



LIFE15 CCA/IT/000089

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## Strumenti di monitoraggio degli impatti del cambiamento climatico sulle foreste

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Alimentari e Ambientali*

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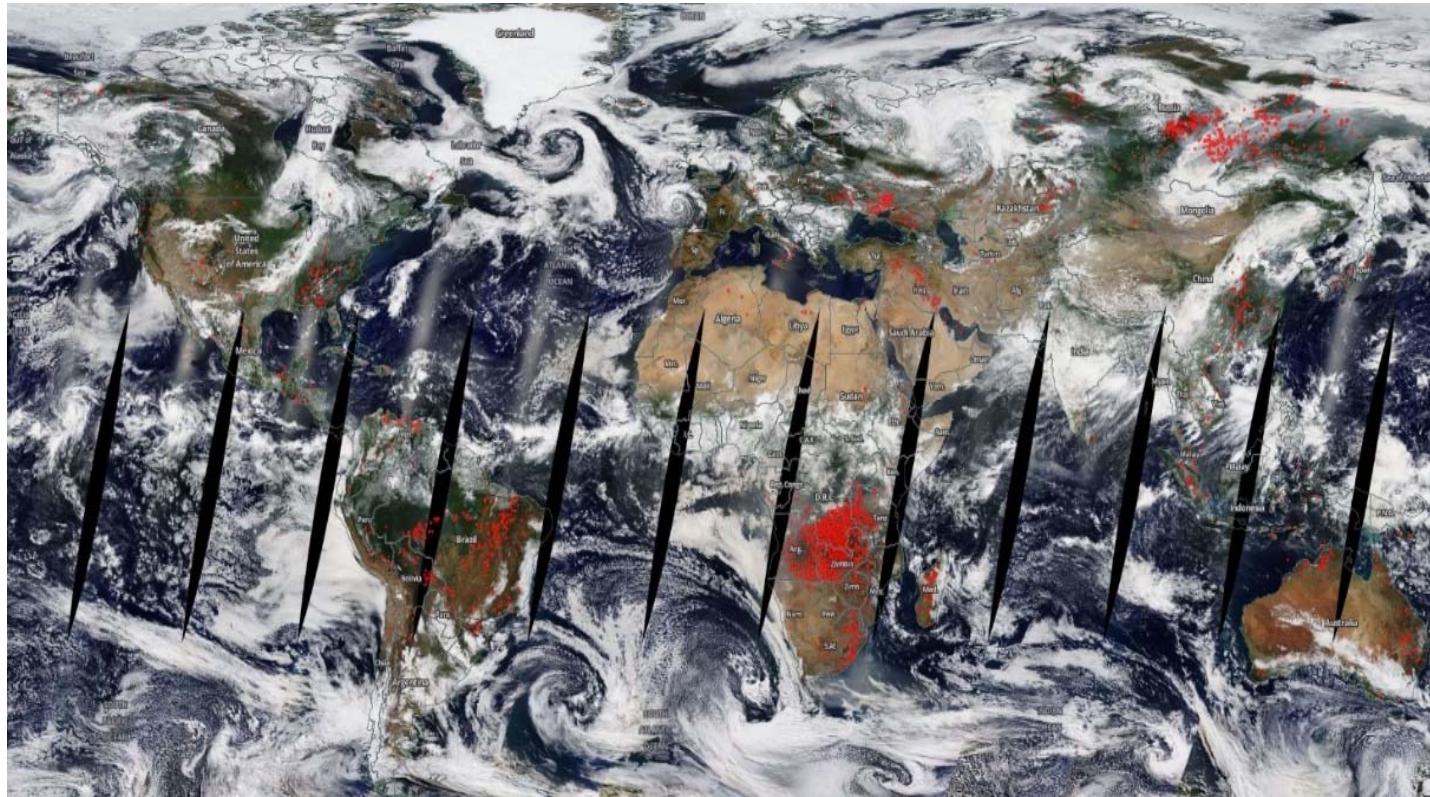
LIFE15 CCA/IT/000089

*Foreste mediterranee e cambiamenti climatici:  
tra mitigazione e adattamento*

## Disturbi e Impatti



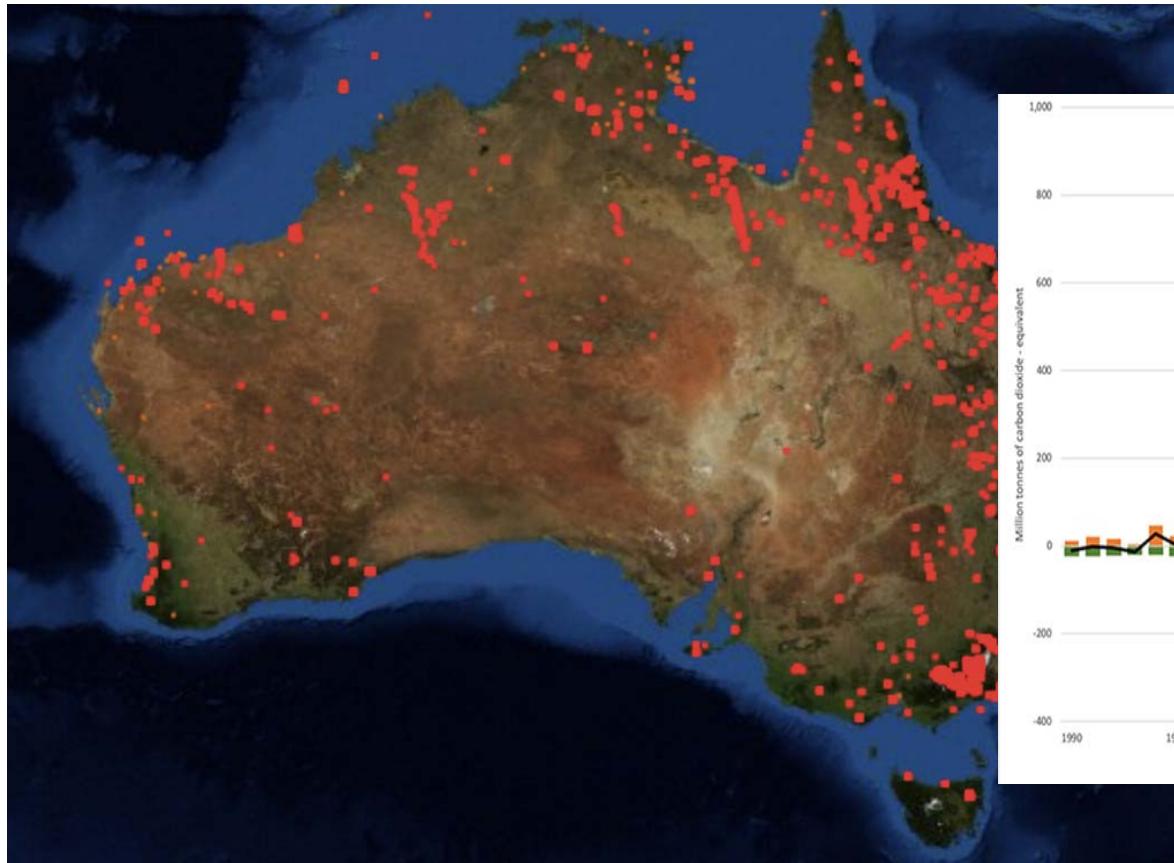
## Incendi Artico 2019



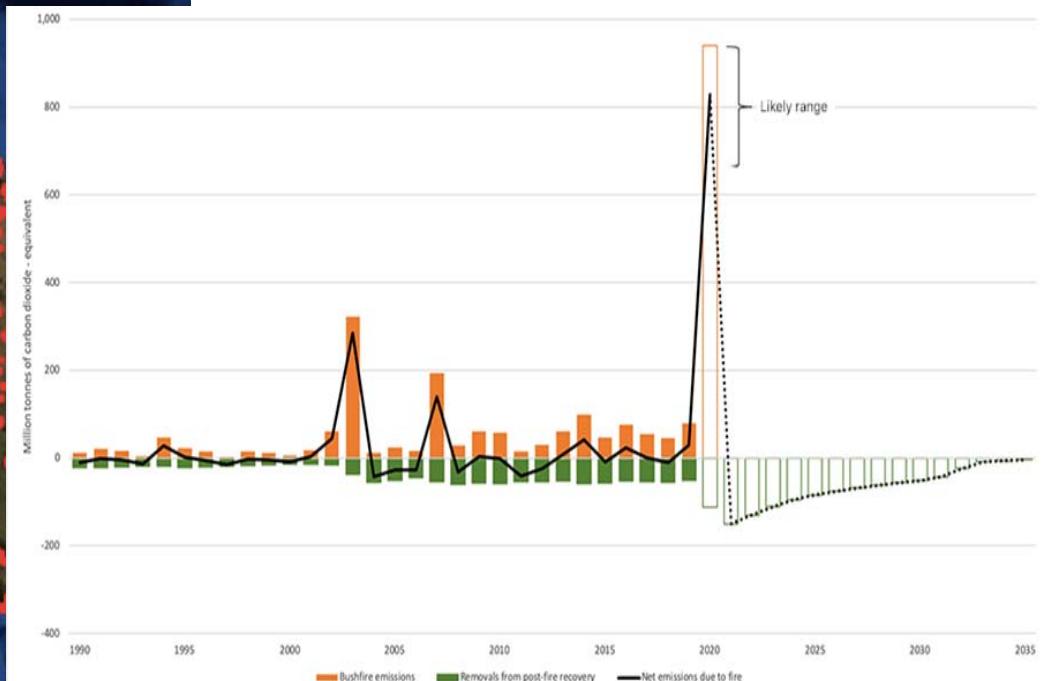
Active Fires del 29/07/2019, Immagine scaricata dal Fire Information for Resource Management System (FIRMS)  
<https://firms.modaps.eosdis.nasa.gov>

## Incendi Australia 2019-2020

Circa 19 Milioni di ettari



≈ 800 M ton di CO<sub>2</sub>



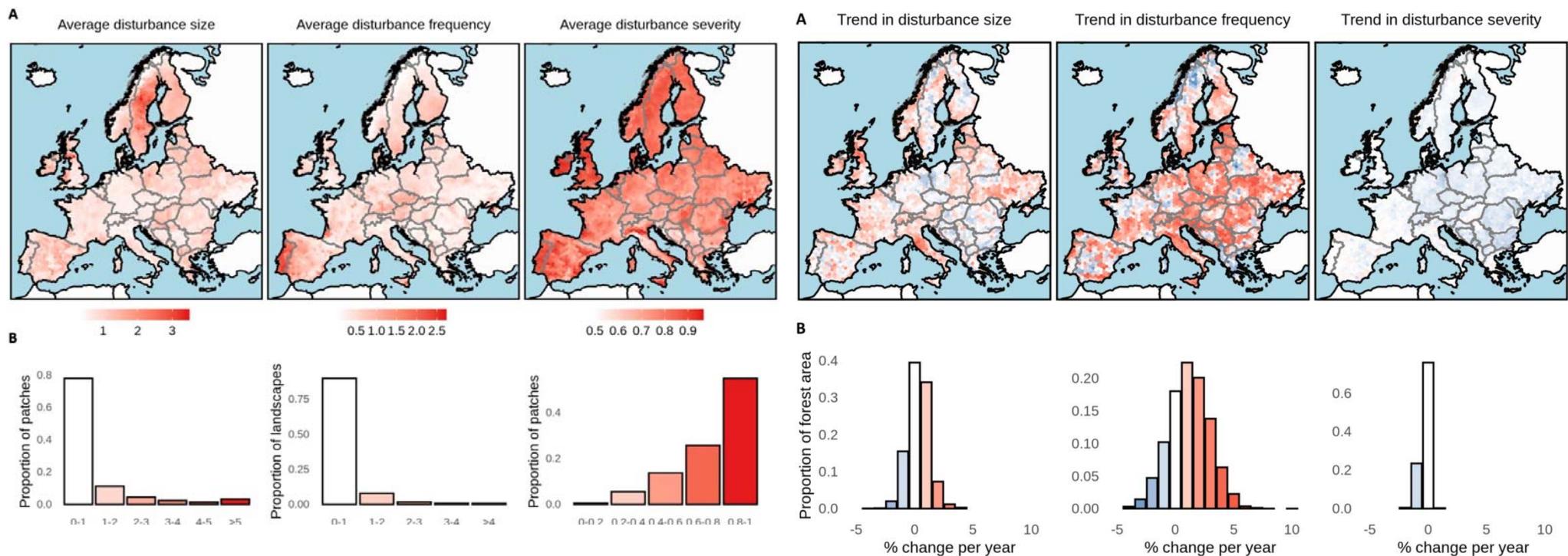
# Eventi estremi Canada 2021

Circa 1 milione di ettari percorsi  
dal fuoco



# Forest disturbance regimes of Europe

(1986-2016)



Senf and Seidl (2021) Mapping the forest disturbance regimes of Europe. *Nat Sustain*

## Disturbi e Impatti

### Disturbance

“Any relatively discrete event in time that disrupts ecosystems, community, or population structure and changes resources, substrate availability, or the physical environment.” (*White and Pickett, 1985*)

### Disturbi in foresta

#### Disturbi Naturali:

- Fuoco (<2% incendi)
- Vento
- Siccità
- neve e ghiaccio
- Valanghe
- Alluvioni
- frane
- Vulcani
- insetti e patogeni

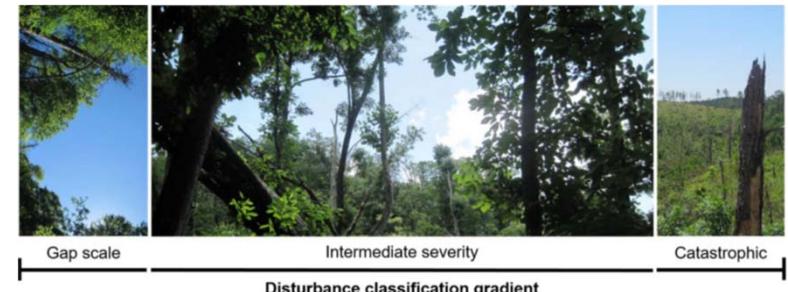
#### Disturbi Antropici:

- Fuoco
- Deforestazione
- Cambio di destinazione d'uso del suolo

## Disturbi e Impatti

# Classificazione

- Tipo di disturbo
  - Intensità del disturbo (magnitudo);
  - Frequenza o tempo di ritorno del disturbo;
  - Estensione spaziale del disturbo;
  - Residui, quantità e qualità di organismi e servizi e funzioni ecosistemiche che sopravvivono al disturbo (*biotic and functional legacies*)



# Regime di disturbo naturale

## Magnitudo

**disturbi minori** (*minor disturbances*) sono quelli che rilasciano una parte più o meno consistente del popolamento preesistente

**disturbi maggiori** (*major disturbances or stand replacing disturbances*) sono quelli che provocano l'eliminazione completa del popolamento preesistente

#### Dal punto di vista ecologico

La magnitudo e l'estensione del disturbo influenzano la *composizione* e *la struttura* del popolamento forestale

# Disturbi e Impatti

Gli impatti dei disturbi possono essere misurati attraverso  
*Biotic and functional legacies*

## Servizi ecosystemici



**Supporto alla vita**  
Produzione primaria  
Ciclo dei nutrienti  
Formazione del suolo

**Approvvigionamento**  
Cibo, Acqua, Legno e prodotti non legnosi, fibre e combustibili

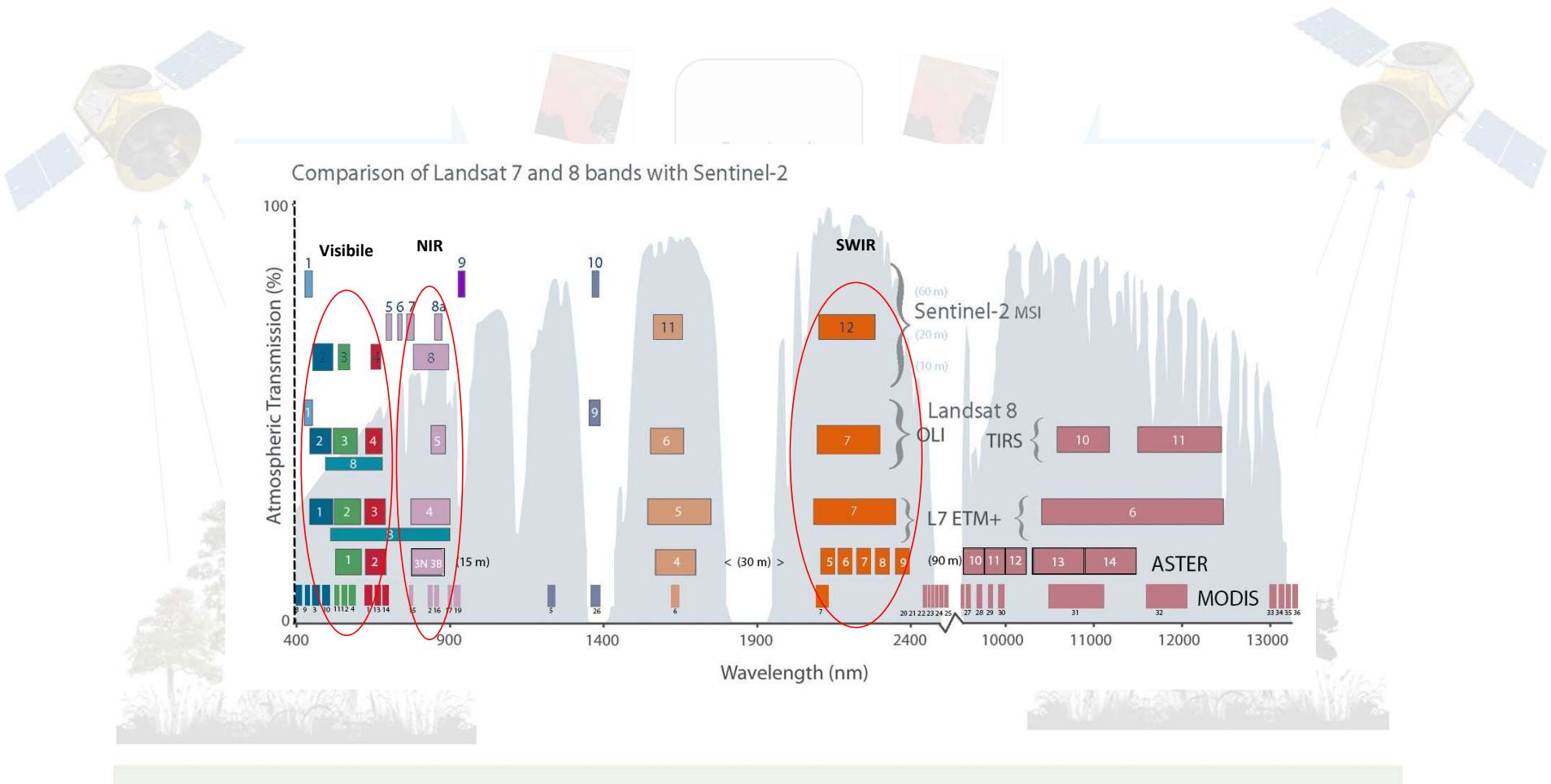
**Regolazione**  
Atmosfera, Clima, Acque, Erosione, dissesto idrogeologico, habitat, biodiversità

**Valori culturali**  
Estetici, Spirituali, Educativi e ricreativi

MEA  
Millennium Ecosystem Assessment (2005)

# Monitoraggio Impatti

## Remote sensing monitoring

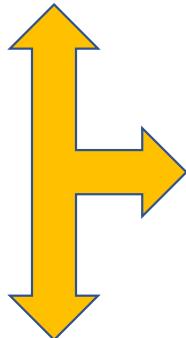


## Le sfide delle foreste nel clima che cambia

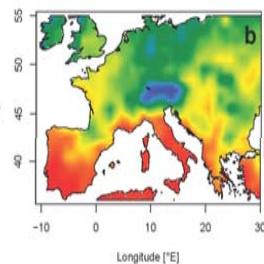
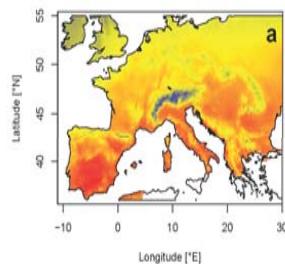
Fuoco



Disturbi



Acqua

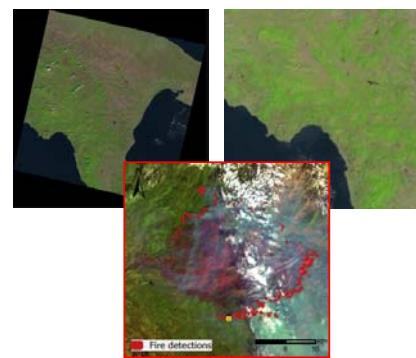
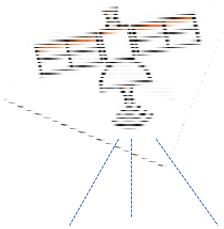


Freddo



## Monitoraggio impatti incendi

SEVERITA' D'INCENDIO

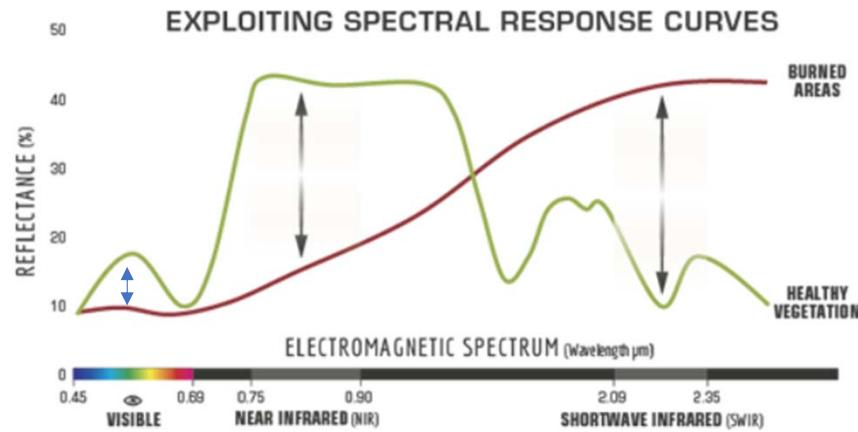


RECOVERY



## Monitoraggio impatti incendi

Il monitoraggio post-incendio da remote sensing si basa sull'analisi delle proprietà spettrali, in termini di riflettanza, delle aree percorse dal fuoco

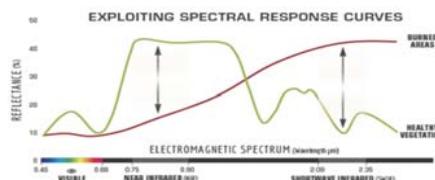
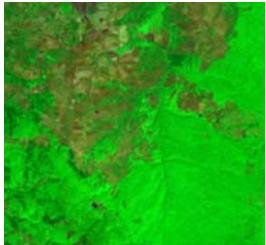


## Monitoraggio impatti incendi

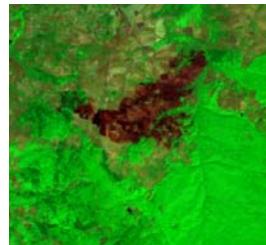
Fire severity  $\Delta\text{NBR} = (\text{NBR}_{\text{pre}} - \text{NBR}_{\text{post}})$

$$\text{NBR} = \frac{\text{NIR-SWIR}}{\text{NIR+SWIR}}$$

Pre-fire

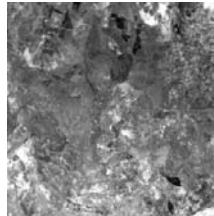


Post-fire

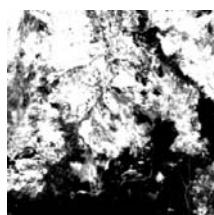


Landsat 8 false-color 752  
(SWIR2, NIR, Blue)

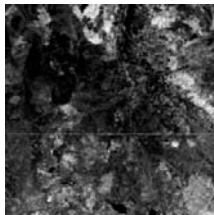
NIR



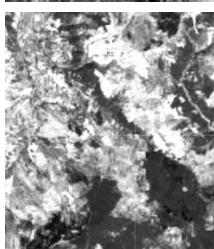
SWIR



NIR

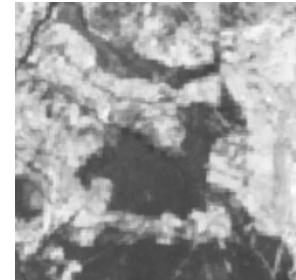


SWIR

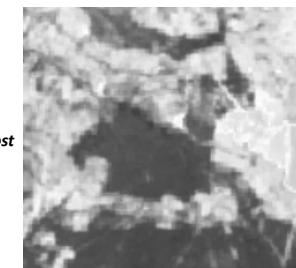


NBR (Normalized Burn Ratio)

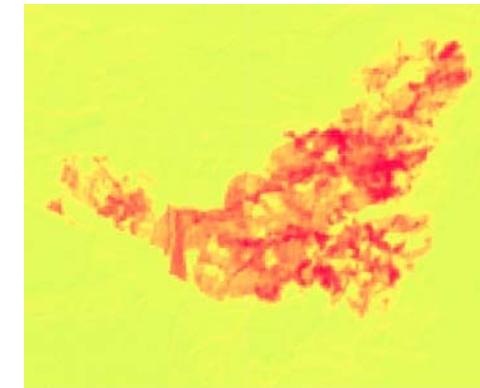
$\text{NBR}_{\text{pre}}$



$\text{NBR}_{\text{post}}$



$$\Delta\text{NBR} = (\text{NBR}_{\text{pre}} - \text{NBR}_{\text{post}})$$



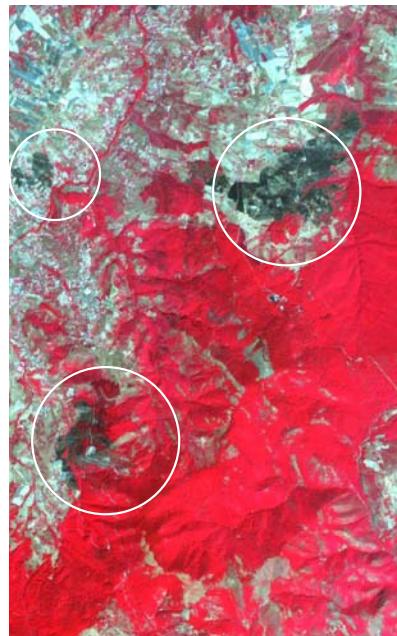
$\Delta\text{NBR}$	Burn Severity
< -0.25	High post-fire regrowth
-0.25 to -0.1	Low post-fire regrowth
-0.1 to +0.1	Unburned
0.1 to 0.27	Low-severity burn
0.27 to 0.44	Moderate-low severity burn
0.44 to 0.66	Moderate-high severity burn
> 0.66	High-severity burn

# Monitoraggio impatti incendi

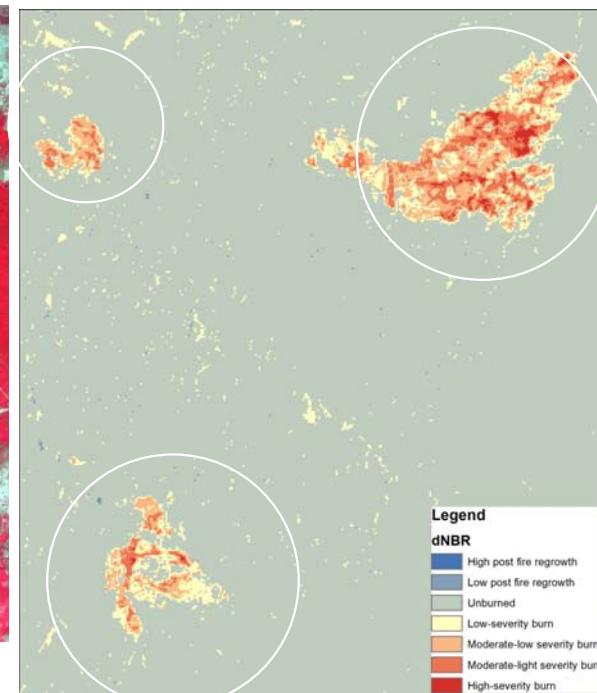
03<sup>rd</sup> - 26<sup>th</sup> august 2017  
True color- bands 4-3-2



03<sup>rd</sup> - 26<sup>th</sup> august 2017  
*False Colro InfraRed* - bands 8-4-3



**ΔNBR Burn Severity Categories**  
03<sup>rd</sup> - 26<sup>th</sup> august 2017

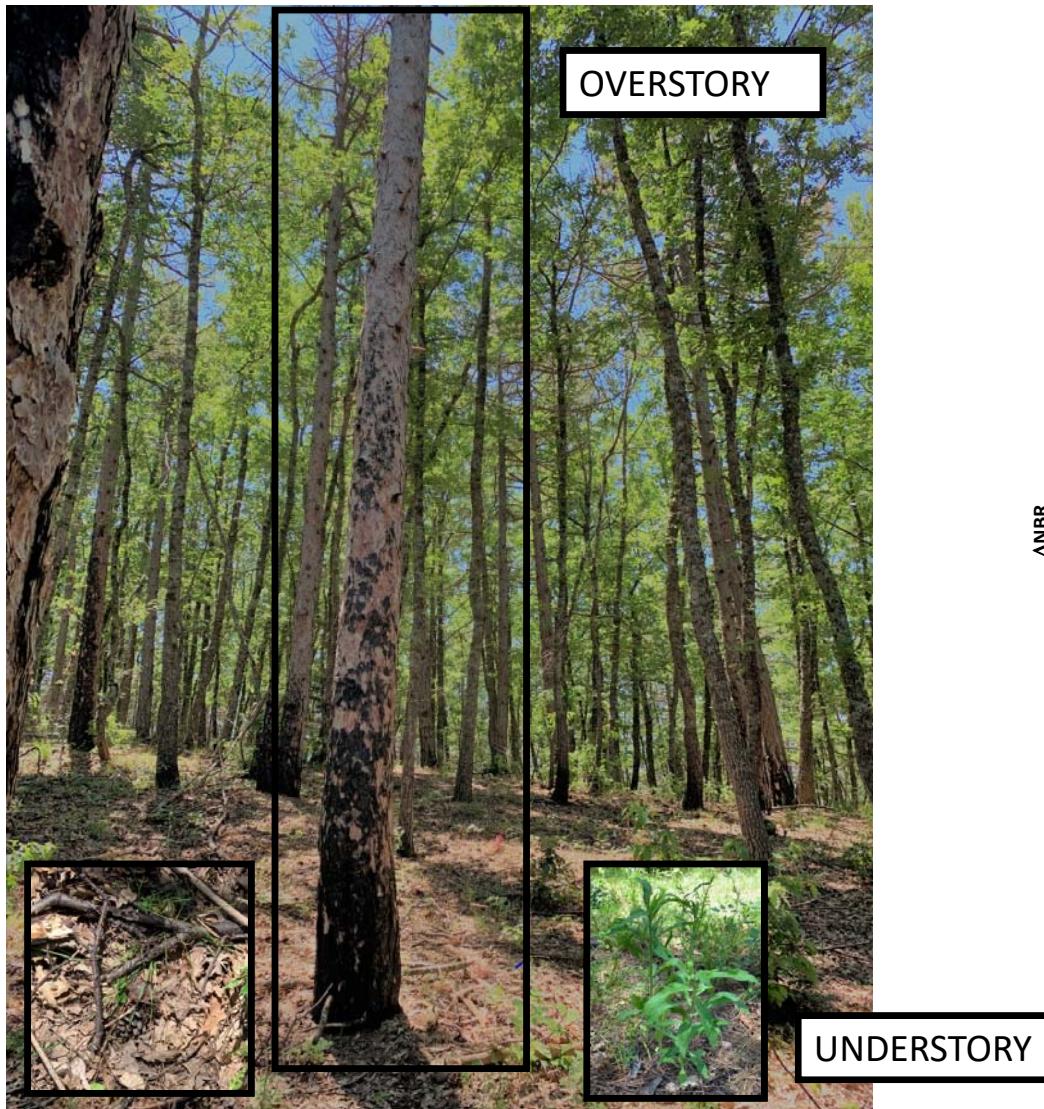


## Legend

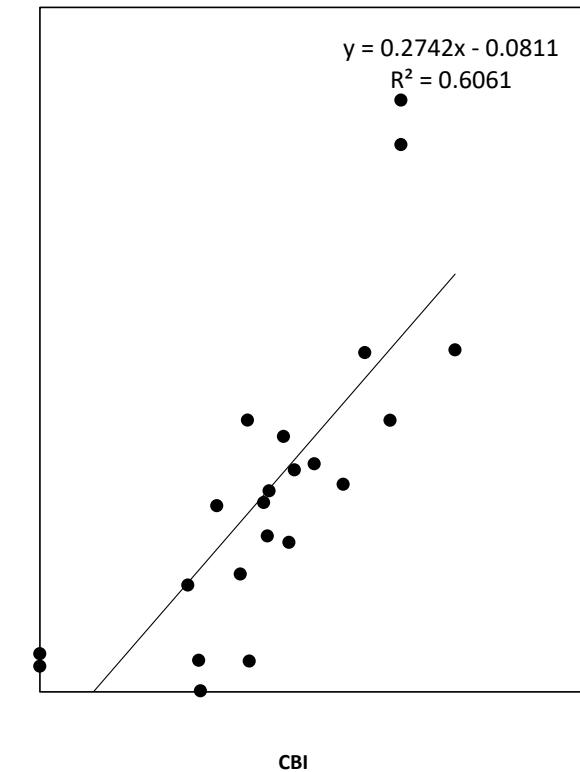
### dNBR

- High post fire regrowth
- Low post fire regrowth
- Unburned
- Low-severity burn
- Moderate-low severity burn
- Moderate-light severity burn
- High-severity burn

## Calibrazione e Validazione in campo



## COMPOSITE BURN INDEX (CBI)

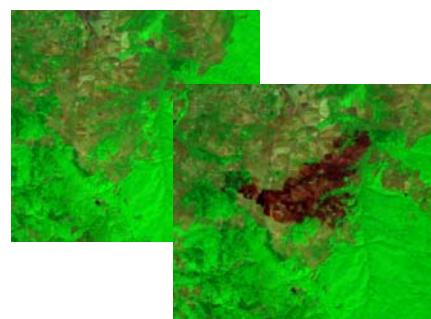


## Validation of the fire severity index

### Identification of study areas

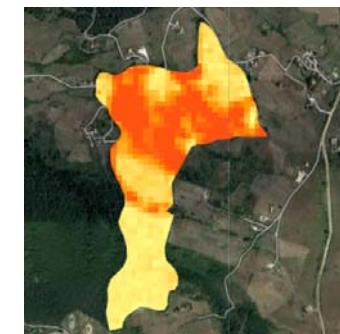


### Image acquisition and Pre-processing



$$NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

$$\Delta NBR = (NBR_{\text{pre}} - NBR_{\text{post}})$$



### Field rating of burn severity by CBI (Composite Burn Index)



BURN SEVERITY – COMPOSITE BURN INDEX (CBI)						
PD - Abreved	Examiner	Fire Name	Plot Photo Series			
Registration Code		Project Code		Plot Number		
Plot Address		Plot Address				
Plot Aspect		Plot % Slope		UTM Zone		
Plot Diameter (meters)		UTM N. plot center		GPS Diam (m)		
Number of Photos		Plot Photo ID#		GPS E (m)		
III - Long Form	% Burned 100 feet (30 m) diameter from center of plot =	Plot Photo Series =				
STRATA	BURN SEVERITY SCALE					
	No Effect	Low	Moderate	High	FACTOR SCORES	
A. SUBSTRATES	8.0	8.5	1.0	1.5	2.5	3.0
Pre Fire Cover: Leaf	None	None	None	None	None	None
Pre Fire Cover: Bark	None	None	None	None	None	None
Pre Fire Cover: Dead	None	None	None	None	None	None
Pre Fire Cover: Duff	None	None	None	None	None	None
Modest: 1-5%	Unchanged	Light	—	10% loss deep char	—	10% loss deep char
Medium: 6-10%	Unchanged	Light	—	100% loss deep char	—	100% loss deep char
Large: 11-20%	Unchanged	Light	—	100% loss deep char	—	100% loss deep char
Extensive: >20%	Unchanged	Light	—	100% loss deep char	—	100% loss deep char
C. HERBS, LOW SHRUBS AND TREES LESS THAN 1 METER TALL	Pre Fire Cover =	% Unburned Growth =				
Pre Fire Cover: Leaf	None	100%	100%	100%	100%	100%
Pre Fire Cover: Bark	None	100%	100%	100%	100%	100%
Pre Fire Cover: Dead	None	100%	100%	100%	100%	100%
Pre Fire Cover: Duff	None	100%	100%	100%	100%	100%
Columnar: 1-5%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: 6-10%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: 11-20%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: >20%	Unchanged	Low	Moderate	High-Low	Low to None	None
D. TALL SHRUBS AND TREES 1 TO 5 FEET TO 5 METERS	Pre Fire Cover =	% Unburned Growth =				
Pre Fire Cover: Leaf	None	100%	100%	100%	100%	100%
Pre Fire Cover: Bark	None	100%	100%	100%	100%	100%
Pre Fire Cover: Dead	None	100%	100%	100%	100%	100%
Pre Fire Cover: Duff	None	100%	100%	100%	100%	100%
Columnar: 1-5%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: 6-10%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: 11-20%	Unchanged	Low	Moderate	High-Low	Low to None	None
Columnar: >20%	Unchanged	Low	Moderate	High-Low	Low to None	None
E. INTERMEDIATE TREES OR CANOPY, POLE-SIZED TREES	Pre Fire Cover =	Pre Fire Number Light =	Pre Fire Number Dead =			
Pre Fire Cover: Leaf	None	—	—	None		
Pre Fire Cover: Bark	None	—	—	None		
Pre Fire Cover: Dead	None	—	—	None		
Pre Fire Cover: Duff	None	—	—	None		
Pre Fire: 1-5%	None	0.30%	—	—		
Pre Fire: 6-10%	None	0.30%	—	—		
Pre Fire: 11-20%	None	0.30%	—	—		
Pre Fire: >20%	None	0.30%	—	—		
Post Fire: 1-5%	Salvaged	—	—	None Mortality		
Post Fire: 6-10%	Salvaged	—	—	None Mortality		
Post Fire: 11-20%	Salvaged	—	—	None Mortality		
Post Fire: >20%	Salvaged	—	—	None Mortality		
F. BIG TREES (PFTA CANOPY, DOMINANT, CODOMINANT TREES)	Pre Fire Cover =	Pre Fire Number Living =	Pre Fire Number Dead =			
Pre Fire Cover: Leaf	None	—	—	None		
Pre Fire Cover: Bark	None	—	—	None		
Pre Fire Cover: Dead	None	—	—	None		
Pre Fire Cover: Duff	None	—	—	None		
Pre Fire: 1-5%	None	0.10%	—	—		
Pre Fire: 6-10%	None	0.10%	—	—		
Pre Fire: 11-20%	None	0.10%	—	—		
Pre Fire: >20%	None	0.10%	—	—		
Post Fire: 1-5%	Salvaged	—	—	None Mortality		
Post Fire: 6-10%	Salvaged	—	—	None Mortality		
Post Fire: 11-20%	Salvaged	—	—	None Mortality		
Post Fire: >20%	Salvaged	—	—	None Mortality		
Community Notes/Comments:	CBI = Sum of Scores / N Rated	Sum of Scores / N Rated	N Rated	CBI		
	Untreated	Untreated				
	Untreated	Untreated				
	Untreated	Untreated				
	Untreated	Untreated				
	Untreated	Untreated				
Total Plot (A+B+C+D+E)						

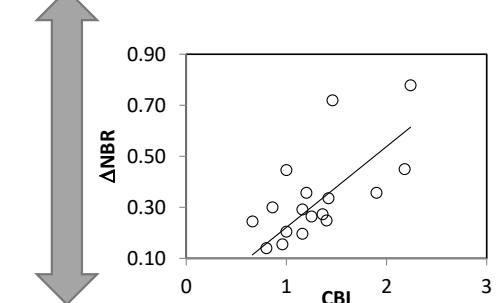
### A. Substrates

### B. Herbs, low shrubs

### C. Shrubs and trees 1 to 5 m tall

### D. Intermediate trees

### E. Big trees

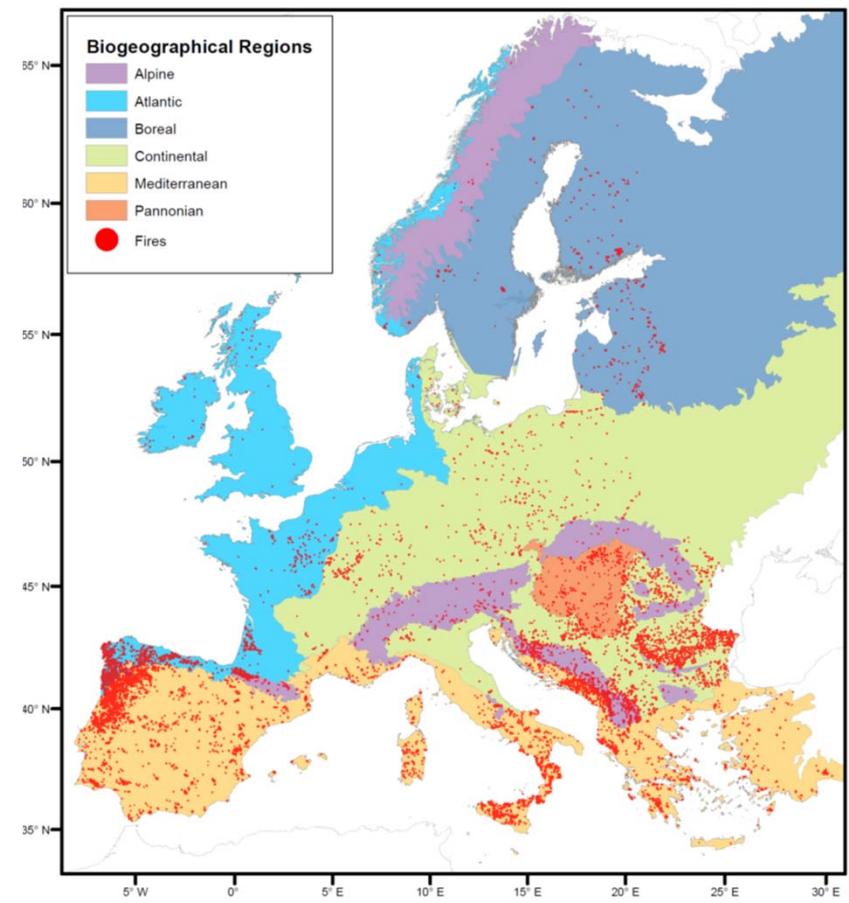
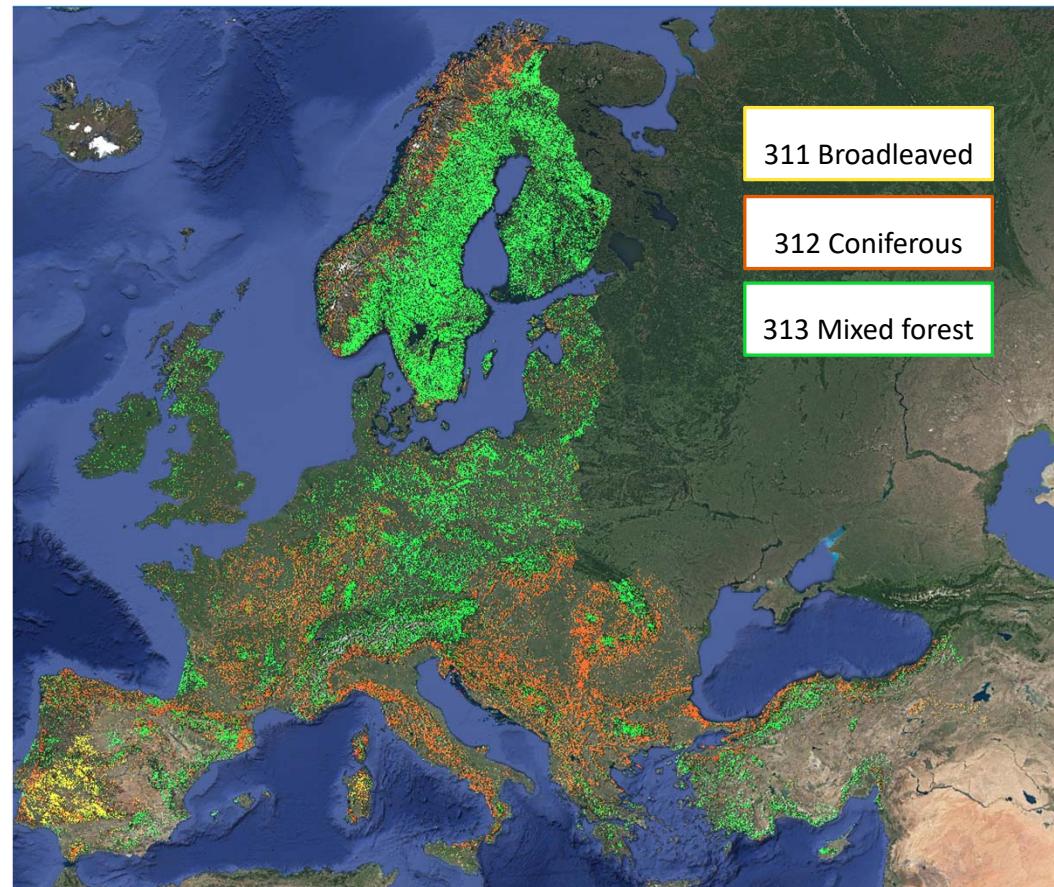


Validation between  
CBI field data with  
"fire severity index"

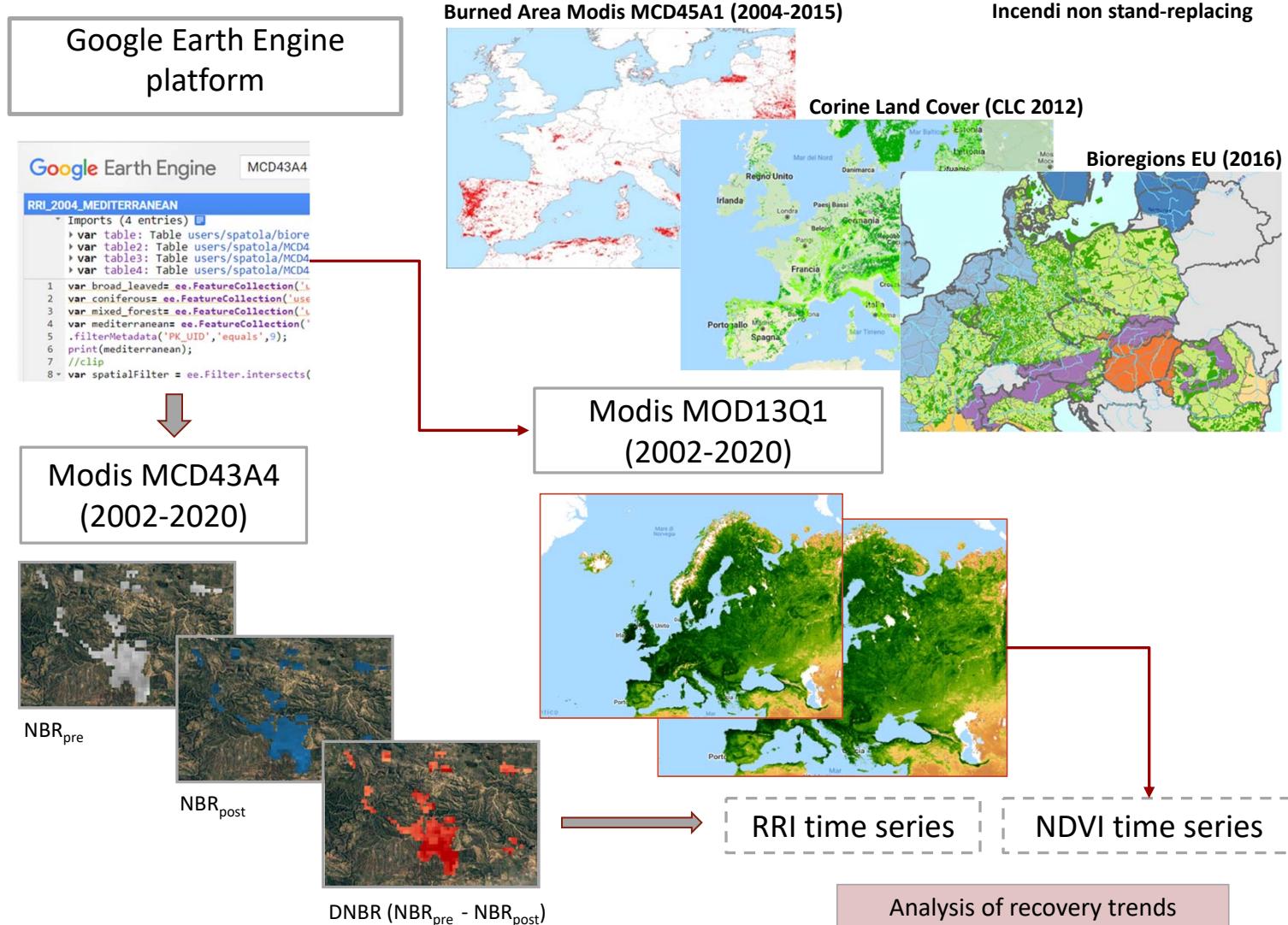
## Monitoraggio post-incendio

Analisi dei trend di ripristino della vegetazione post-incendio  
NDVI vs RRI trends (2002-2020)

European Forests Corine Land Cover (CLC 2012)



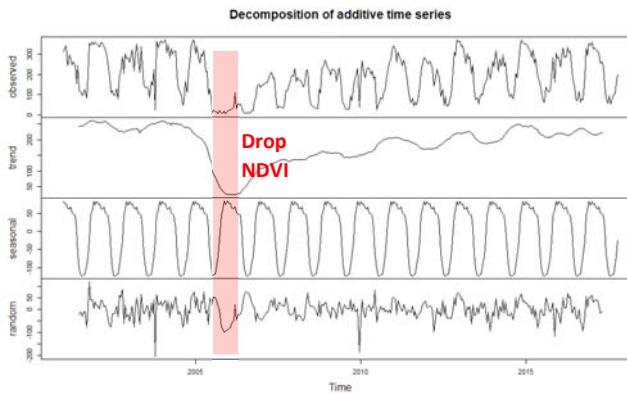
## MATERIALS AND METHODS – Data Analysis



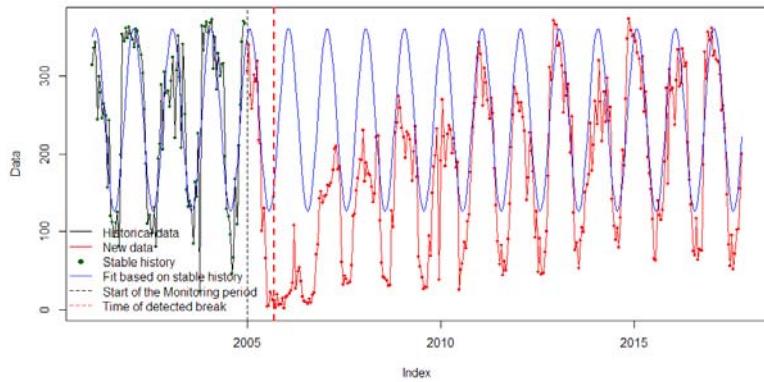
# Monitoraggio post-fire recovery NDVI

## BFAST (Breaks for Additive Season and Trend) e recovery onset

Scomposizione del trend di NDVI (2002-2020) per ogni area incendiata



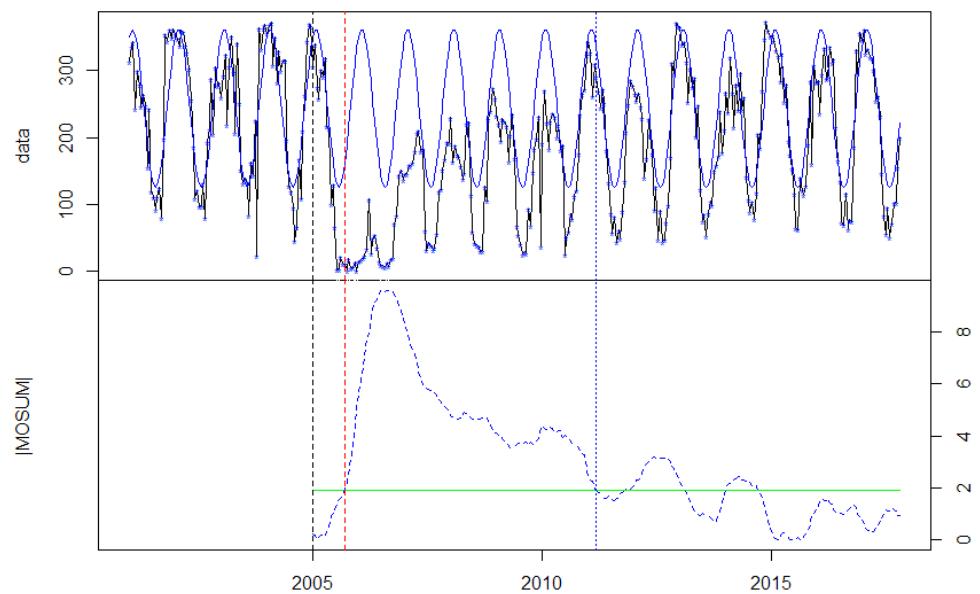
Break detected at: 2005(255)



BFAST: algoritmo per l'individuazione del break point (incendio).

Variazioni di NDVI in termini di deviazione del valore osservato rispetto al valore atteso stimato dal modello

Tempo di 'spectral' recovery post-incendio, basato sull'andamento della somma mobile dei residui MO (MOSUM) tra i valori osservati rispetto ai valori attesi di NDVI stimati dal modello



$$MQ = \frac{1}{\hat{\sigma}\sqrt{n}} \sum_{s=t-h+1}^t \left( y_s - \hat{y}_s \right)$$

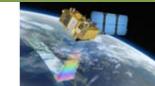
Lo spectral recovery avviene quando MO risulta minore della soglia statisticamente significativa (0.2) per almeno 2 stagioni vegetative successive.

[NDVI si attesta sui valori di 'equilibrio' per almeno due stagioni vegetative consecutive]

# Monitoraggio post-fine recovery RRI

**Post-fire monitoring**

*Remotely sensed data*



## Spectral indices

### BURN SEVERITY

**Normalized Burn Ratio**  $NBR = (NIR-SWIR)/(NIR+SWIR)$  [Key & Benson, 2006]

**Delta Normalized Burn Ratio**  $\Delta NBR = NBR_{\text{prefire}} - NBR_{\text{postfire}}$  [Key & Benson, 2006]

### POST-FIRE VEGETATION RECOVERY

**Relative Recovery Indicator**  $RRI = ARI / \Delta NBR_{\text{disturbance}}$  [R.J.

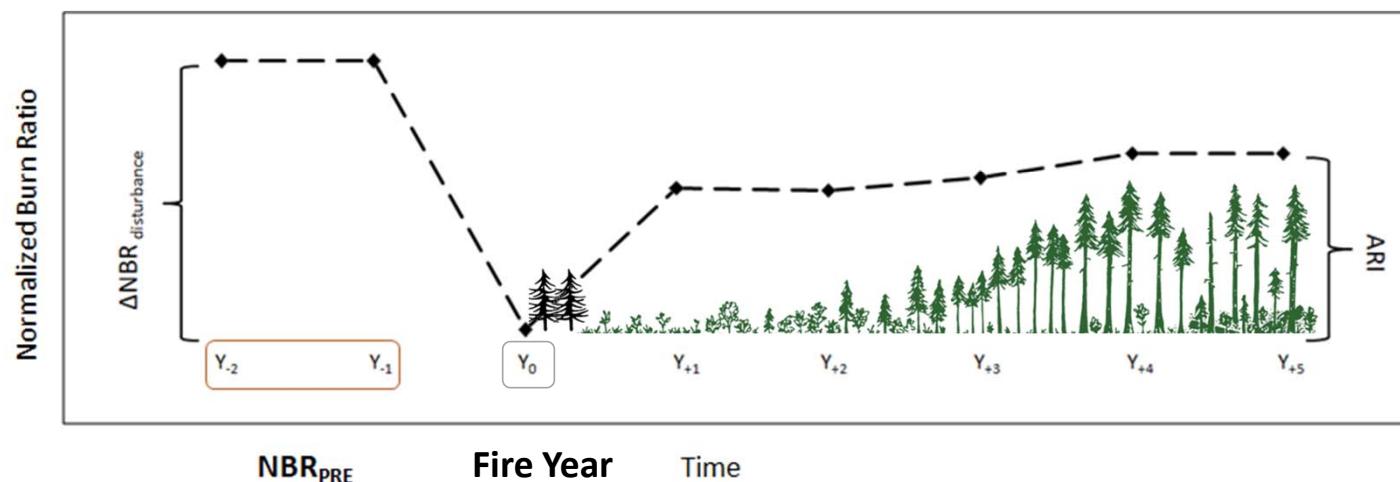
Frazier et al. 2018]

Absolute Recovery Indicator

$$ARI = \text{Max}(NBR_{Y+5}, NBR_{Y+4}) - NBR_{Y_0}$$

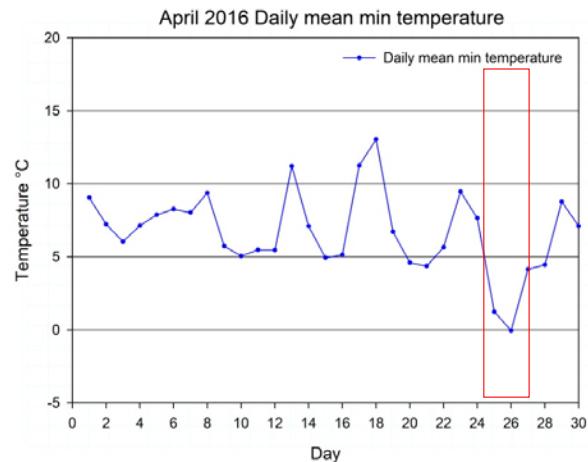
Delta Normalized Burn Ratio disturbance

$$\Delta NBR_{\text{disturbance}} = NBR_{\text{pre}} - NBR_{Y_0}$$



## Freddo -

**Late spring frost  
25<sup>th</sup>-26<sup>th</sup> April 2016 (doy 116-117)**



## Gelata Faggete 2016



June 2016



15<sup>th</sup> July 2016

**Freddo -**

## Gelata Faggete 2016

### Vegetation change detection 2015 - 2016

$$\text{NDVI-Differencing } \Delta\text{NDVI} = \text{NDVI}_t - \text{NDVI}_{t-n}$$

$$\Delta\text{NDVI} < (\mu - n \times \sigma)$$

$\mu$   $\Delta\text{NDVI}$  medio

$\sigma$  Standard deviation

$n$  threshold

$$\mu - n\sigma \leq \Delta\text{NDVI} \leq \mu + n\sigma$$

*no change*

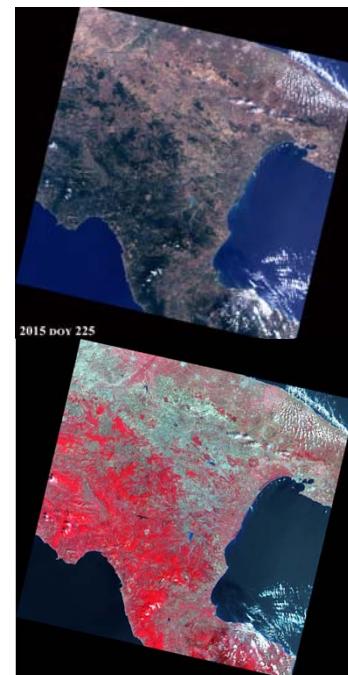
$$\Delta\text{NDVI} \leq \mu - n\sigma$$

*negative change*

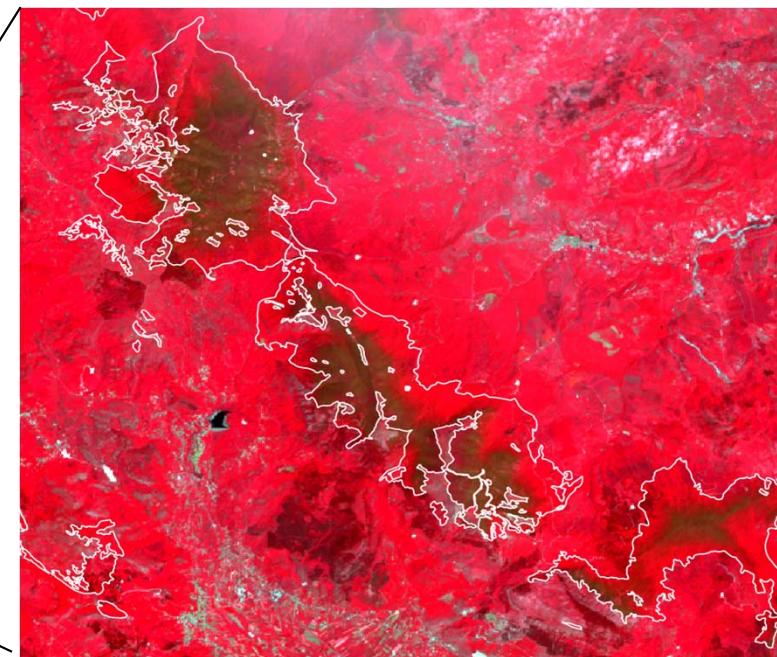
$$\Delta\text{NDVI} \geq \mu + n\sigma$$

*positive change*

DOY 225 - 2015



DOY 228 – 2016

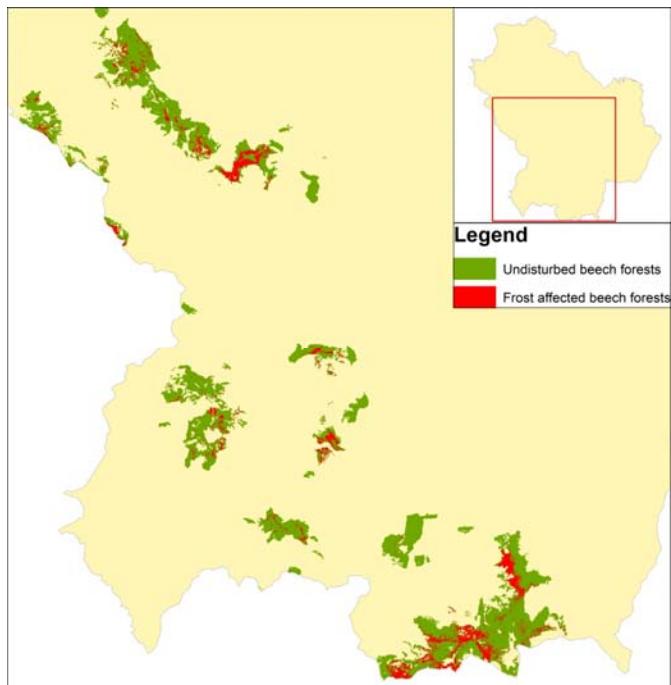


27<sup>th</sup> May 2016 – DOY 148  
IRFC - bands 543

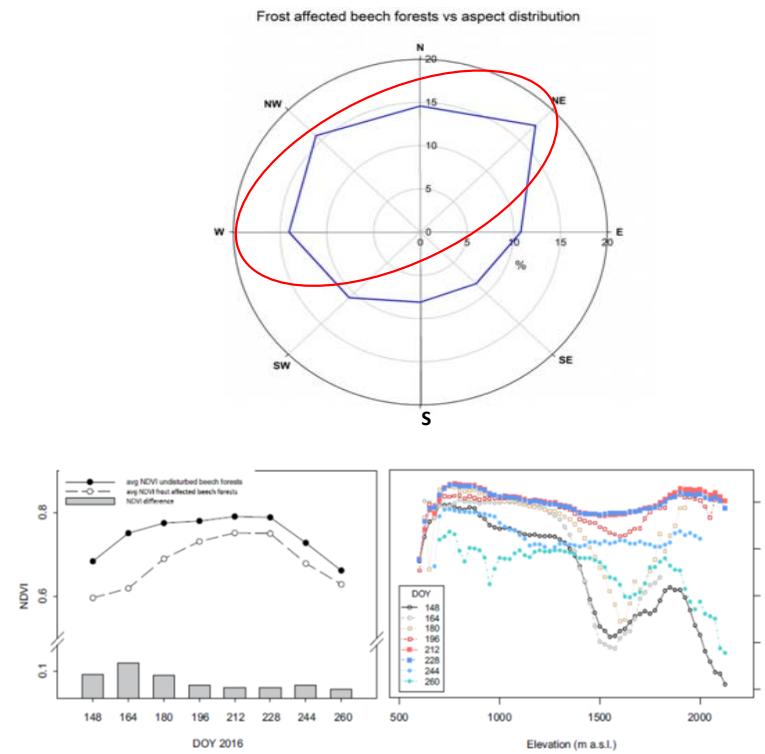
## Freddo -

## Gelata Faggete 2016

Frost affected areas (13%;  $\approx 4000$  ha)

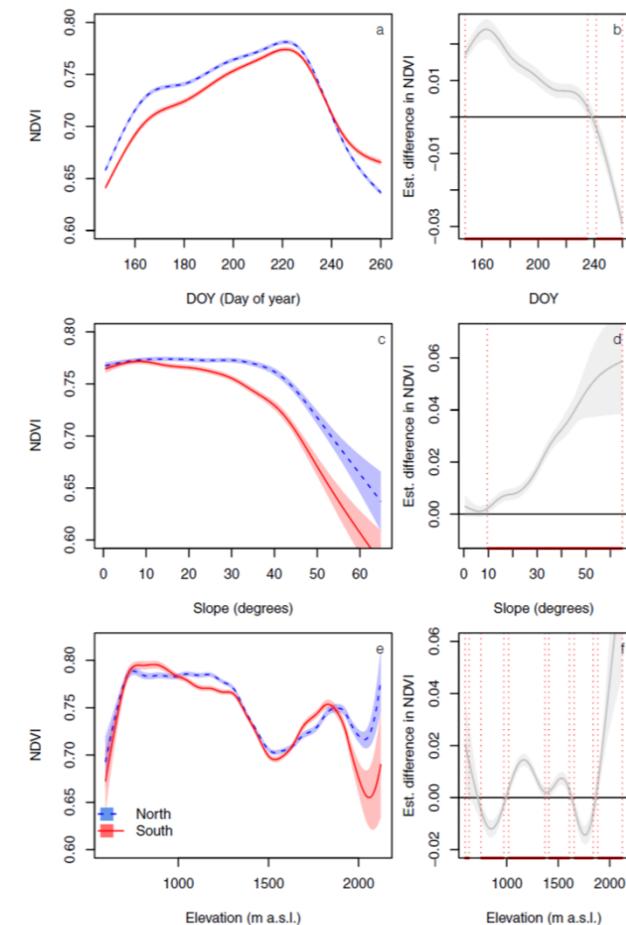


### Frost disturbance aspect distribution



Seasonal patterns of average NDVI  
(disturbed and undisturbed)

### Generalized additive model (GAM)



Nolè, A., Rita, A., Ferrara, A.M.S. and Borghetti, M. 2018 Effects of a large-scale late spring frost on a beech (*Fagus sylvatica* L.) dominated Mediterranean mountain forest derived from the spatio-temporal variations of NDVI. *Annals of Forest Science*, 75 (3)

**Freddo -**

**Gelata Faggete 2016**

3<sup>rd</sup> July 2016



NSC (Carbonio non strutturale)  
Carbonio di riserva stoccati nei  
tessuti dalla piante, messo da  
parte dai 5 ai 9 anni prima

Riserve in grado di supportare  
fino a 4 ricacci

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