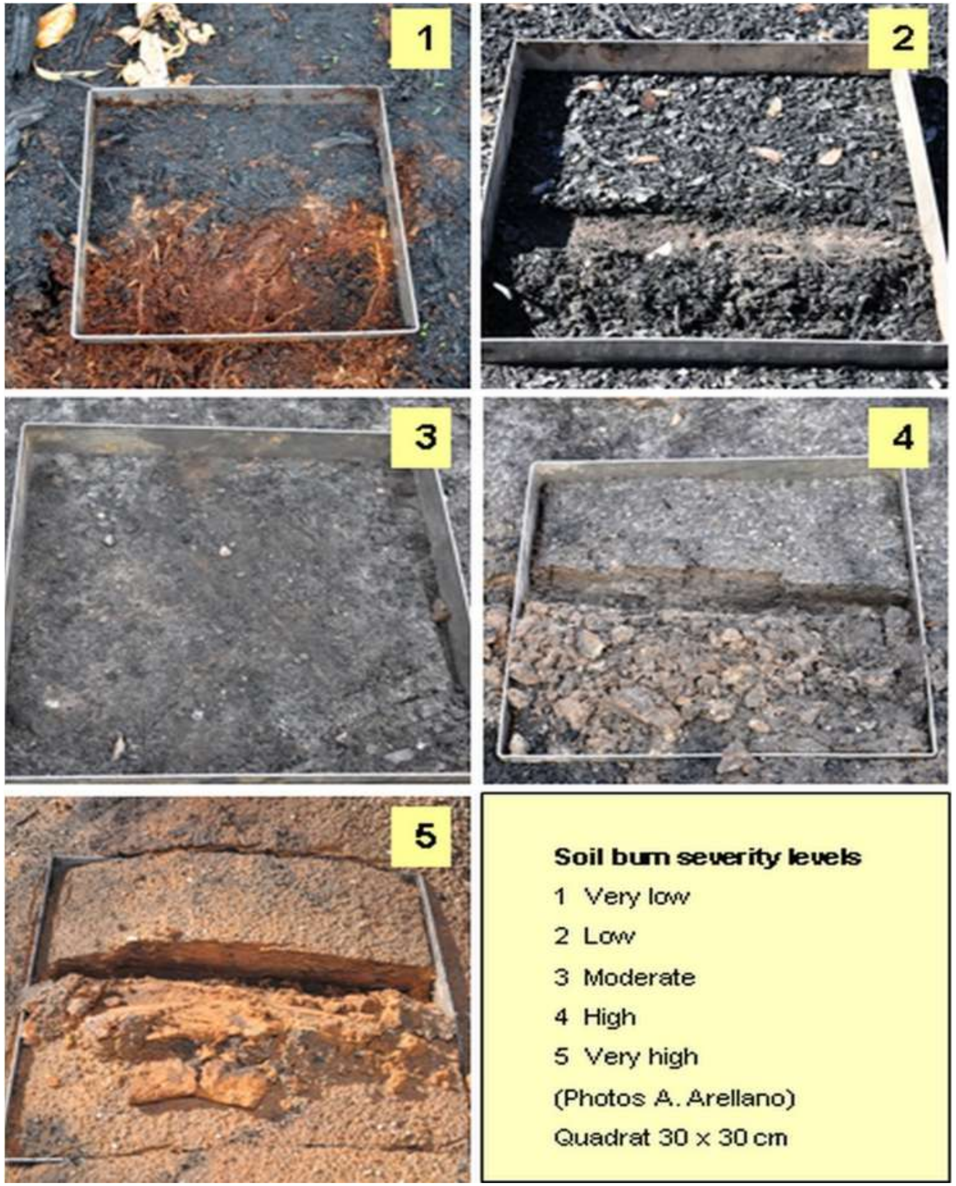
-ground cover: amount , conditio n and depth

-ash colour and depth

- soil structure and colour

-roots condition

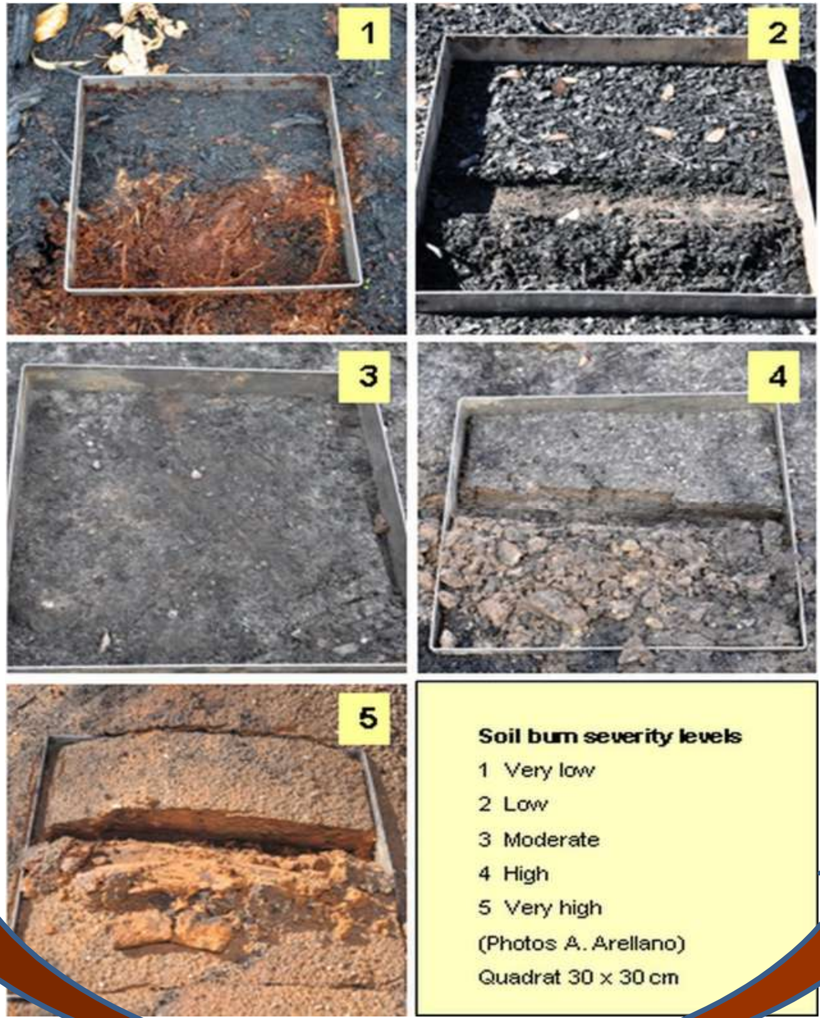
-water repellency



Vega J.A.; Fonturbel, M.T; Merino, A.; Fernández, C.;Ferreiro, A.; Jiménez, E. 2013. Testing the ability of visual indicators of soil burn severity to reflect changes in soil chemical and microbial properties in pine forests and shrubland. Plant and Soil.369:73-91

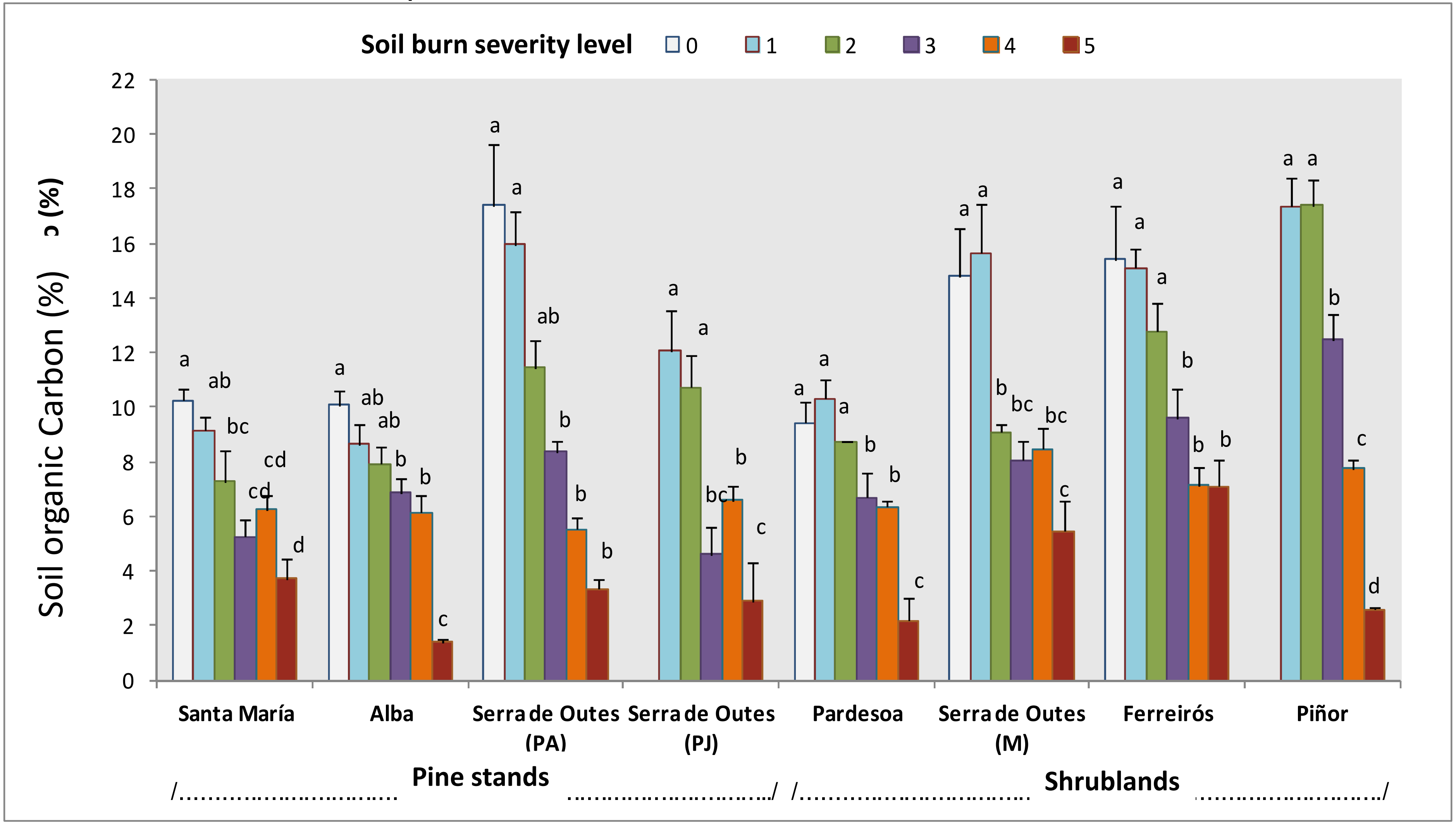
Why those five levels of severity?

Because this classification is simple, ease of learning , and operationally useful in the field.
More importantly...



... These levels are closely related to soil temperatures during fire and changes in relevant physical, chemical and biological properties of the affected soils

EFFECT OF WILDFIRE ON SURFACE SOIL ORGANIC CARBON CONTENT in pine stands and shrubland in Galicia

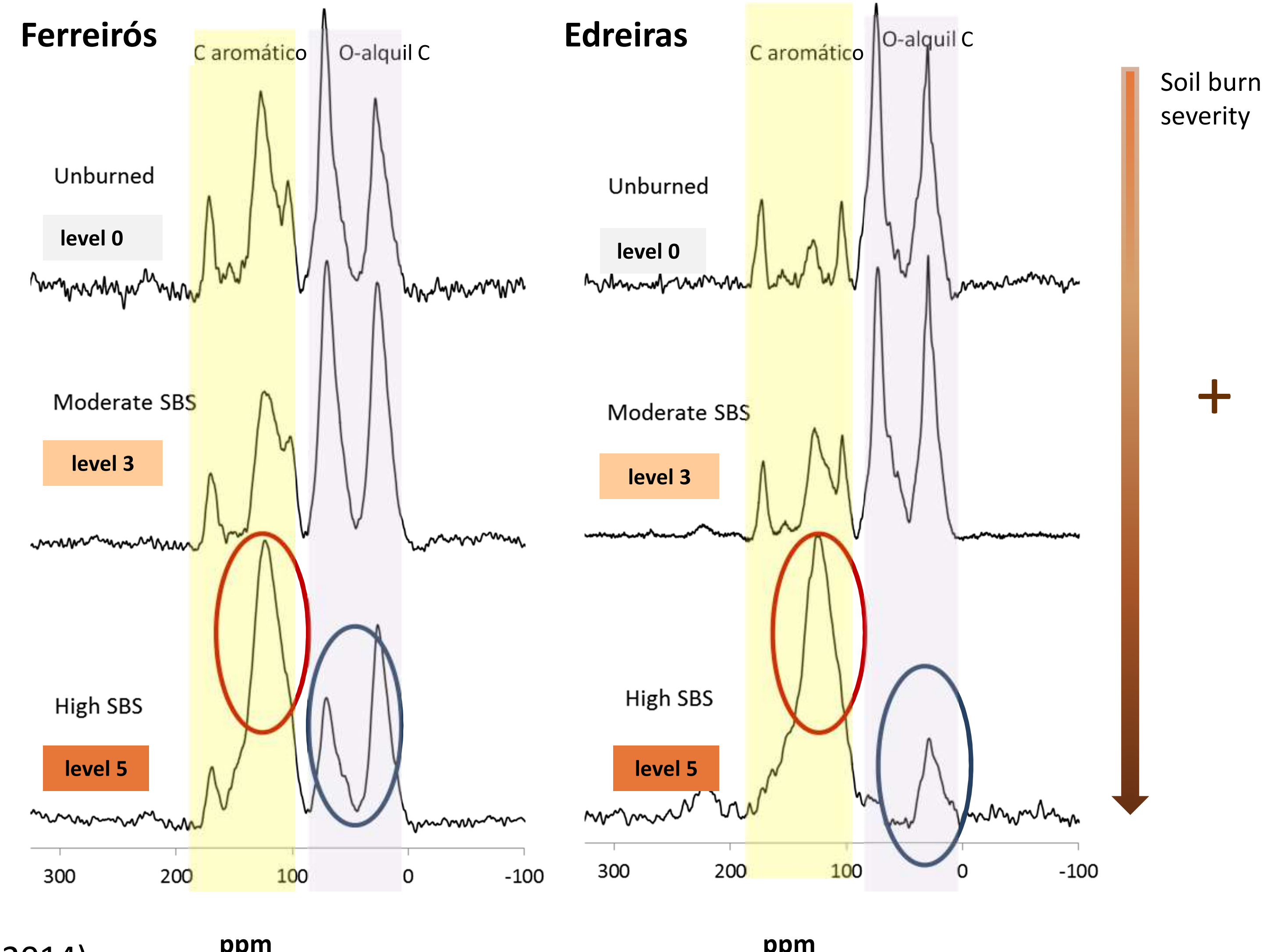


Vega et al. (2013)

Relative decreases of between **54** and **86%** respect to control in **level 5**

Chemical characterization of soil organic matter changes in two forest soil affected by contrasted burn severity levels. (RMN-^{13}C spectra)

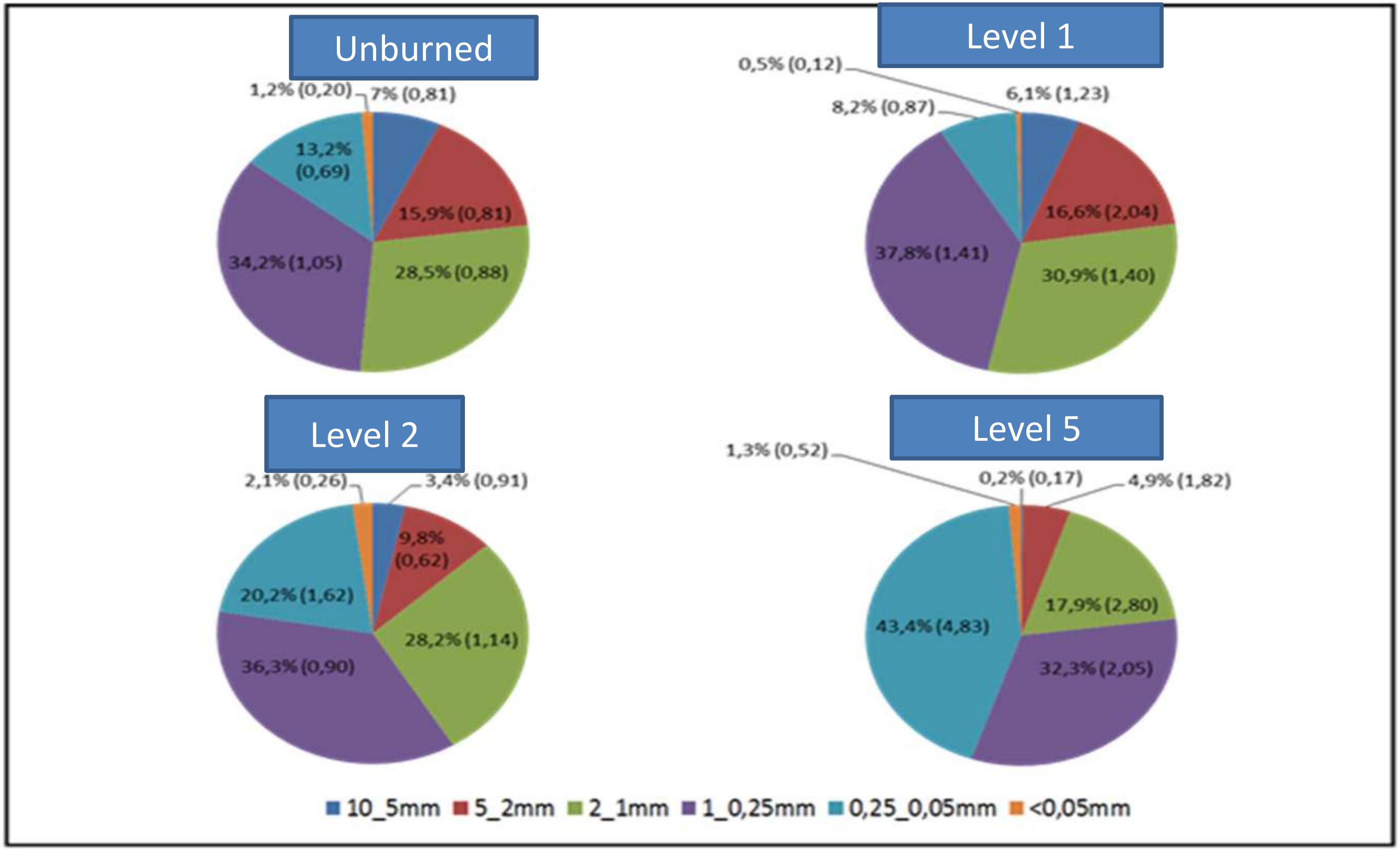
Increase and dominance of aromatic C in level 5.
Reduction of O-alquil C compounds



Merino et al. (2014)

O-alquil C compounds : Carbohidrates, cellulose and hemicelluose

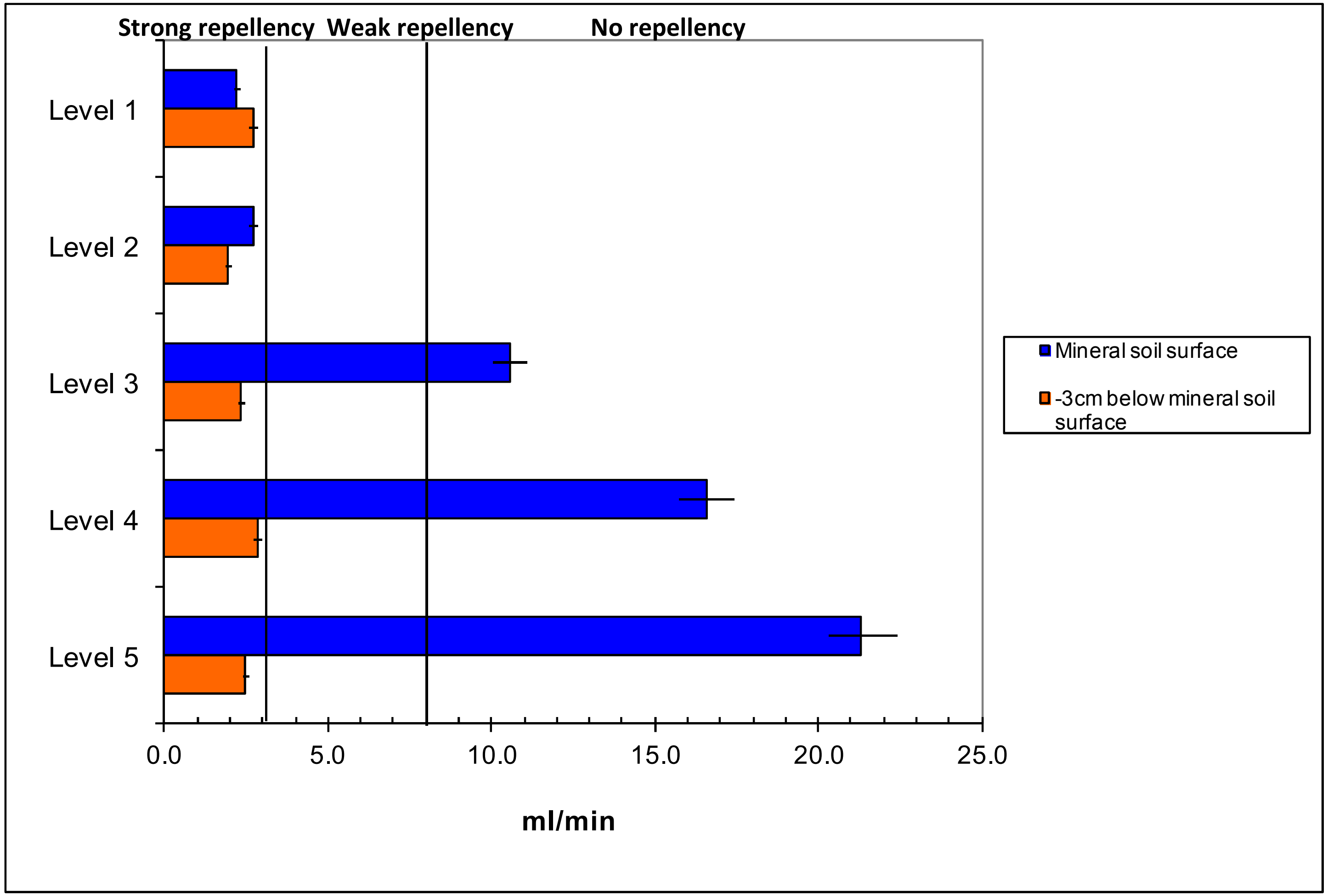
Changes in percentage of soil aggregates size ranges of soil monoliths experimentally burned



↑ Temperature/heat duration → organic C ↓ → Macroaggregates ↓

Regueira, N.; Benito, E.; Fontúrbel, T.; Fernández, C.; Jiménez, E.; Vega, J.A. 2015. Efectos de quemas experimentales de diferente severidad en el carbono orgánico y en propiedades físicas del suelo. Flamma. 6(3): 129-133.

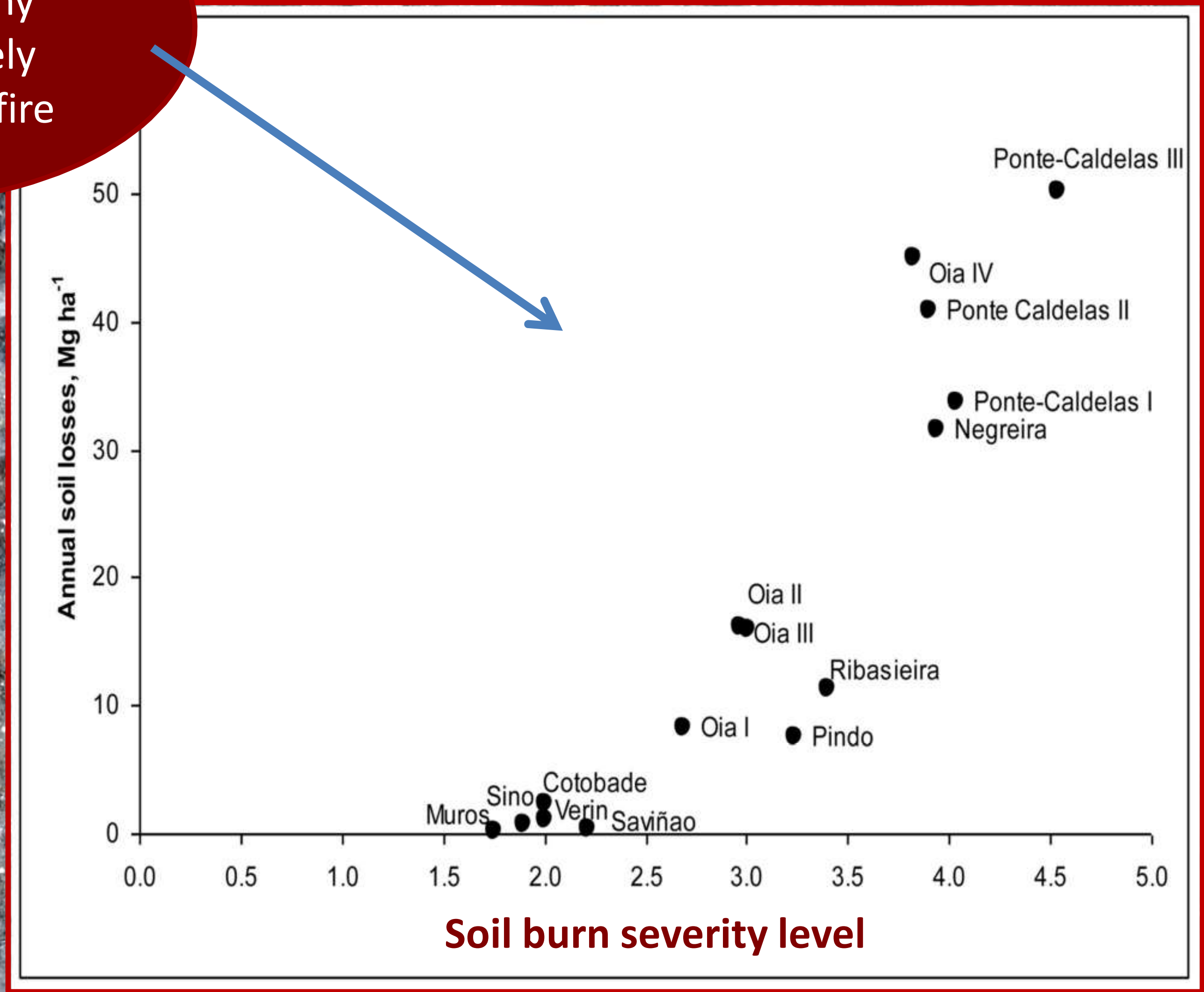
Effect on burn severity on water repellency (measured as infiltration velocity with minidisc-infiltrometer in wildfire-affected soils in Galicia)



Water repellency reduction in the higher soil burn severities

Fernández, C.; Vega, J.A. ; Fontúrbel, T. 2013. Severidad del fuego y repelencia al agua en el suelo después de incendios forestales en Galicia. VI Congreso Forestal Español.

..BUT MOST OF ALL beacuse in temperate rainy climate is closely related to post-fire soil erosion



Fernández, C.; Vega, J.A. 2016.. Modelling the effect of soil burn severity on soil erosion at hillslope scale in the first year following wildfire in NW Spain. . Earth Surf. Process. Landforms 41, 928–935

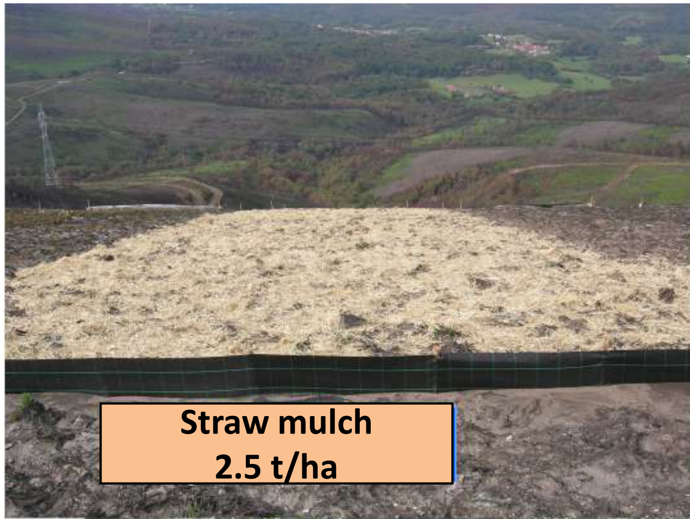
$$SE = 0{,}0004 * \exp(0{,}7284\ SBSI) * P * LU$$

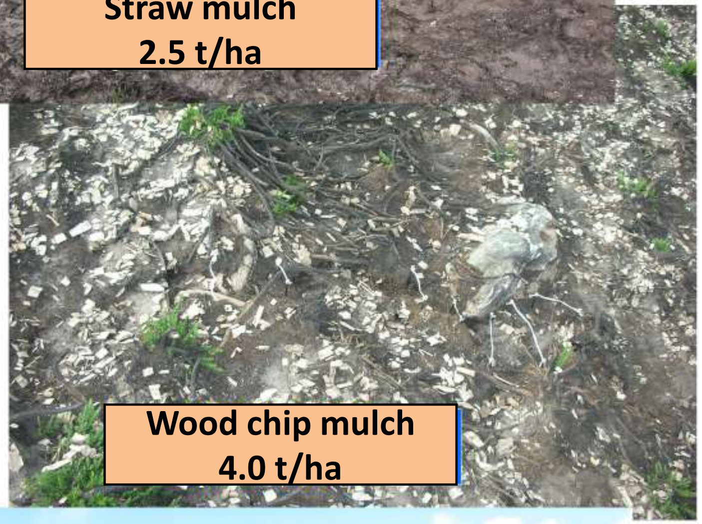
SE soil erosion first year following wildfire (Mg ha^{-1} year^{-1})
SBSI soil burn severity level(1-6)
P accumulated precipitation during the 1st year post-fire, mm
LU land use factor . 1 :shrubland burned 5 years before fire and juvenile plantations with mecanized site preparation. 2: shrublands not burned or forest stands not harvested within 5 years before fire. 3 : pole size stands with a well developed forest floor or shrublands not burned at least within 10 years before fire and with a thick litter layer.

Data from
65 experimental (20 x 4 m)sediment fenced-plots from 10 wildfires in Galicia were used to construct the model
Validation was made with data from 32 plots-year

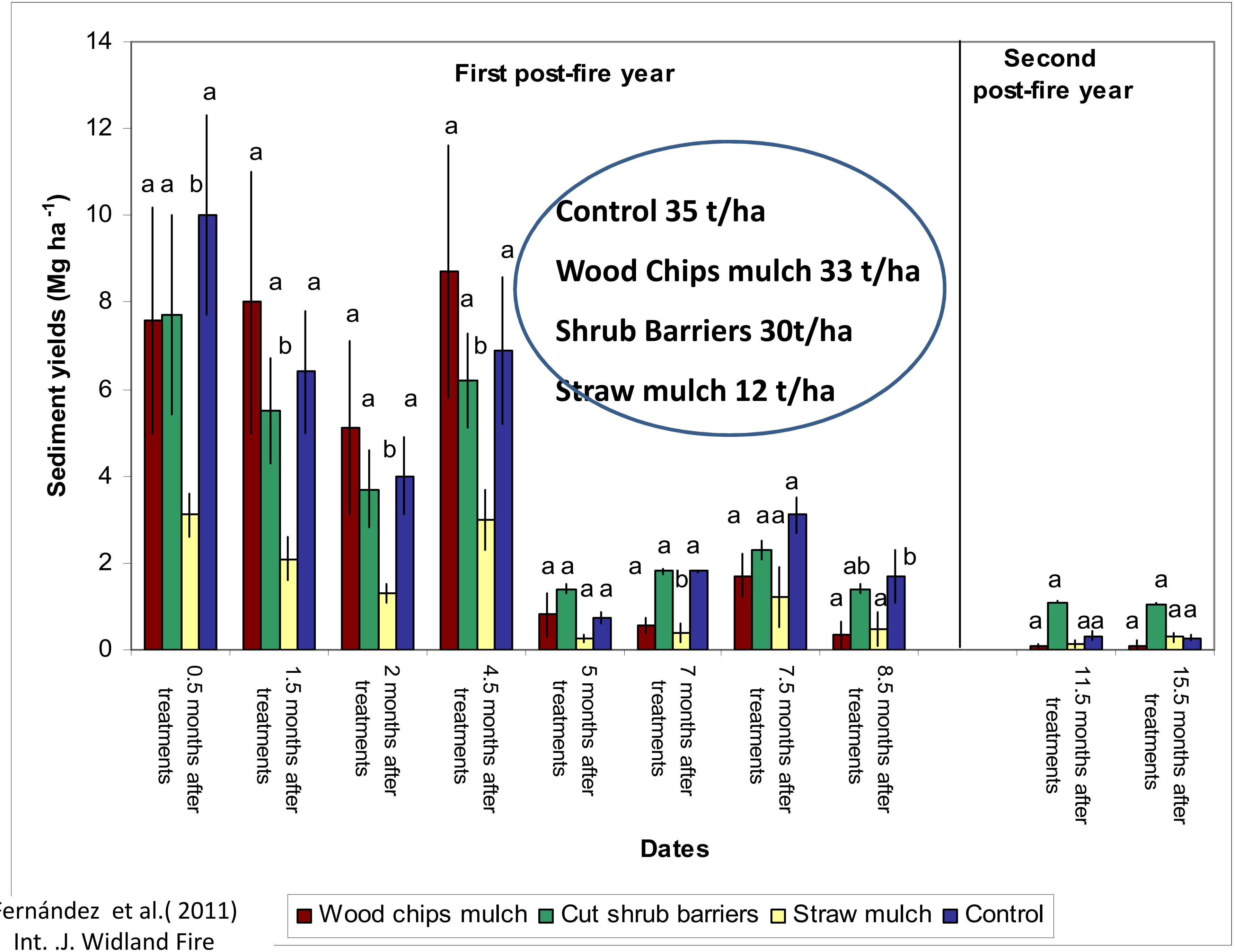
Fernández and Vega (2016)

We have been testing the efficacy and effects of a variety of treatments and materials for post-fire erosion reduction at hillslope scale in the last ten years





Fernández, C., Vega, J.A., Jiménez, E., Fonturbel, T., 2011. Effectiveness of three post-fire treatments at reducing soil erosion in Galicia (NW Spain). International Journal of Wildland Fire, 20, 104-114.



Fernández et al.(2011)
Int. .J. Widland Fire

Soil erosion reduction

-Straw mulch (2t/ha) : 91%

-Eucalypt bark strands mulch (4 t/ha): 86%

Fernández, C., Vega, J.A., 2014. Efficacy of bark strands and straw mulching after wildfire in NW Spain: Effects on erosion control and vegetation recovery. Ecological Engineering, 63, 50-57.

The efficacy of different treatments depends on the type material, load, size and arrangement. The higher soil burn severity the lower the efficacy. Rainfall characteristics and wind can also diminish effectiveness.

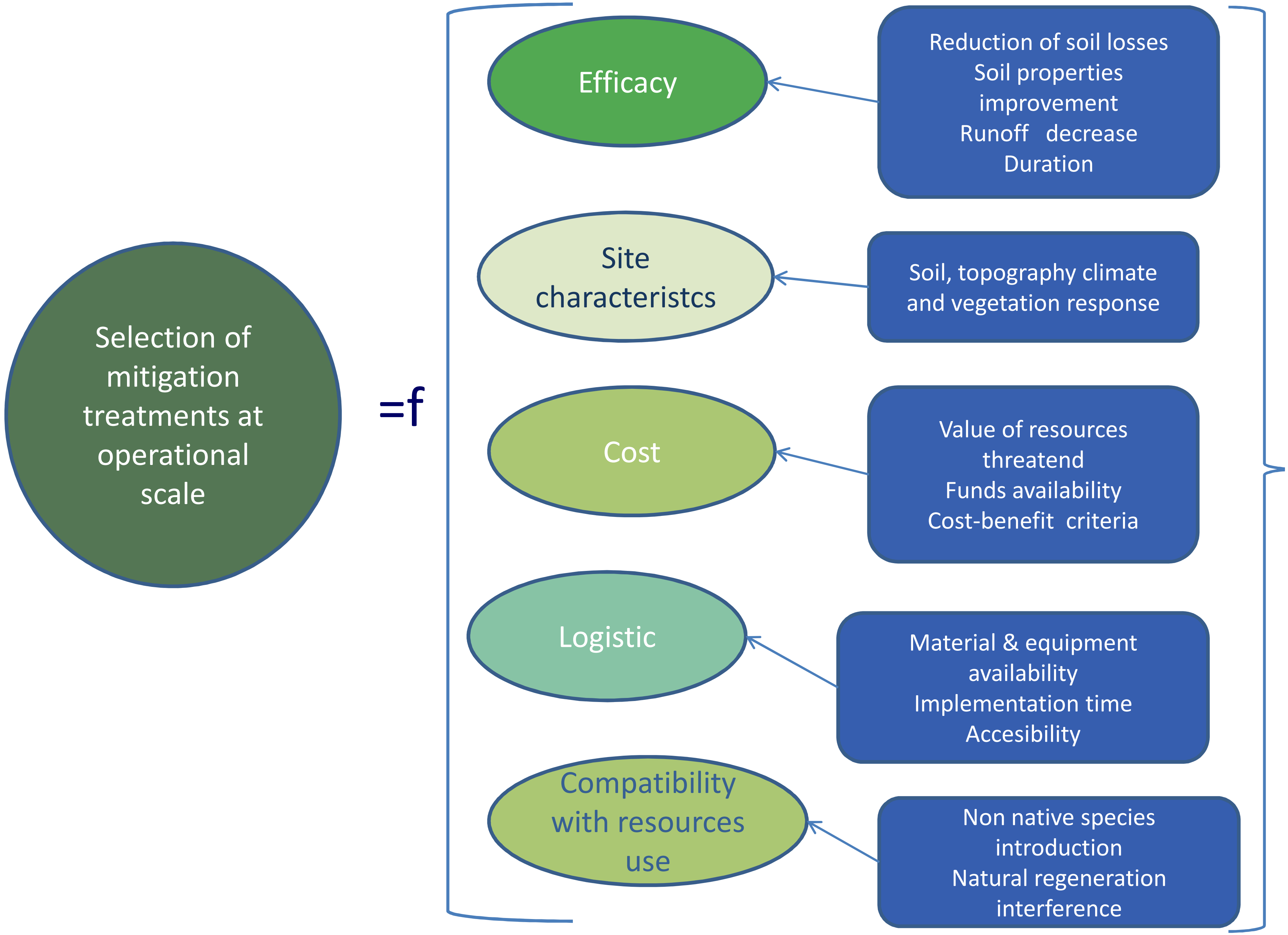
Straw mulch offers the best efficiency ,in terms of efficacy /cost.

Loads> 2.5 -3.5 Mg/ha of straw have showed 67-96% of erosion reduction , being sensitive to slope length and rainfall intensity and high wind, specially in drier climates

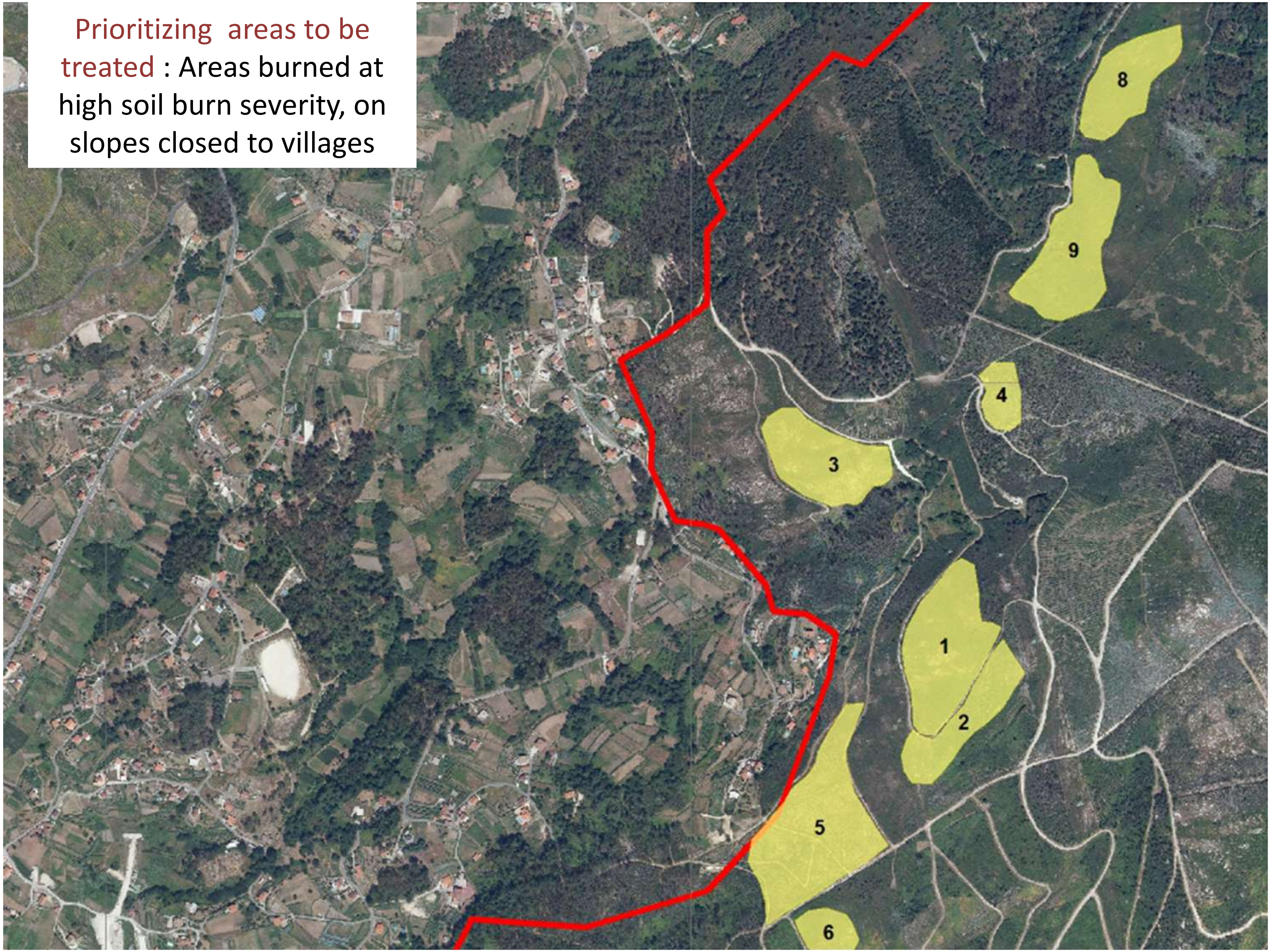
Logs and shrub barriers are time consuming to install and show low efficacy but fiber rolls can play a role , combined with other treatments

Wood chip at < 4 Mg/ha is not effective , but bark shreds (8-11 Mg/ha) and mixes of wood shreds and larger and heavier particles (around 12 Mg/ha) can be effective at four times the cost of straw mulch

Seeding alone gives poor outcome but can help combined with other treaments


Selection of mitigation treatments at operational scale
=f
Efficacy
Reduction of soil losses
Soil properties improvement
Runoff decrease
Duration
Site characteristcs
Soil, topography climate and vegetation response
Cost
Value of resources threatend
Funds availability
Cost-benefit criteria
Logistic
Material & equipment availability
Implementation time
Accesibility
Compatibility with resources use
Non native species introduction
Natural regeneration interference

Prioritizing areas to be treated : Areas burned at high soil burn severity, on slopes closed to villages



Mulching application in strips in a long hillside. (Petáns wildfire 2010)

Combining straw mulch strips with fiber rolls barriers in Fragas del Eume (Galicia) wildfire in 2012


Navia de Suarna 2015


Camba wildfire (2010)
First time helimulching was applied in Europe


Ponte Caldelas (2013)


Navia de Suarna (2015)


Combinig helimulch
and geotextiles
Arbo (2016)

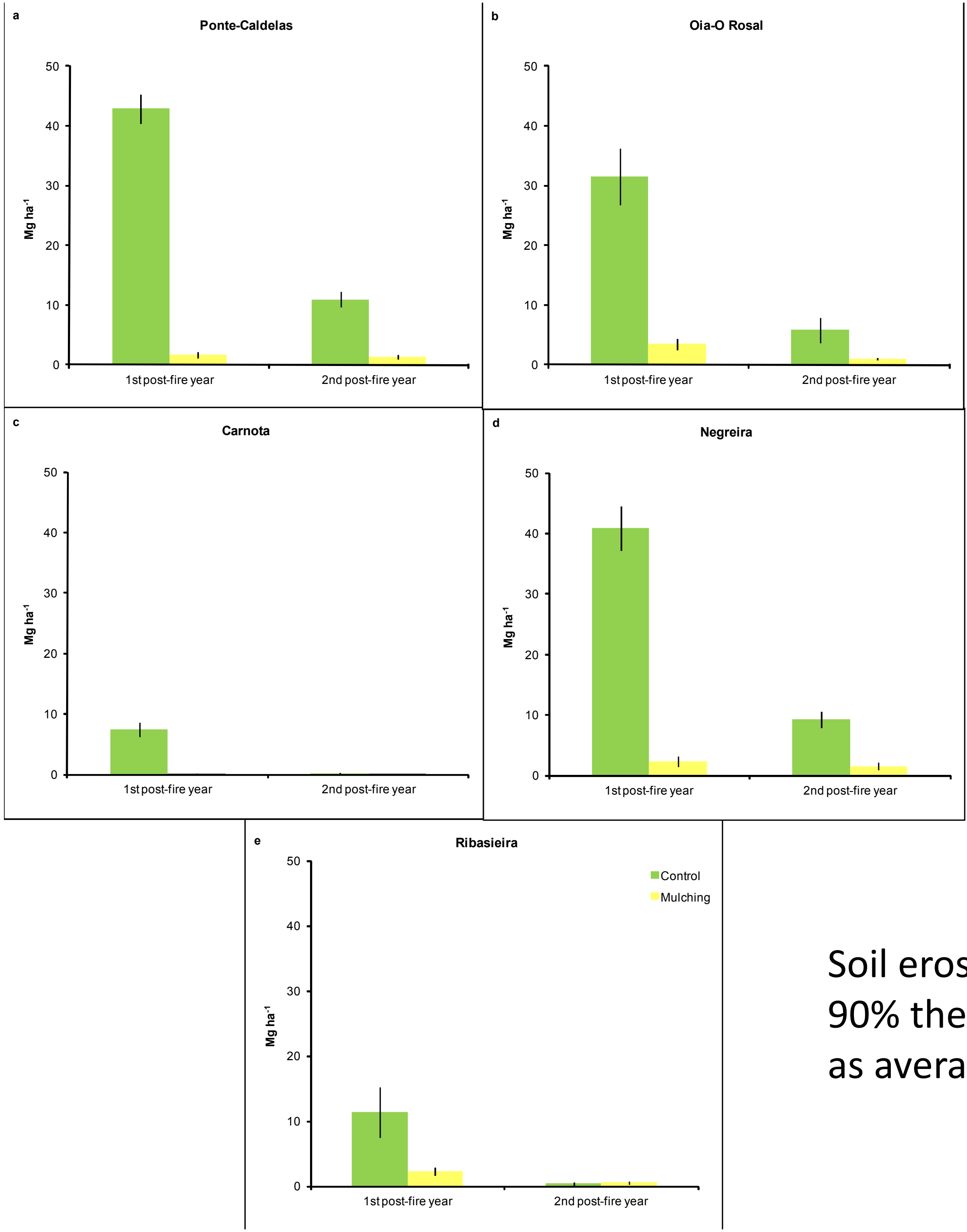

Porto do Son (2016)

Monitoring of hillslope treatments

Helimulching treatment monitoring

70 plots were setup in five wildfires in 2013

Fernández, C.; Vega, J.A, Fontúrbel, T. 2016.. Reducing post-fire soil erosion from the air: Performance of heli-mulching in a mountainous area on the coast of NW Spain. Catena 147 : 489–495



Soil erosion reduction was 90% the first post-fire year as average.

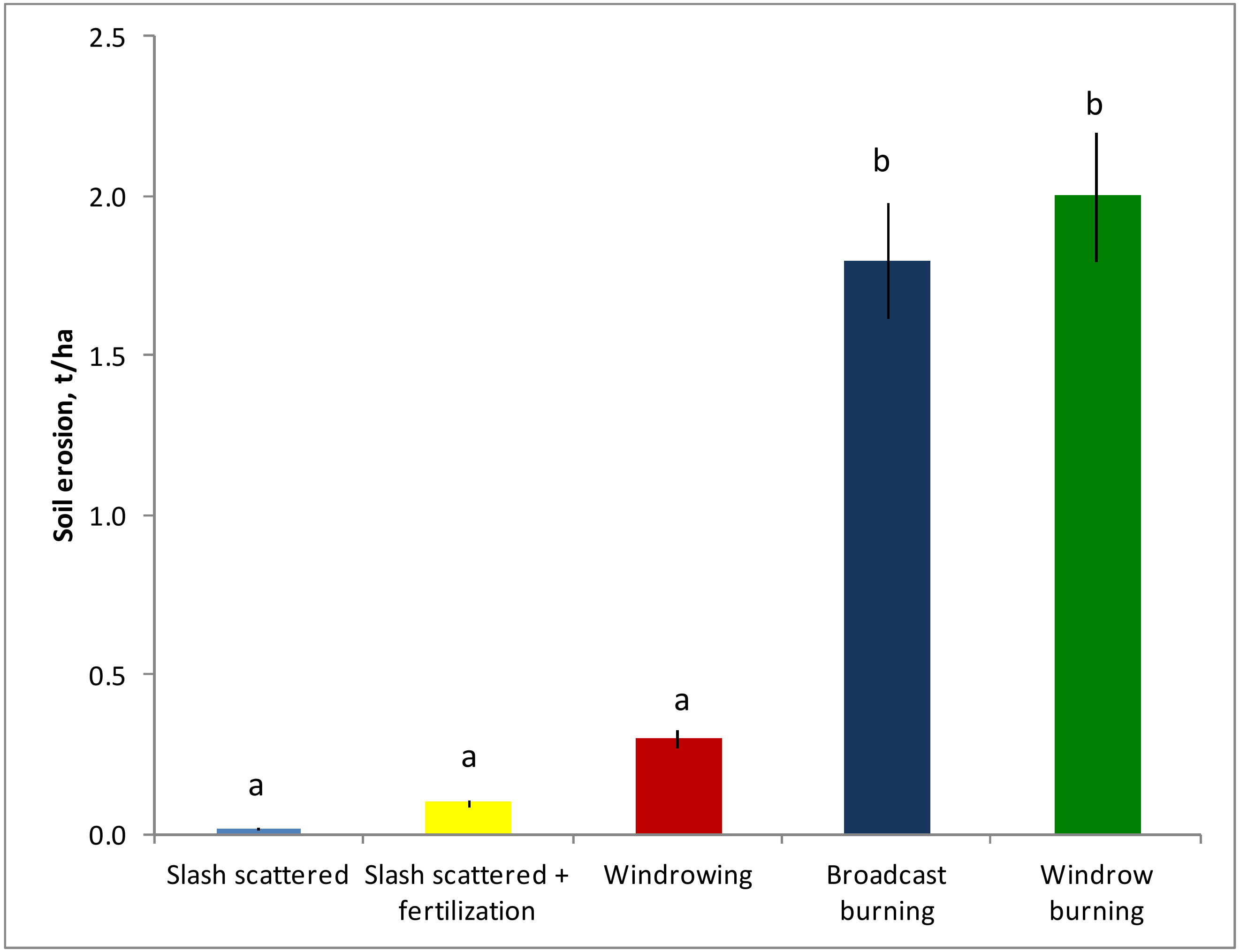
Fernández et al.(2016)


In the last years, The Centro de Investigación Forestal (Lourizán), through our group, is providing scientific and technical support to the Post-fire Actions Coordination Board, a government committee coordinating the emergency stabilization planning in Galicia.

In many occasions, the incomes from burned trees harvesting need to be tradeoff with soil conservation.

Field research concerning the effects of post-fire salvage logging on sediment production is still limited

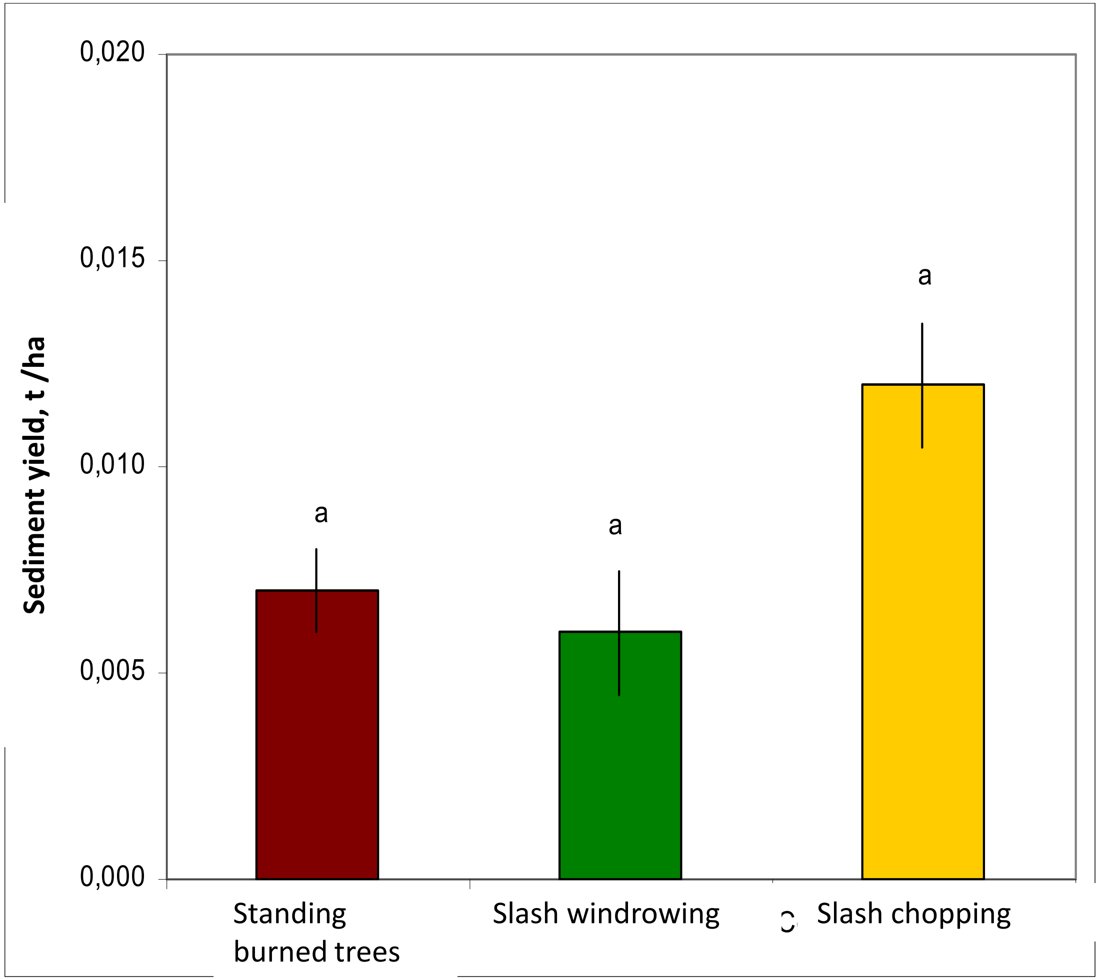
Soil erosion after clearcutting in a *Eucalyptus globulus* stand: differences between logging slash disposal methods



Fernández, C.; Vega, J.A; Gras, J.M.; Fonturbel, M.T ; Cuiñas, P.;. Dambrine, E.; Alonso, M. 2004. Soil erosion after Eucalyptus globulus clearcutting: differences between logging slash disposal treatments. Forest Ecology and Management.. 195(1-2): 85-95

Soil losses after salvage logging in burned areas affected by moderate fire severity

(tree crown scorched generating a needle cast layer)

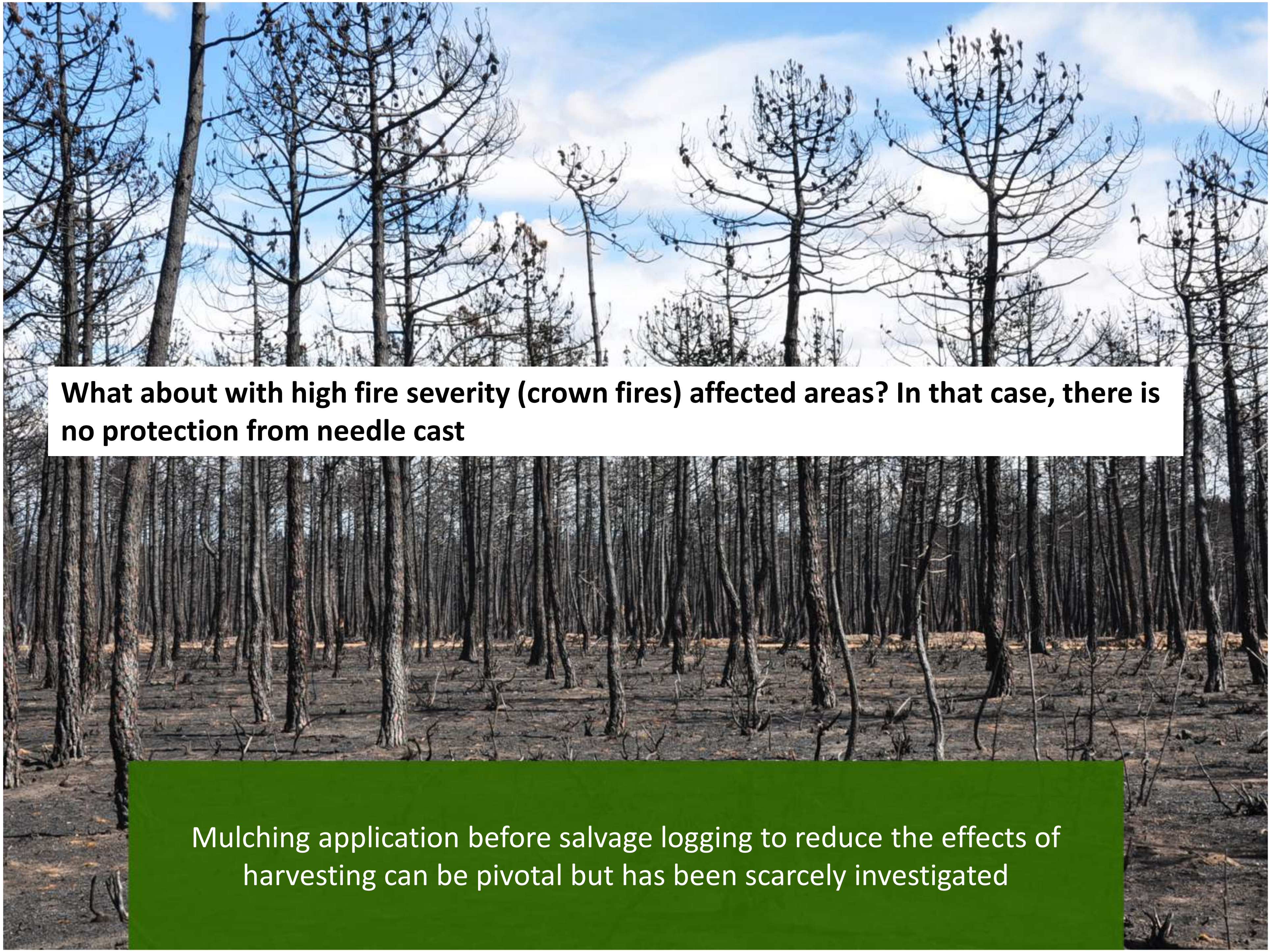


Fernández, C.; Vega J.A.; Fonturbel, M.T.; Pérez-Gorostiaga, P.; Jiménez, E.; Madrigal, J. 2007. Effects of wildfire, salvage logging and slash treatments on soil degradation. Land Degradation and Development. 38 (6): 591-607.

Standing burned trees (control)

Harvesting + slash windrowing

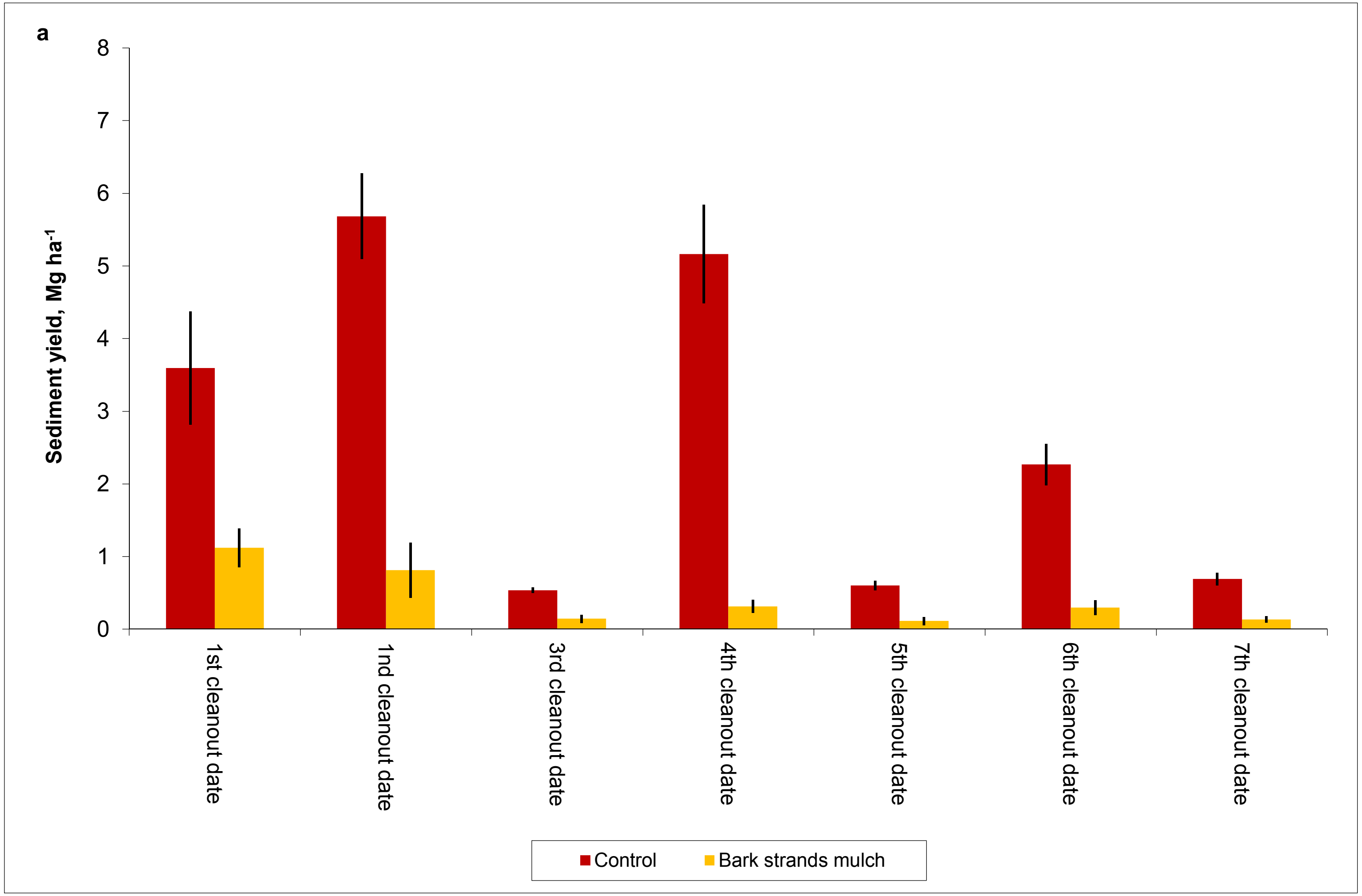
Harvesting + slash chopping



What about with high fire severity (crown fires) affected areas? In that case, there is no protection from needle cast

Mulching application before salvage logging to reduce the effects of harvesting can be pivotal but has been scarcely investigated

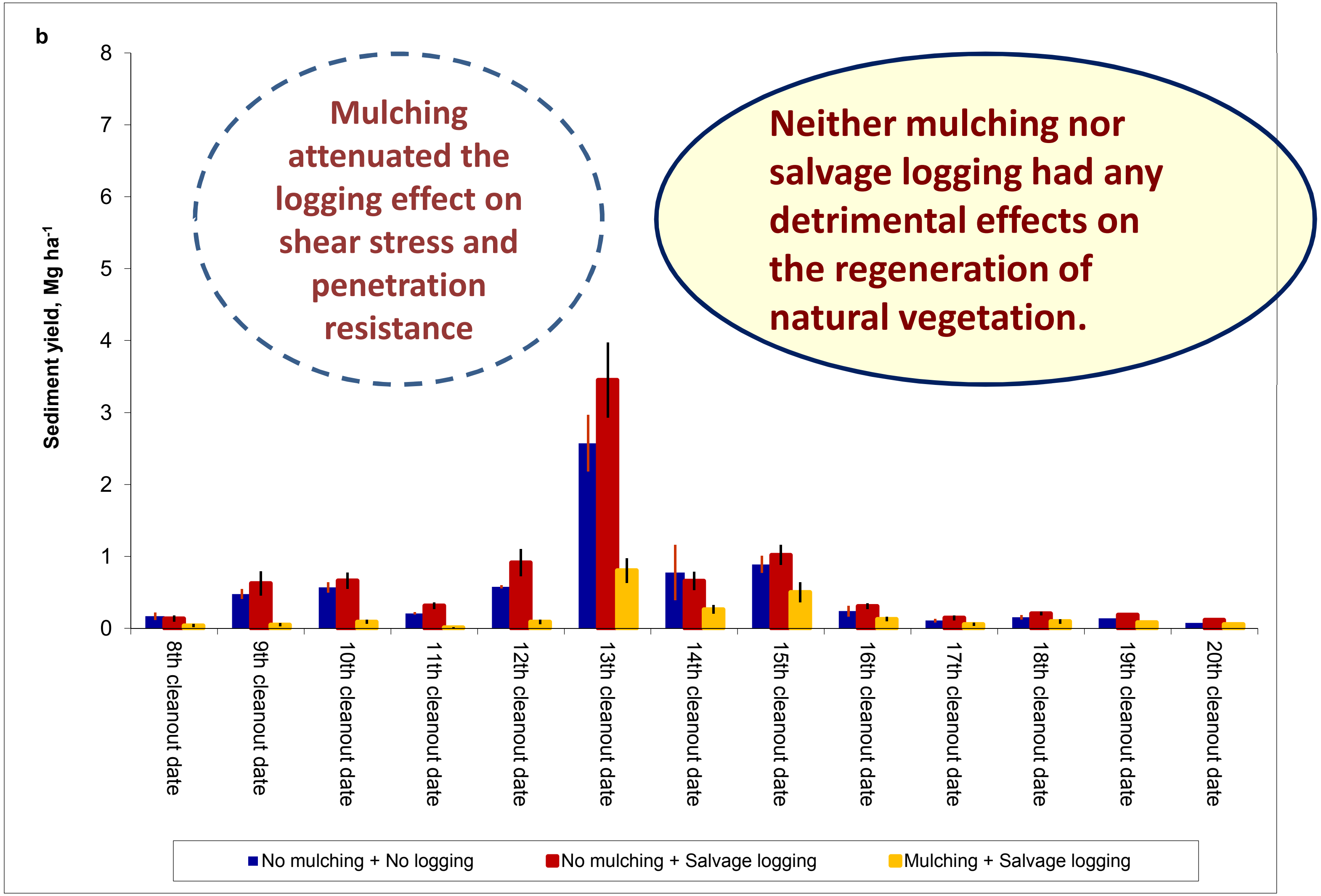
During the six month between the wildfire and salvage logging, the average soil loss in the untreated burned soils was 18.5 Mg ha^{-1}. In that period, mulching significantly reduced soil loss (84%).



In the 18-month period following salvage logging:

•In the absence of mulch there was no increase in erosion due to logging (8.7 Mg ha^{-1}) compared with the unlogged treatment (7.0 Mg ha^{-1})

• Mulching continued reducing significantly soil losses even after logging (2.3 Mg ha^{-1}).

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The “ spider”. A frontal crusher partially suspended tractor

Concluding remarks:

-Impact of climate change: How annual rainfall distribution and intensity shifts will affect soil losses after fire?
-Introduction of uncertainty in the models: spatial probability of high soil burn severity coinciding with post-fire adverse meteorological events occurrence.
-Vulnerability at operational scale appraisal.
-Genetic selection of soil microorganisms to be jointly used with physical treatments to accelerate post-fire recovery.
-To improve the combination of post-fire harvesting and soil protection measures.

Concluding remarks:

-More faster and precise soil burn severity assessment

-In the coming years there will be an increasingly pressing need to manage the wildfire impact on drinking water quality.

[redacted]


Thank you!