Inaugural Global Forest Biodiversity Initiative Conference & GFBI-FECS Joint Symposium 2017
Forest Research in the Big Data Era, September 6-9, 2017 Beijing, China

Linking forest diversity and tree health in Europe: preliminary insights from a large-scale surveys in Italy

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UNIVERSITÀ DEGLI STUDI FIRENZE

SAPIENZA
UNIVERSITÀ DI ROMA

1. to provide a periodic overview on the spatial and temporal variation of forest condition in relation to anthropogenic and natural stress factors (in particular air pollution) by means of European-wide and national large-scale representative monitoring on a systematic network (**Level I**);

2. to gain a better understanding of the cause-effect relationships between the condition of forest ecosystems and anthropogenic as well as natural stress factors (in particular air pollution) by means of intensive monitoring on a number of selected permanent observation plots spread over Europe and to study the development of important forest ecosystems in Europe (**Level II**).

UNECE

The ICP Forests **Level I** network in Europe

30 years observational data on:

6,807 transnational Level I plots
135,388 sample trees

From: Michel A, Seidling W eds. (2016)

The main parameter assessed is *defoliation*

Picea abies (L.) Karst. (Norway spruce)

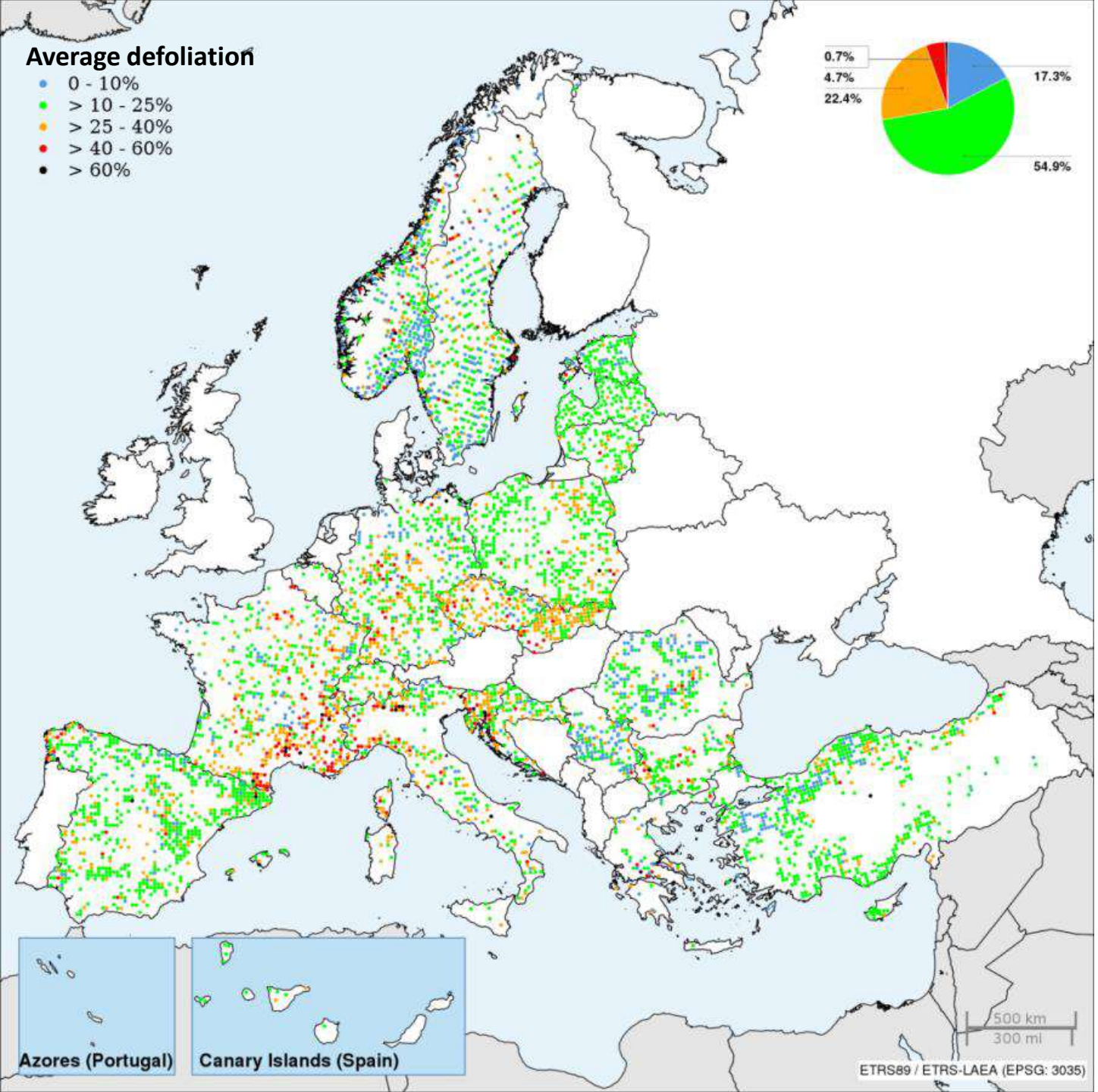
Fagus sylvatica L. (European beech)

Photos from: Müller and Stierlin (1990)

Reliability and comparability of data are assured by:

- A common field manual.
- Photo exercises and training courses.
- Field checks.
- Post-assessment checks on plausibility and coherence of data.
- Common database.

All data are available on request !
(www.icp-forests.net)



Data are reported:

<u>Per plot</u>

- Mean defoliation;
- Percent of trees with defoliation >25%.

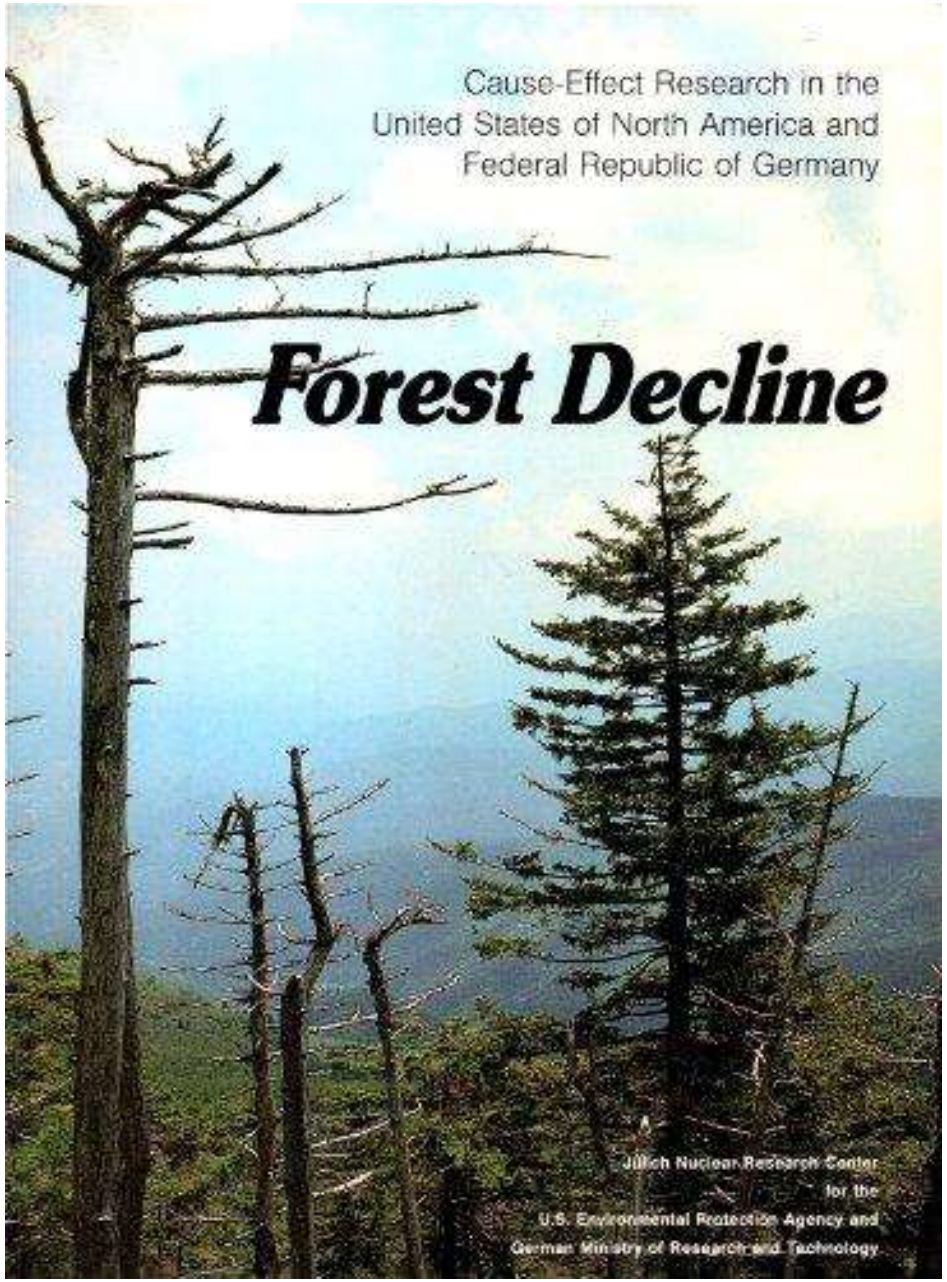
<u>Per country</u>

- Percent of trees with defoliation >25%, subdivided by conifers and broadleaves.

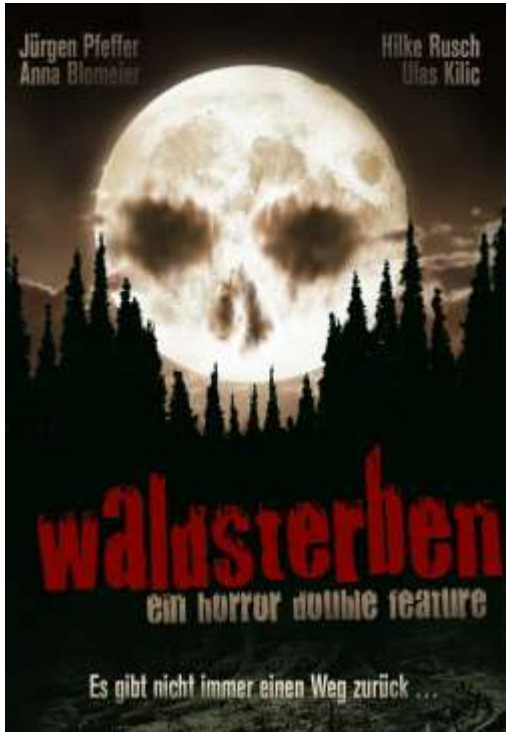
<u>Results</u>:

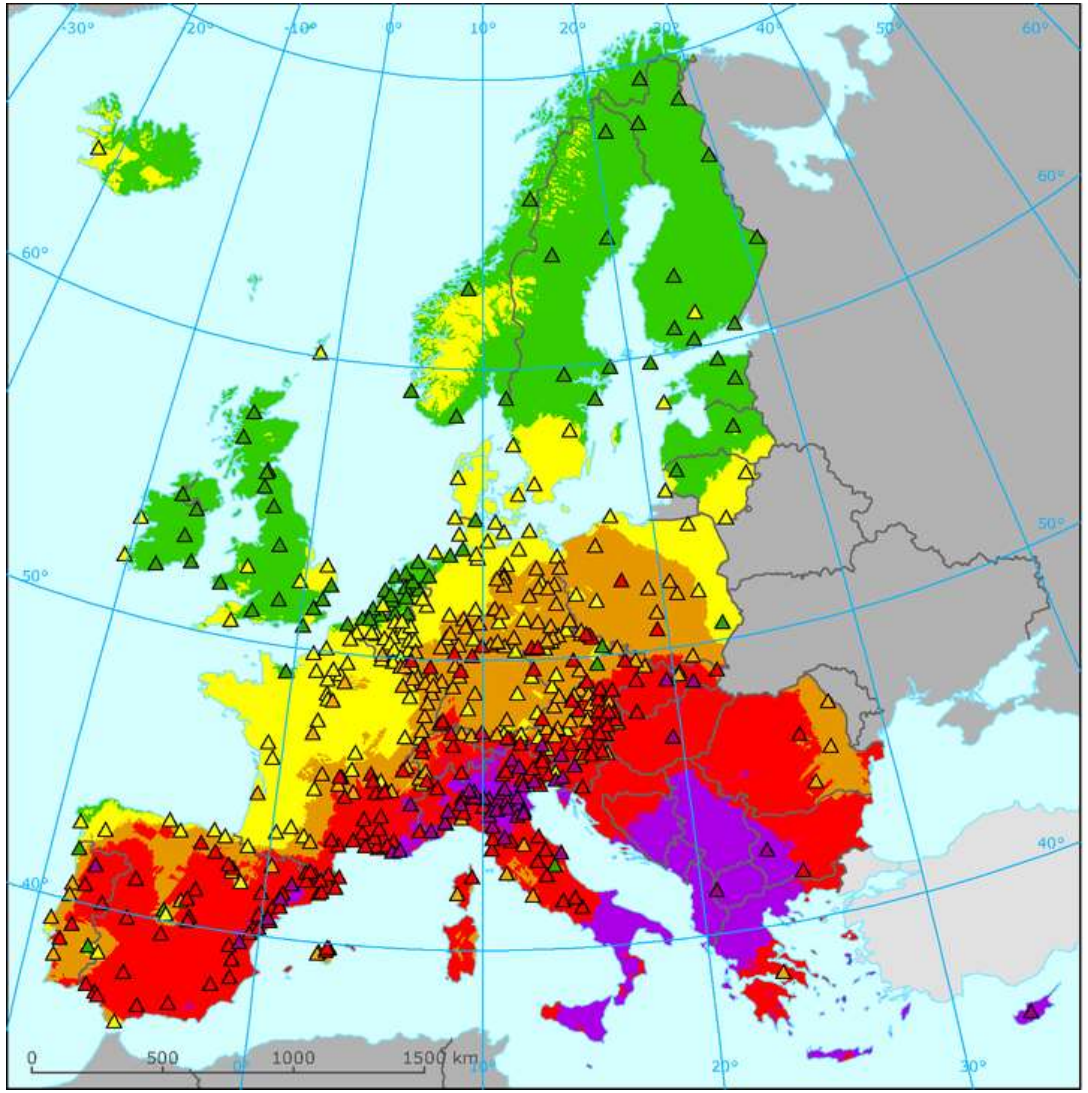
Defoliation status and trends vary in relation to country, climatic regions and species.

From: Michel A, Seidling W eds. (2016)



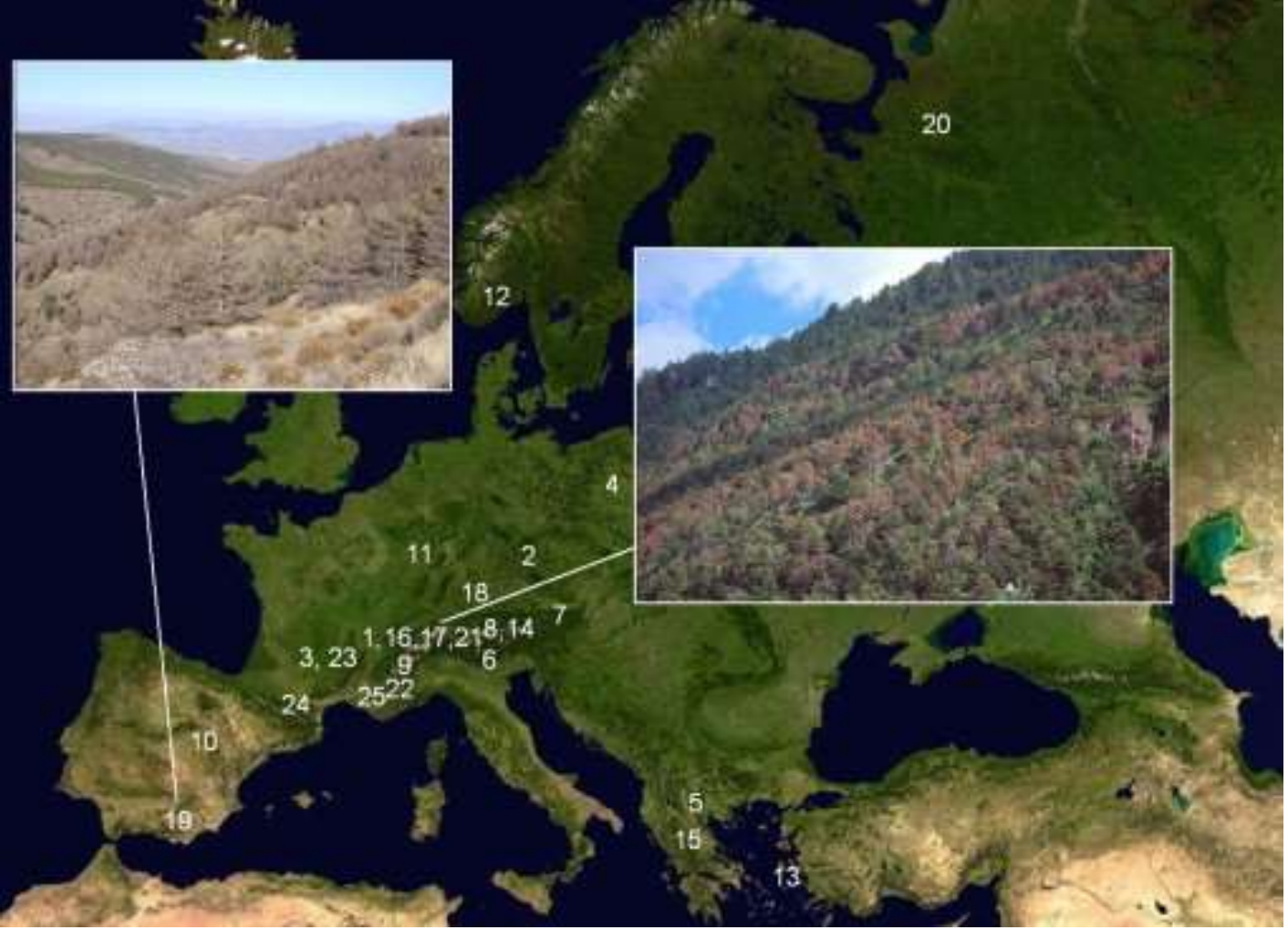
After the widespread forest decline (*Waldsterben*) of the 70th – 80th of the past century, acidic depositions and air pollution are still a problem for European forest?





From: European Environmental Agency
https://www.eea.europa.eu/

Tropospheric ozone pollution is considered one of the most dangerous environmental pressure on forests, but the field evidences of a negative role of this pollutant on tree vitality are scarce.



From: Allen et al. (2010) A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. For. Ecol. Manage. 259: 660-684.

Drought damage on holm oak in Tuscany. Photo: Bettini (2012)

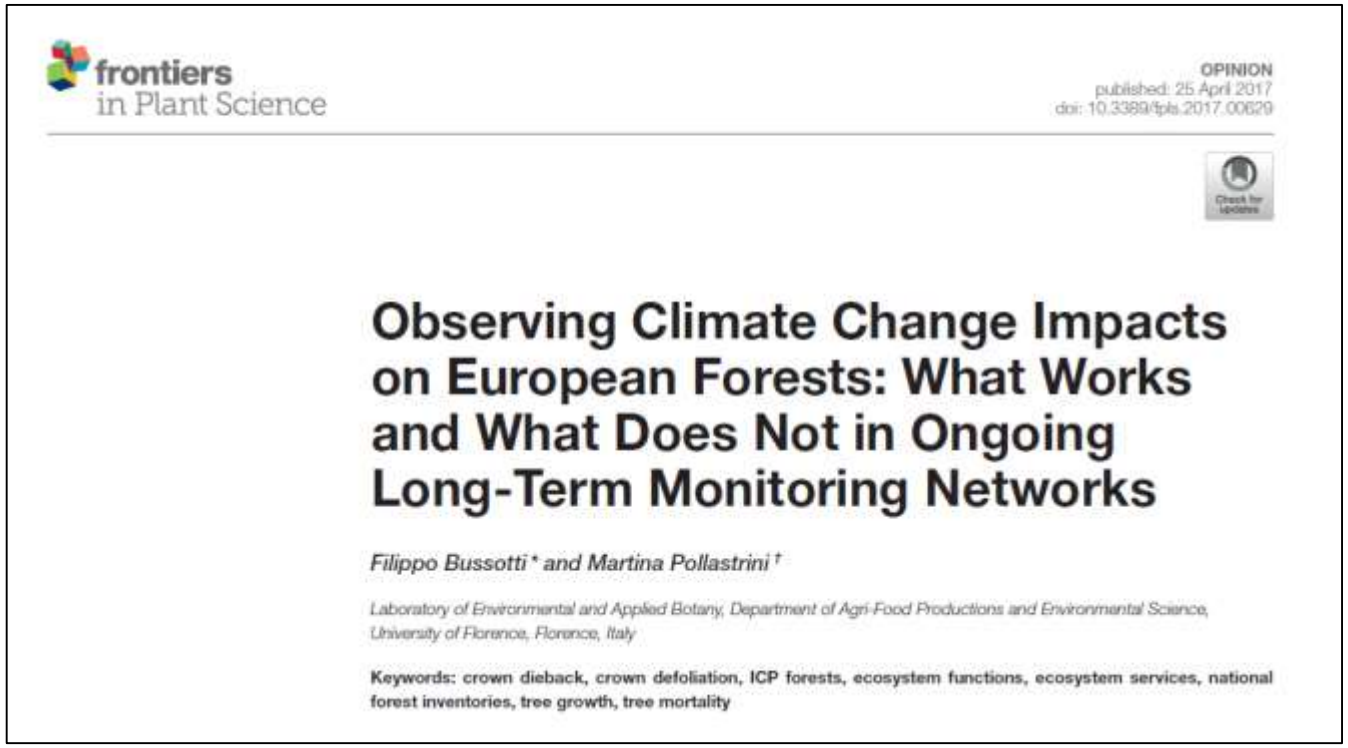
Climate change: drought-induced forest decline and tree mortality are currently observed in many European regions.

A severe drought affected forests in Italy in the summer 2017. European beech (A) and pubescent oak (B)

Photos: Bussotti (2017)

The general question is:

Do the large scale ICP Forests (Level I) network, designed for monitoring the effects of air pollution on forests, can be suitable also to assess the impact of climate change?



frontiers in Plant Science

OPINION
published: 25 April 2017
doi: 10.3389/fpls.2017.00629

Observing Climate Change Impacts on European Forests: What Works and What Does Not in Ongoing Long-Term Monitoring Networks

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Keywords: crown dieback, crown defoliation, ICP forests, ecosystem functions, ecosystem services, national forest inventories, tree growth, tree mortality

The state-of-the art suggests the adoption of additional measurements and parameters.

More specific questions concern:

Which information is possible to achieve, at the current state of the program, using the available databases?

What we can study?
Role of tree species composition (***tree diversity at plot level***) and forest structure parameters.
Analysis of «key years» (i.e., when sudden increases of defoliation occur),
Occurrence of highly defoliated trees (>60%), tree mortality and resilience.
Defoliation – productivity relationships.
Use of composite indices combining defoliation and symptoms.

Our goal is to assess the role (if any) of tree diversity at plot level as contributing factor for defoliation

How tree diversity can affect tree health and defoliation?

- Tree diversity enhances growth rate (Liang et al. 2016) and stability (Jucker et al. 2014), as well photosynthetic efficiency (Bussotti and Pollastrini, 2015), although with site-specific effects;

- Tree diversity reduces the attacks of parasitic insects (Guyot et al., 2015);

- Tree diversity reduces the diffusion of root rot fungi (Lindén and Vollbrecht 2002);

- Preliminary observations suggest a role of diversity in reducing crown defoliation (Eichhorn et al., 2005).

He and Bertness (2014) and Ratcliffe et al. (2015) suggest that diversity play a more positive role in resource limited (for. ex., water limited) conditions.

A preliminary exploratory survey is carrying out in Italy

Available datasets and data sources
Crown condition data on ca. 250 plots, for the period 1997-2014 (from Italian National Forest Services, Corpo Forestale dello Stato – CFS, now Carabinieri – Forestali) – CONECOFOR programme.
Composition and structure (tree mapping and basal area) at plot level (CFS, under the Life+ project: «Further Development and Implementation of an EU-level Forest Monitoring System" - FutMon.
Soil properties (CFS, under the BioSoil project)
Mean yearly meteorological data (average for year, from WorldClim database, *www.worldclim.org)*
Functional traits (current available literature; TRY Plant Trait Database - https://*www.try-db.org*

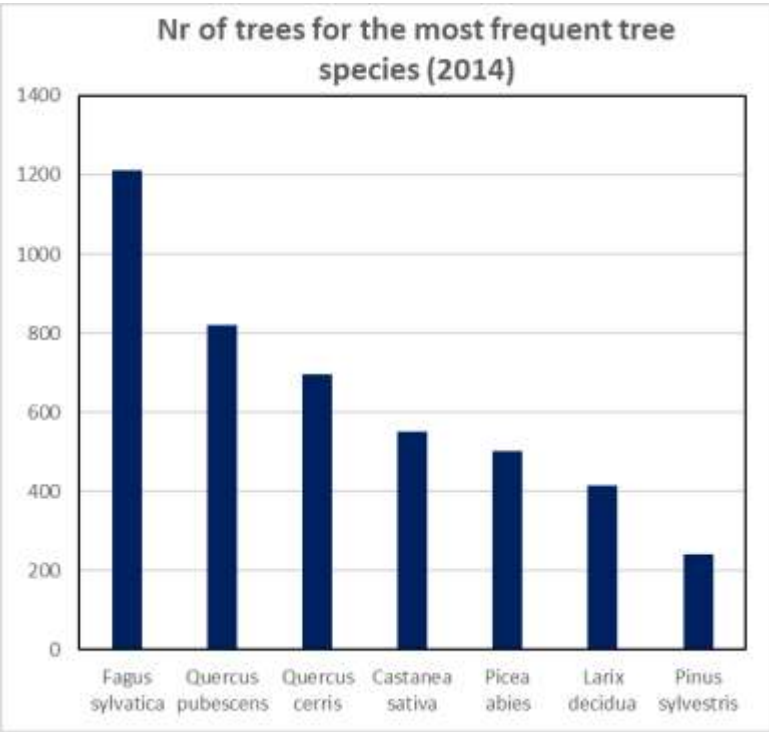
Statistical analyses

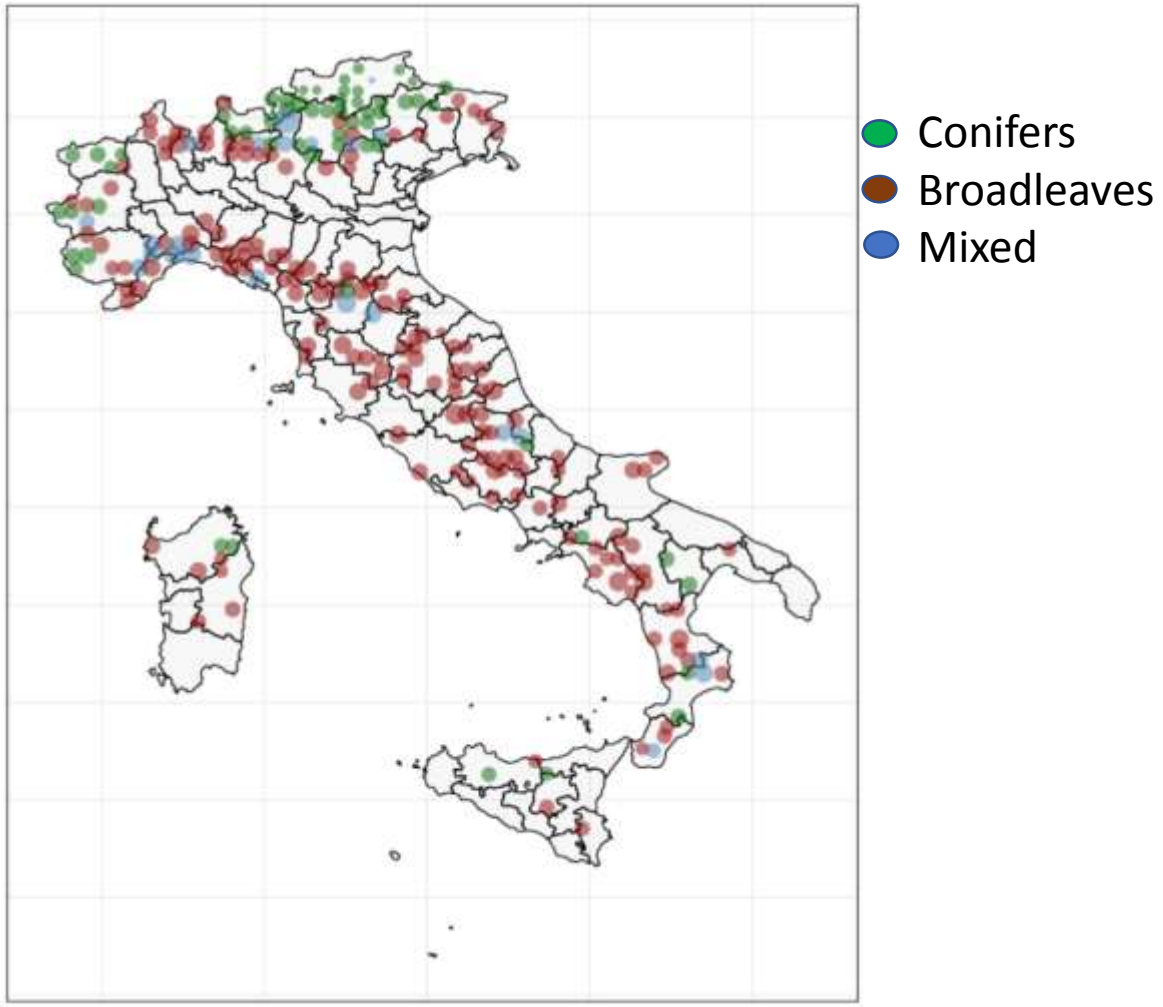
- Descriptive statistics (level and change of defoliation, in space and time).
- Cluster analysis (identification of homogeneous groups of plots and driving factors on defoliation).
- Local functional interactions (neighbouring trees analysis).

Results /1 - Descriptive Statistics

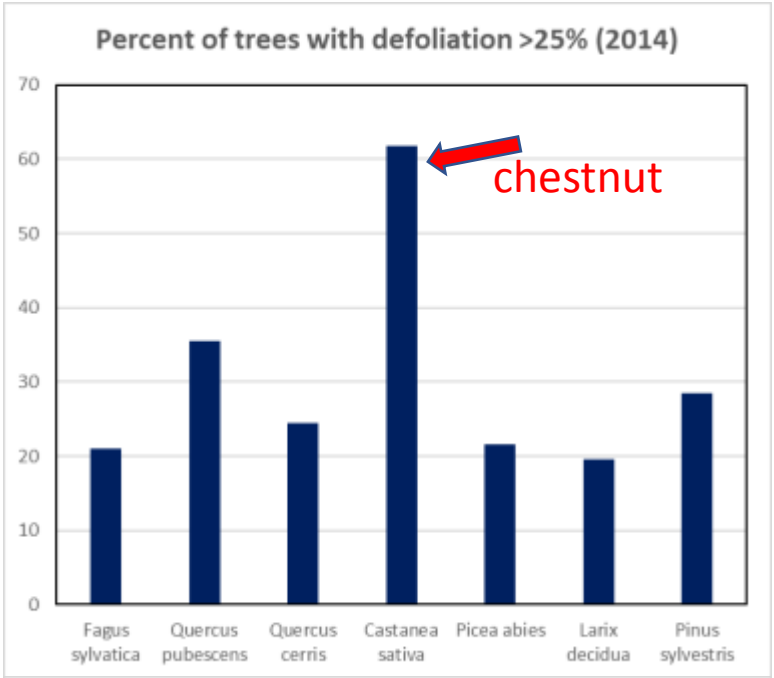
General results

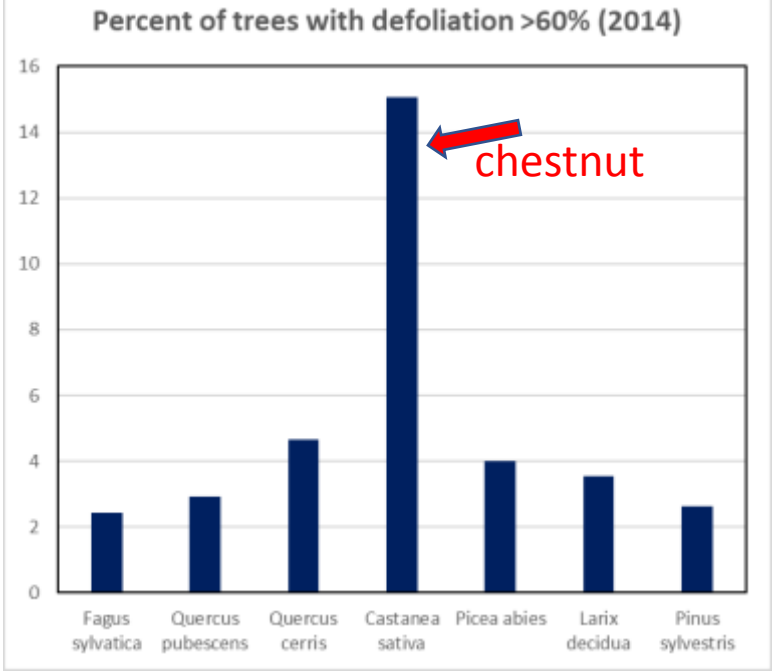
Overall figures of the survey (2014)	
Number of plots	254
Number of trees	4967
Conifers	1310
Broadleaves	3656

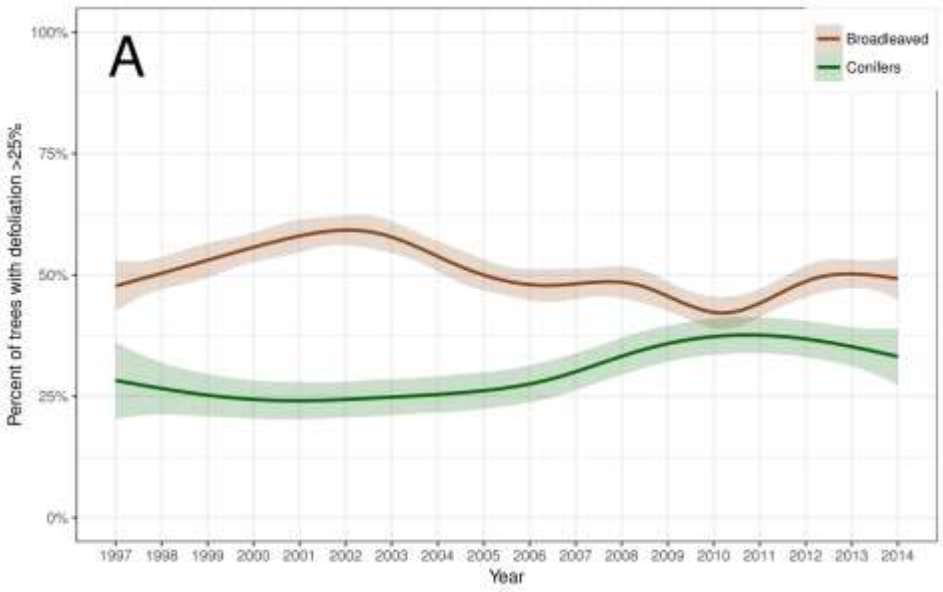




Spatial distribution of conifers and broadleaved tree species - Conifers (Norway spruce, European larch, Scots pine) are widely distributed at the higher elevations in the alpine range (North Italy). Among broadleaves, European beech is distributed at intermediate elevation in Alps and it is abundant at the higher elevations in the whole Apennine chain in central and southern Italy. At lower and intermediate elevations oak forests are dominating.

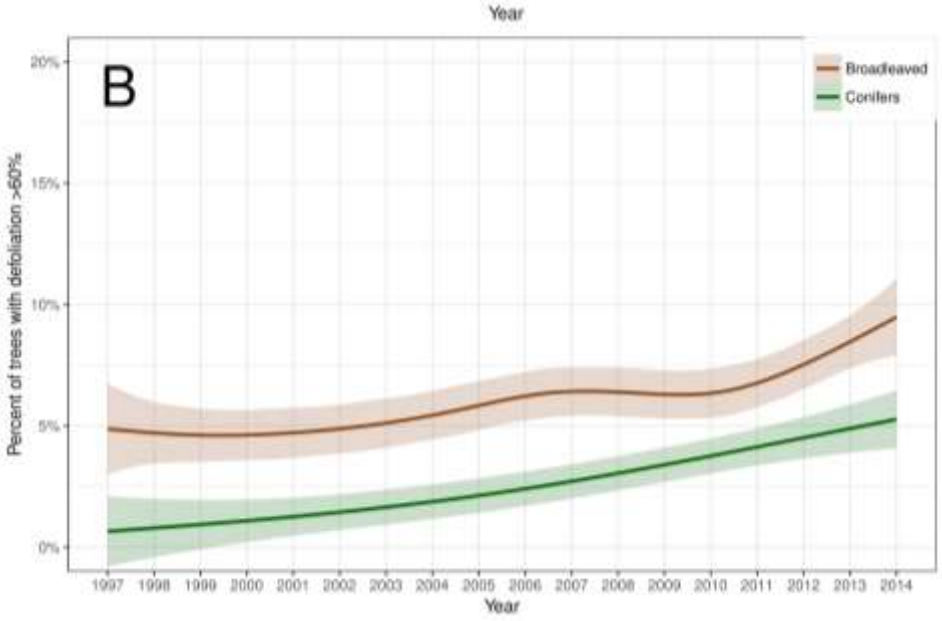






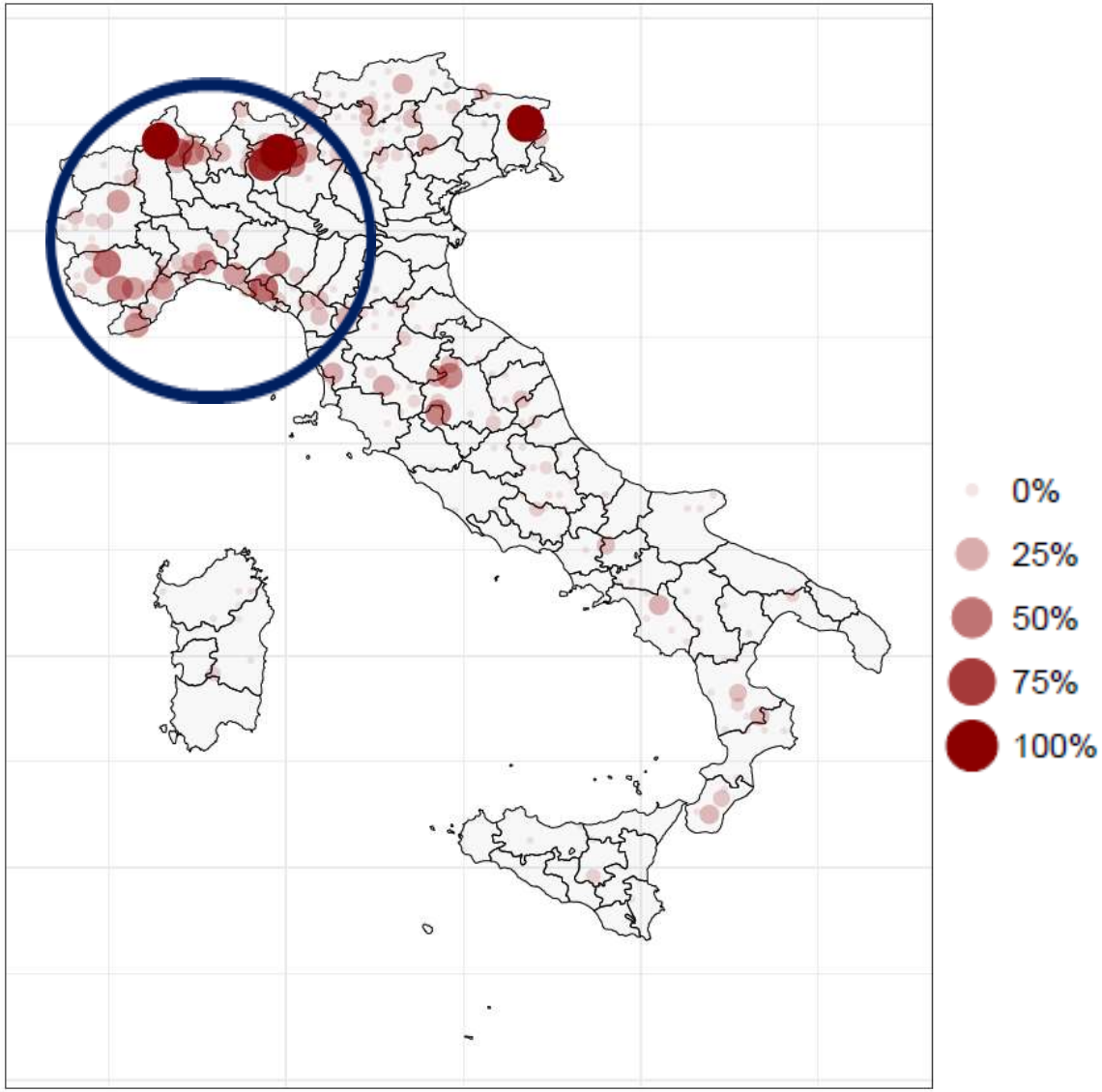
Among broadleaves, chestnut has been attacked by pests and diseases.

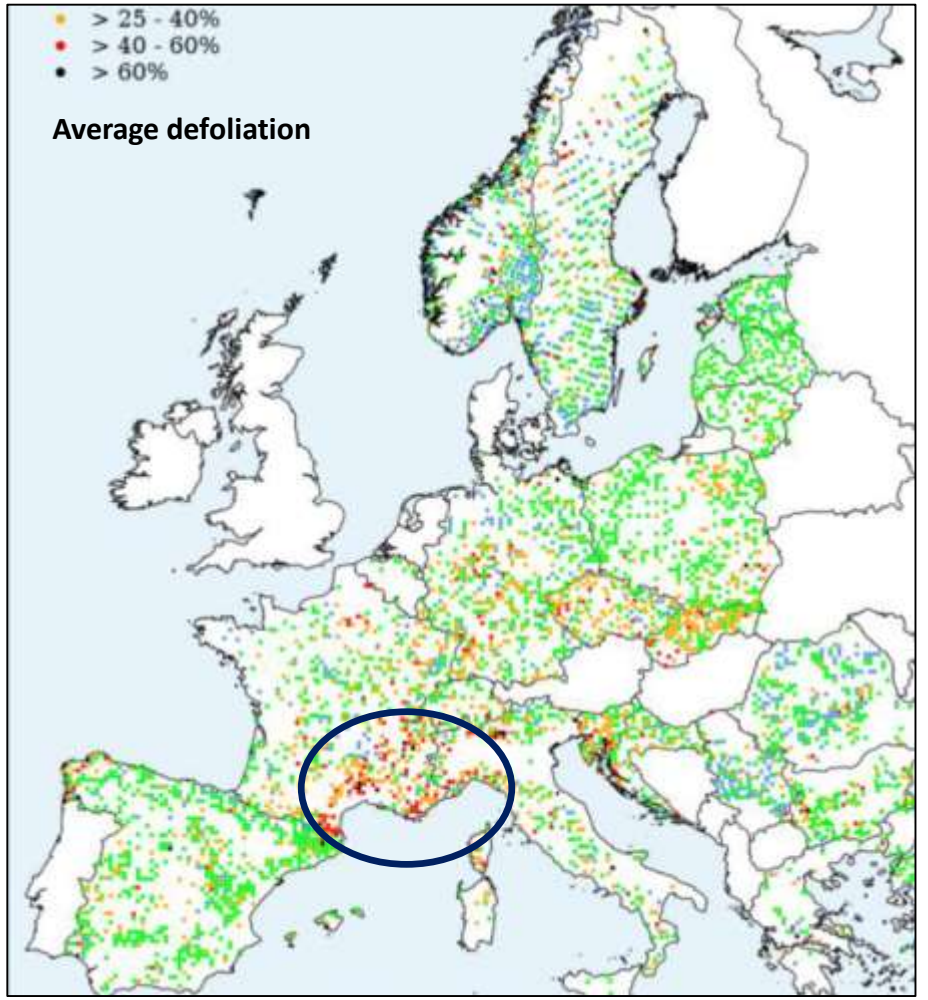
The pattern of defoliation (>25%) evidences two distinct behaviours for conifers and broadleaves: between 1997 - 2000 increased in broadleaves and decreased in conifers. The opposite behaviour was observed in 2001 -2010.



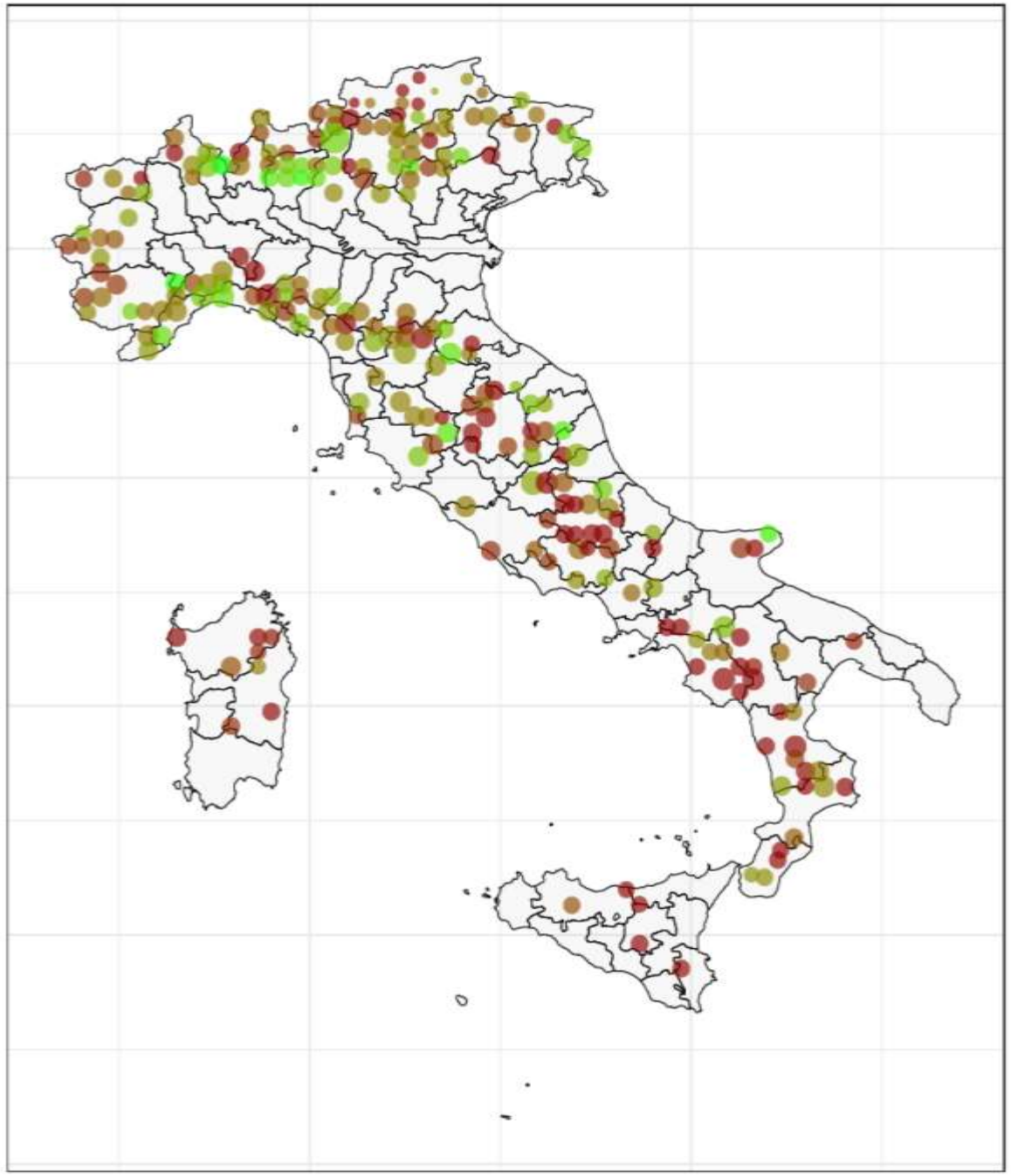
The percent of tree with high defoliation (>60%) increase over time in broadleaves and conifers.

The distribution of defoliation per plot (highly defoliated trees, >60%) evidences a «hot spot» in the N-W regions. This behavior is part of a more extended «highly defoliated» transnational region, including the South-East of France.





From: Michel A, Seidling W eds. (2016)



Distribution of tree diversity in Italian forests, by Shannon Index.

1. Descriptive statistics/ Comments

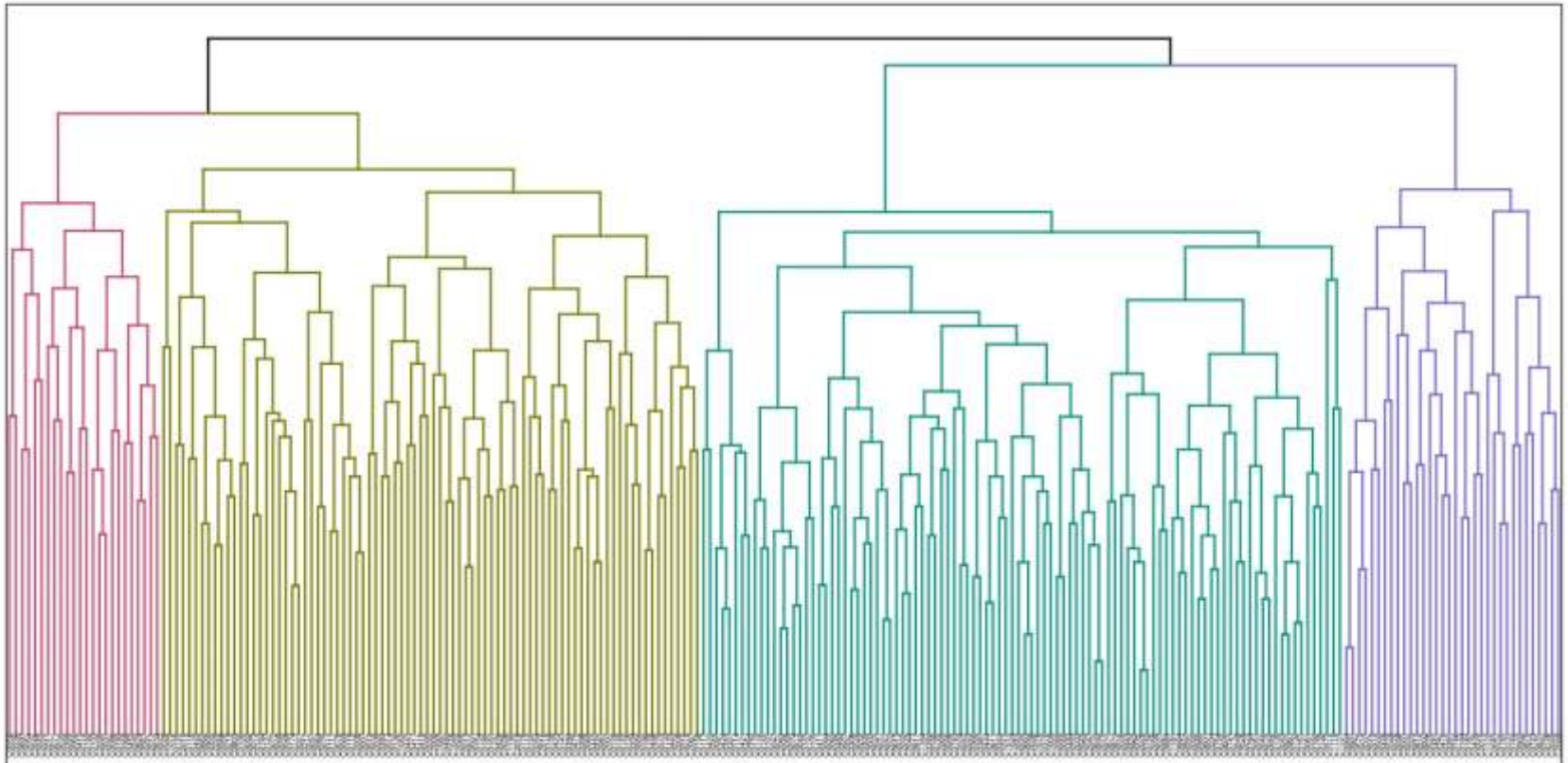
- Crown defoliation at plot level depends from the tree species present in the stand (species identity) and their interactions with environmental factors (i.e. abiotic and biotic factors)
- The extent of the trans-national ‘hot area’ may be attributed to presence of critical tree species (*Castanea sativa*, *Pinus sylvestris*)
- The study of changes occurring in key years may be more relevant than trends. The increase of trees of trees with defoliation >60% suggests that *high defoliation* is not easily reversible.

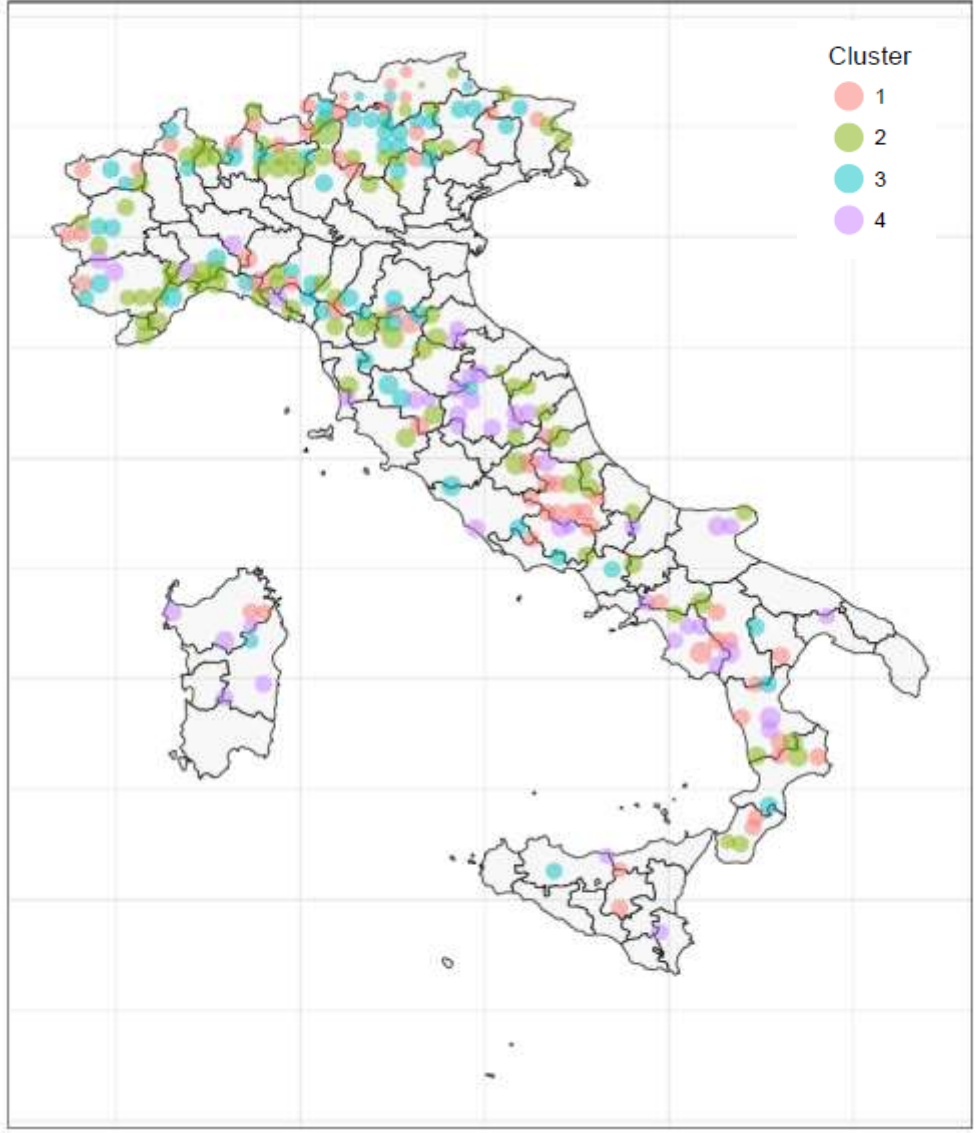
Results /2
Cluster analysis

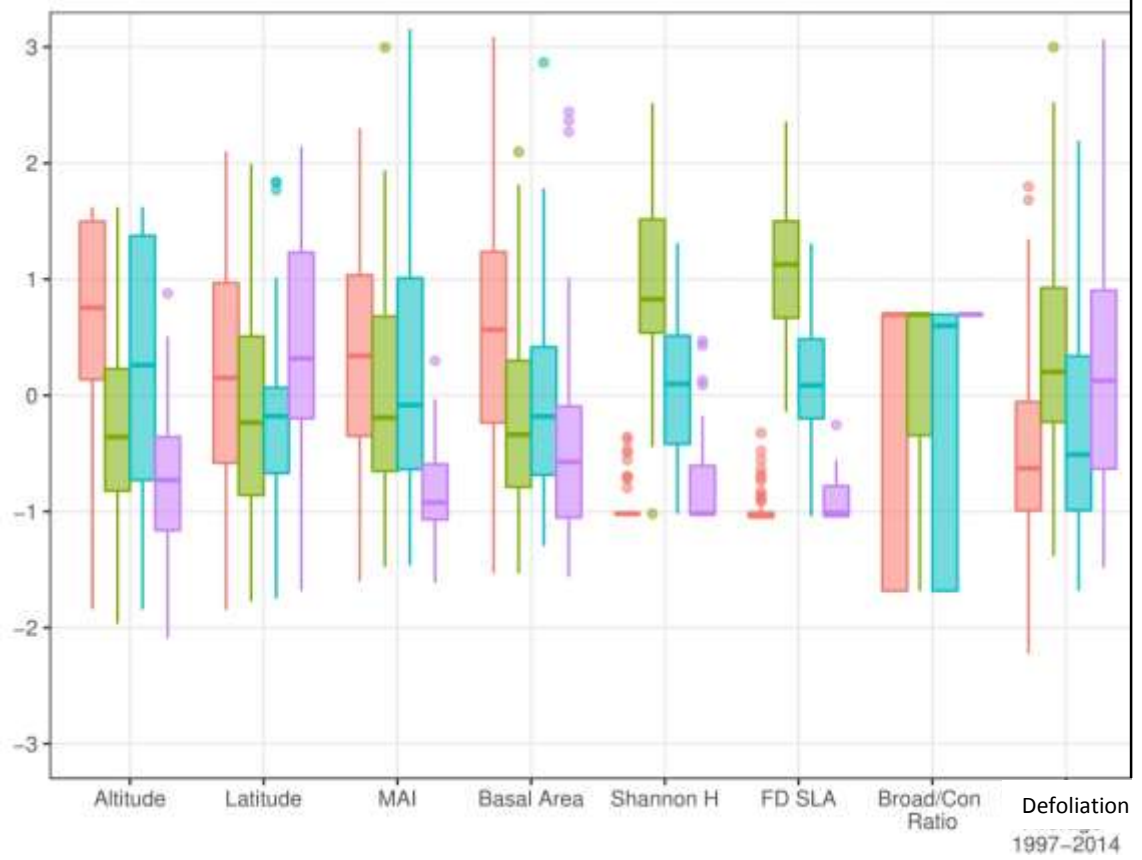
Physical characteristics	Forest structure and composition	Soil
Latitude	Basal area	Depth
Longitude	Broad/Conif ratio	pH
Altitude	Shannon Index	C/N
Temperature	Funct Div Indices	CEC
Precipitation	(SLA, WD, N, H)	Exchangeable Elements

The cluster analysis was carried out by considering a range of physical, vegetational and soil attributes at plot level.

This analysis allowed to identify 4 cluster of plots.







Cluster 1 (red) includes high elevation forests across Italy, monospecific or with low level of diversity. LOW DEFOLIATION

Cluster 2 (green) includes sub-mountain or basal forests, distributed in Northern and Central Italy, with high diversity. HIGH DEFOLIATION

Cluster 3 (sky-blue) includes sub-mountain forests, distributed specially in central and north Italy, with low diversity. LOW DEFOLIATION

Cluster 4 (purple) includes low elevation xerophylous broadleaved forests, at low elevation, with low diversity. HIGH DEFOLIATION

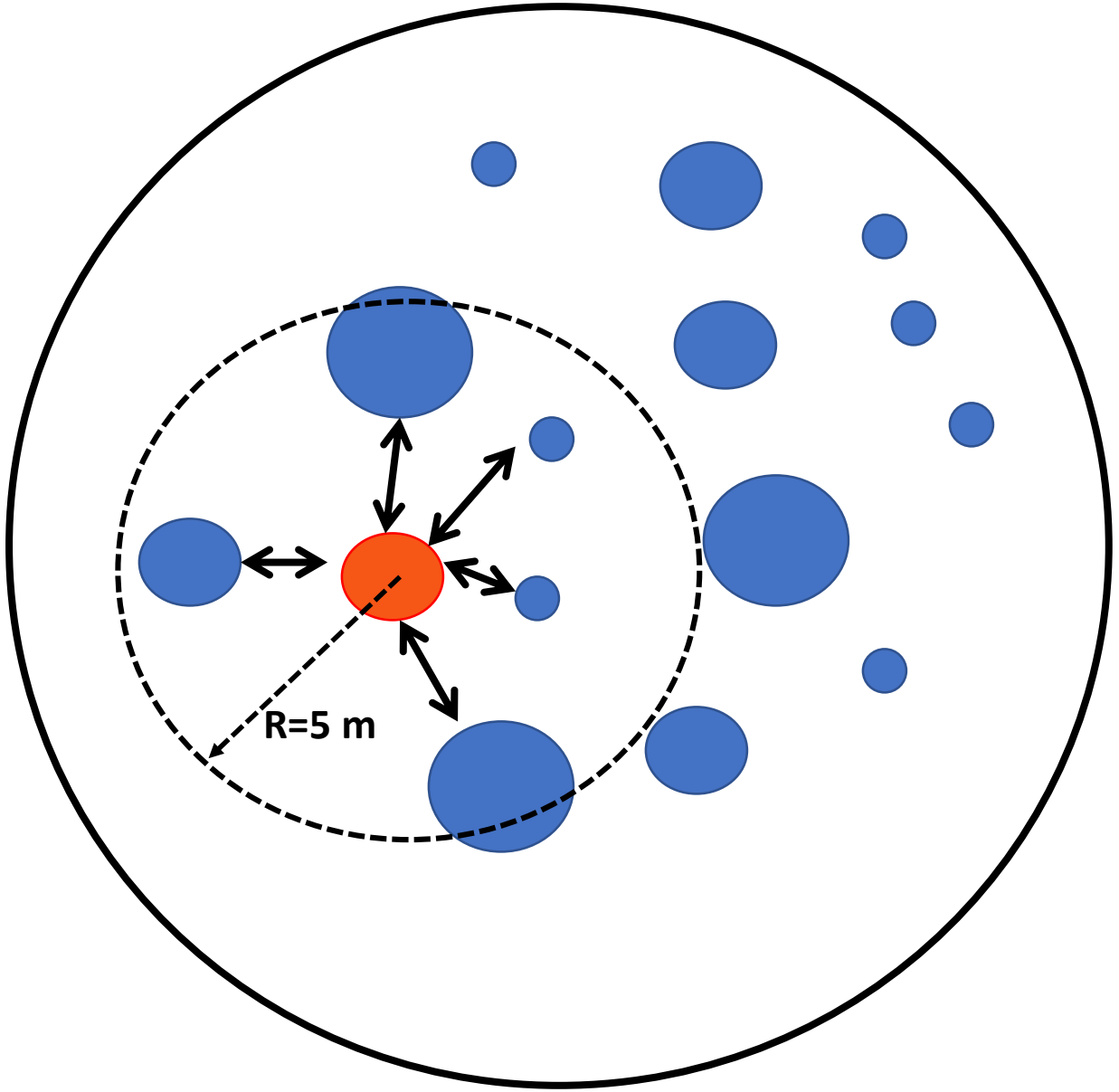
2. Cluster analysis/ Comments

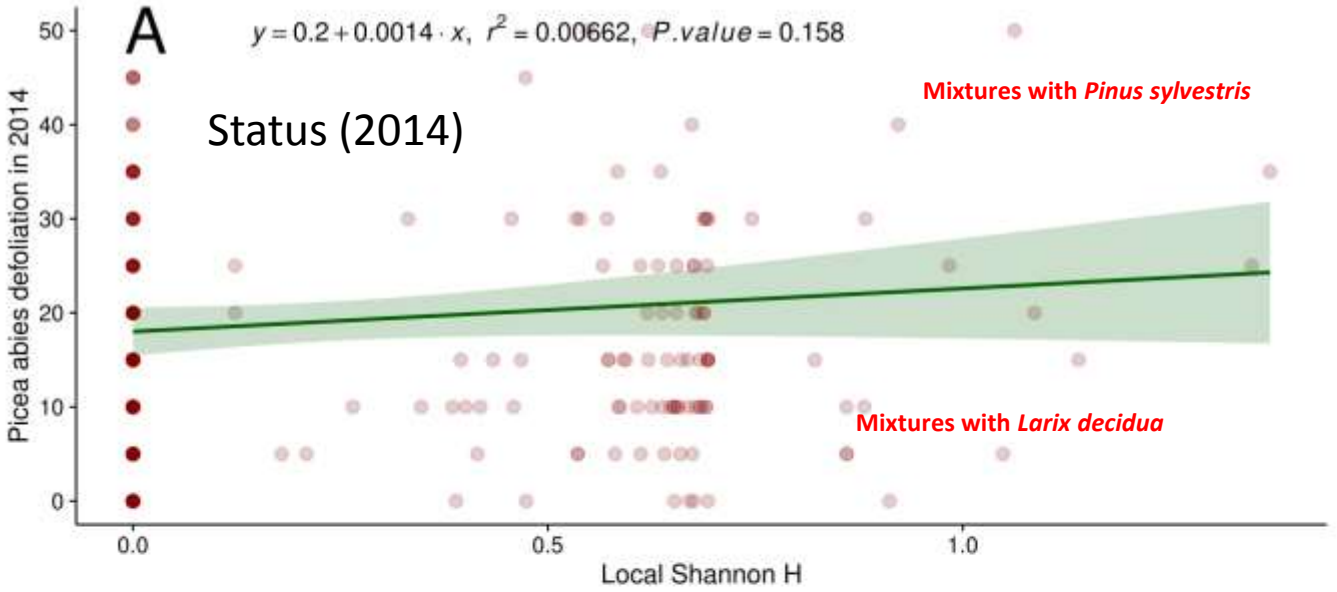
- Tree species growing in monospecific forests in their climatic optimum (mountain forests of Norway spruce and European larch in Alps, and European beech in Apennines) show the lowest levels of defoliation.
- High defoliation was found in submontain forests, in ecological transition zones and richer in diversity. Maybe these forests are more sensitive to environmental variations. In such forests are diffuse critical species as sweet chestnut and Scots pine.
- High defoliation was also found in Southern forests, under Mediterranean climate conditions.

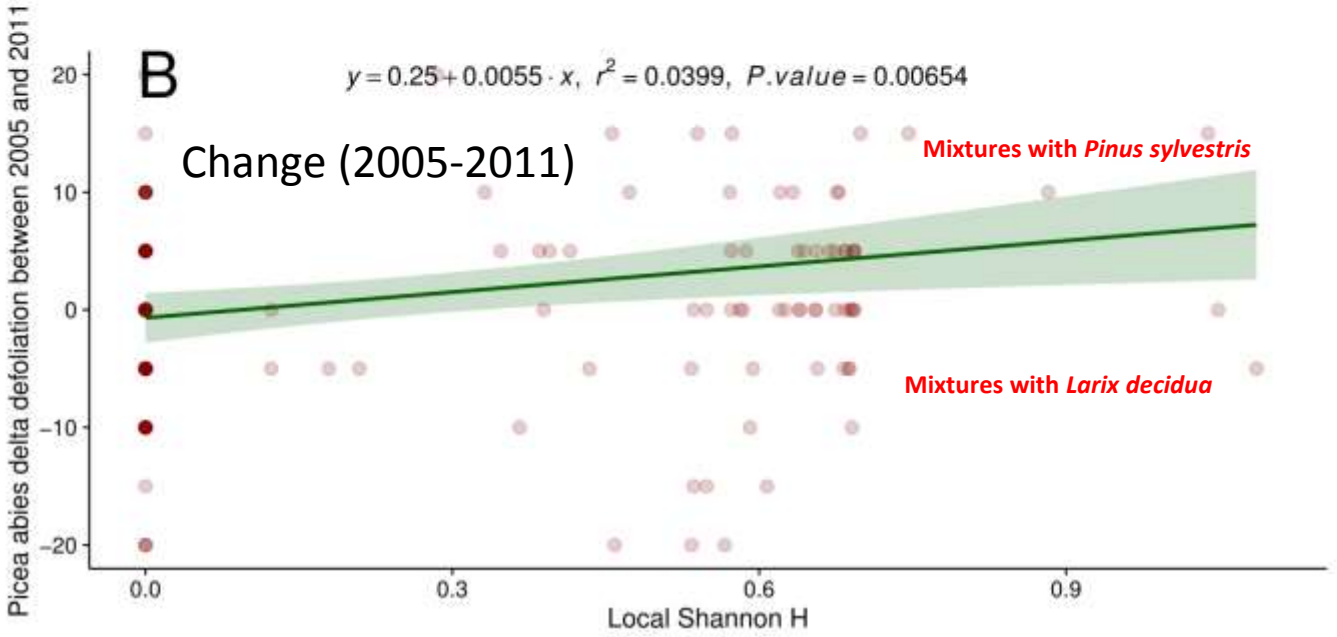
Results /3
Local functional interactions

To understand the species-specific and environmental interactions on defoliation, crown condition of Norway spruce, growing in the Italian Alpine belt, was analysed.

A neighborhood (5 m radius-area) of target spruce trees was defined, identifying the species of surrounding spruces and calculating the local Shannon Index.







A general increase of defoliation of Norway spruce with local Shannon Index was observed both for the **Status** at a given year (2014) and the **Change** between 2005-11).

This response outlines the tendency of this specie to establish pure forests. It is may driven by the mixture with Scots pine in more xeric condition (trees included in Cluster 2).

Although the trends were significant ($p>0.05$), the coefficients of determination R^2 are very low.
The role of ecological and structural factors that interfere with tree diversity will be analyzed.

Neighboring tree anlysis / Comments

Tree species assemblage reflects the ecology of the plot. The behavior of the target tree may be affected by the ecological constraints rather than by the diversity itself.

Conclusions /1: what we learned (*take home message*)

- Tree species distribution and identity as well ecological interactions with environmental (climatic) factors are the main drivers of defoliation across heterogeneous regions.

- In a national and continental-scale survey the effect of tree diversity on crown defoliation is masked by ecological features of the plot. Tree species mixtures may be related to various soil and climate conditions.

Conclusions /2: future directions

- Analyses of status and trends, as well the role of tree diversity, will be carried out separately for the main tree species within each homogeneous cluster.

- Multivariate analyses will be applied to individuate the role and the contribute of explaining factors for defoliation at plot and neighbouring trees level.

- Climatic variables, in combination with tree diversity, will be investigated to explain the defoliation changes observed in key years for the main species.

- The possibility to extend this analysis at a wider level, taking into account European and North American data, will be explored.

Thank you for your attention!

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…. and thank to all CFS personnel that supported this survey over 20 years!