IV CONGRESSO NAZIONALE DI SELVICOLTURA
IL BOSCO: BENE INDISPENSABILE PER UN PRESENTE VIVIBILE E UN FUTURO POSSIBILE
TORINO 5-9 NOVEMBRE 2018

UNIVERSITÀ DEGLI STUDI FIRENZE

SAPIENZA UNIVERSITÀ DI ROMA

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Forest diversity and tree health relationships in Italian forests depend on environmental context

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Introduction

Tree diversity is accredited to enhance ecosystem functions in forests and to improve resistance and resilience of trees subjected to environmental stress, including climate change. This effect, however, can be different for tree species and ecological context. The pan-european programme for monitoring tree health (ICP-Forests) assumes crown defoliation as indicator of tree vitality. Some few studies analyzed the role tree diversity as factor affecting crown defoliation, with contrasting results. This paper analyzes the relationships between defoliation and diversity in a country (Italy) characterized by very different ecological features, from Mediterranean to Alpine-Boreal, and with a wide range of tree species and functional groups.

Methods

The Italian Level I - ICP Forests monitoring network consists of 245 plots (year 2014), with 4,967 trees subdivided into 1,310 conifers and 3,656 broad-leaved trees. Main tree species are *Fagus sylvatica* (beech), *Quercus pubescens* (downy oak), *Quercus cerris* (Turkey oak), *Quercus ilex* (holm oak), *Castanea sativa* (chestnut) among broadleaves, and *Picea abies* (spruce) and *Larix decidua* (larch) among conifers. Conifers are distributed mostly in the Alpine belt.

To reduce the environmental variability, a Cluster Analysis was carried out tacking in account geographical, ecological and vegetational variables. This analysis allowed us to identify 4 clusters oh more homogeneous plots (Fig. 1).

General results

Broadleaved tree species were more defoliated than conifers (Fig. 2). Conifers showed a peak of defoliation in the period 2008-2012, followed by a recovery. Broadleaved showed an increase of defoliation (specially for Def>60%) in the years 2016-2017.

Among singular tree species (Figs. 3A – 3D), chestnut was the most defoliated species, suffering for the Asian wasp *Dryocosmus kuriphilus*. Recent partial recovery can be attributed to the biological treatments with *Torymus sinensis* and to the improvement of management (Fig. 3A).

Environmental causes for recent increase of defoliation were the late frost in 2016 and 2017 springs (beech, Fig. 3B) and the extreme heath and drought wave of the 2017 summer.

The analysis of the distribution of defoliation, Fig. 4, evidenced a critical area in the north-western regions, including Piedmont, Liguria, part of Lombardy and northern Tuscany.
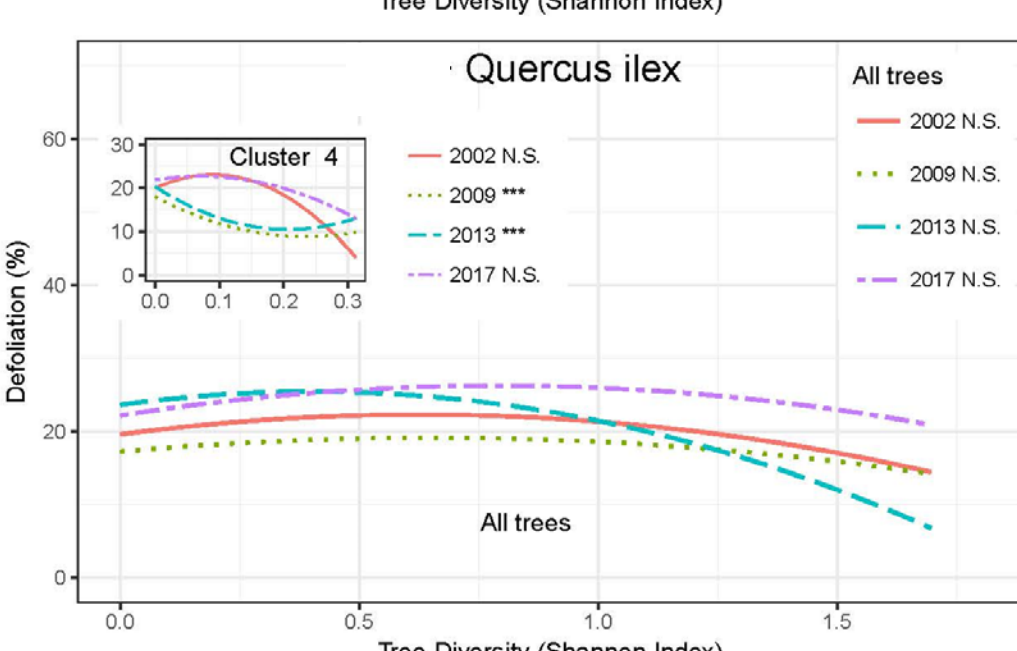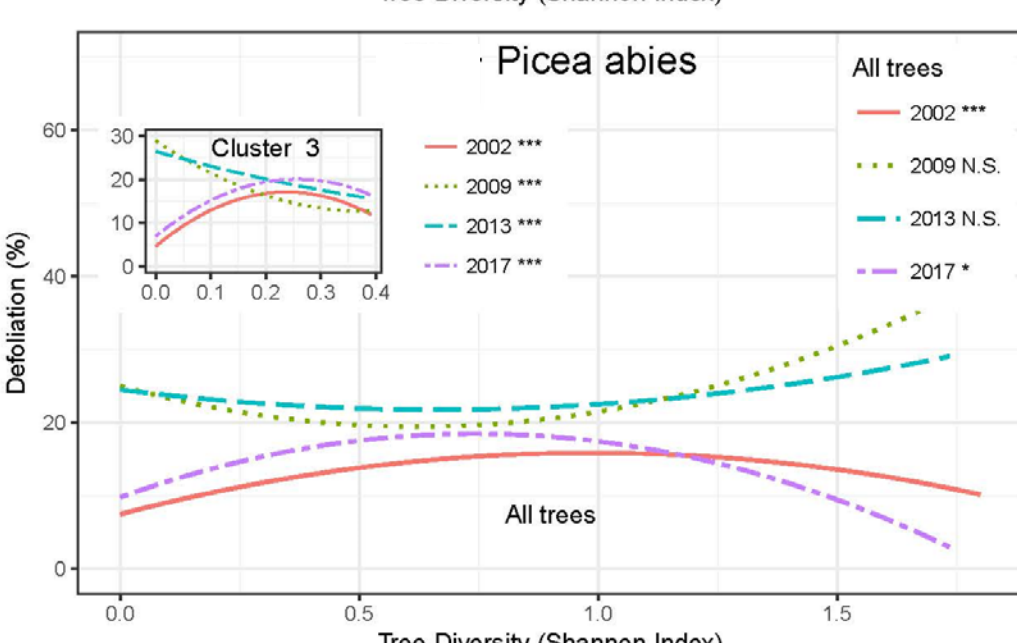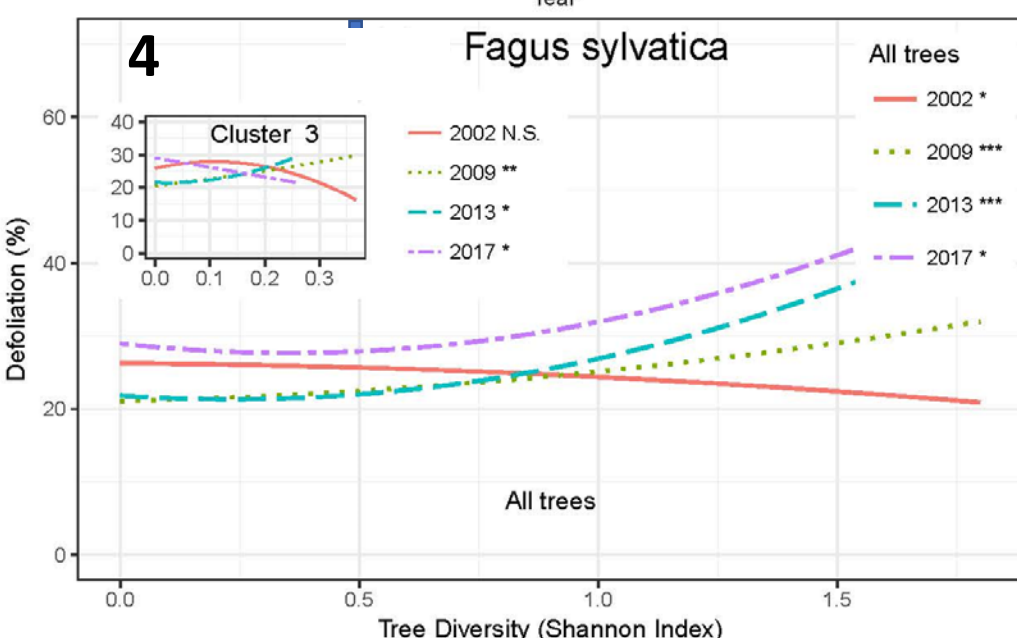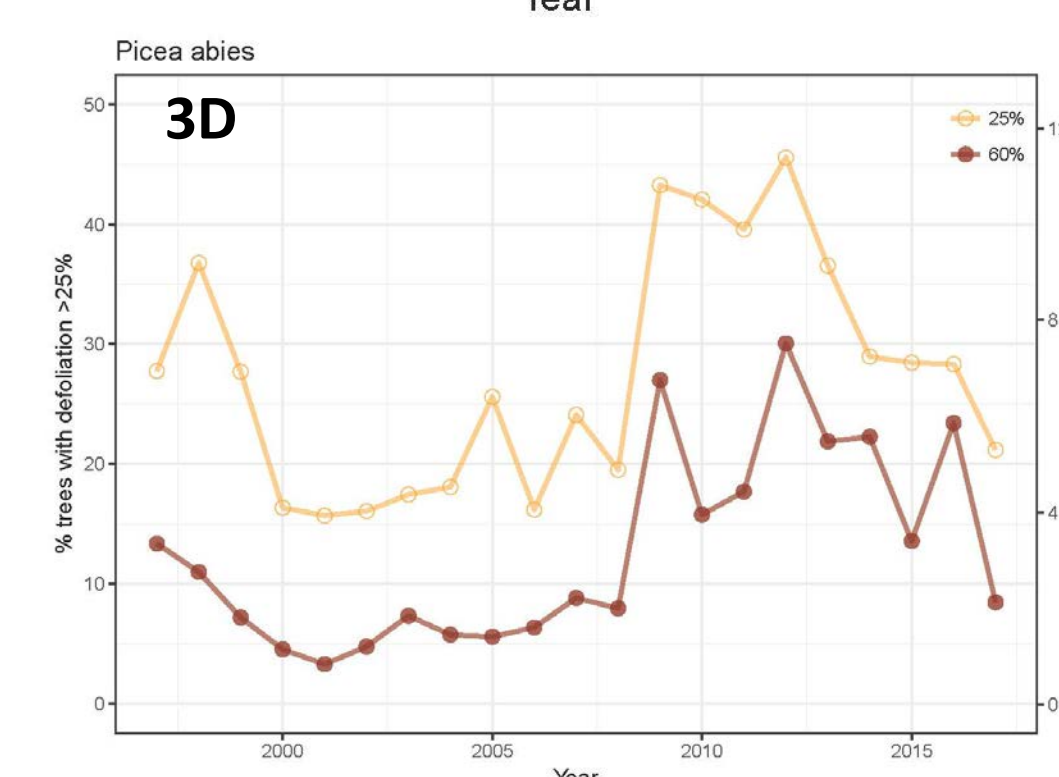

1

Cluster
1
2
3
4

4

Ratio of highly defoliated trees
0.00
0.25
0.50
0.75
1.00
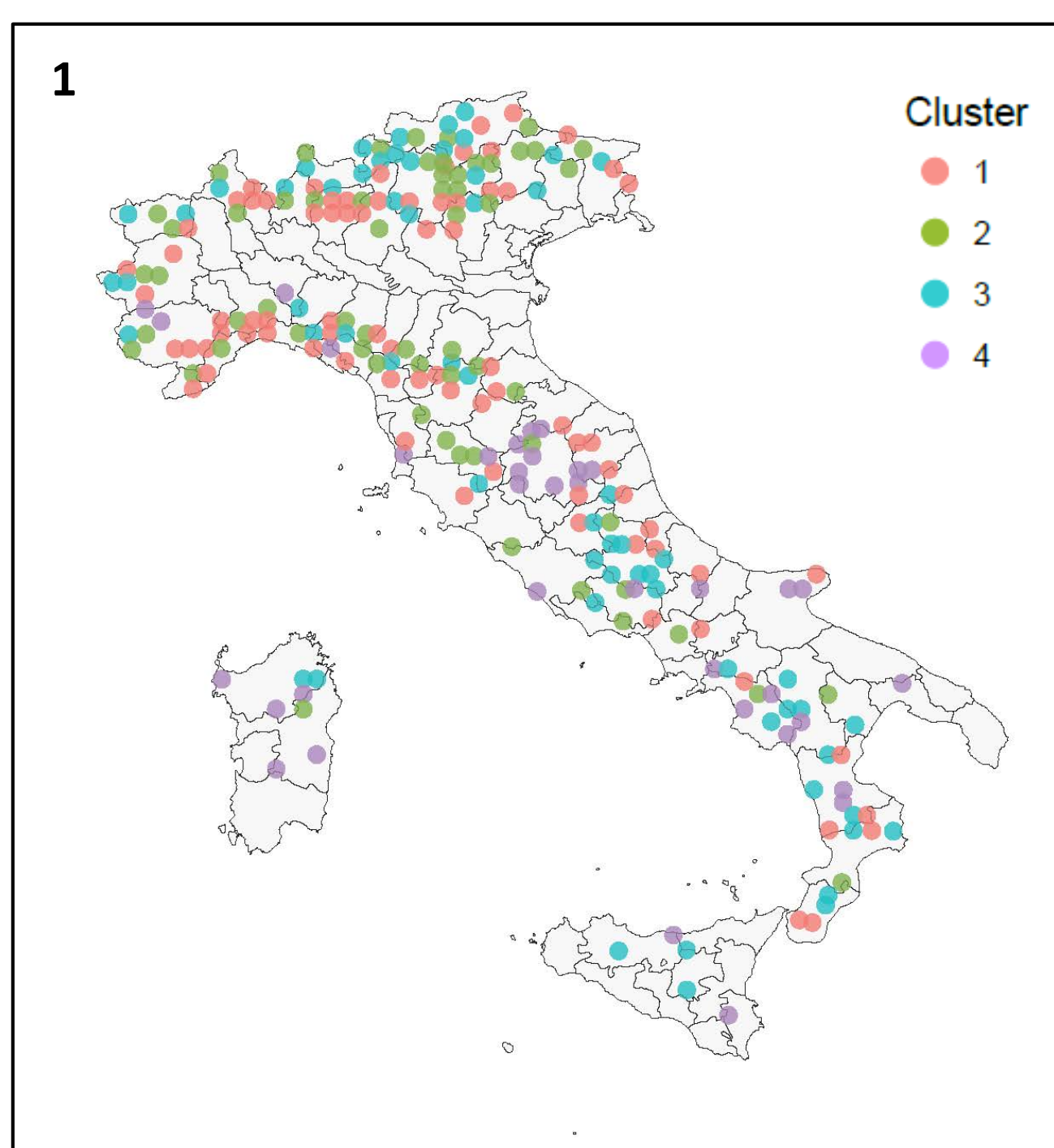
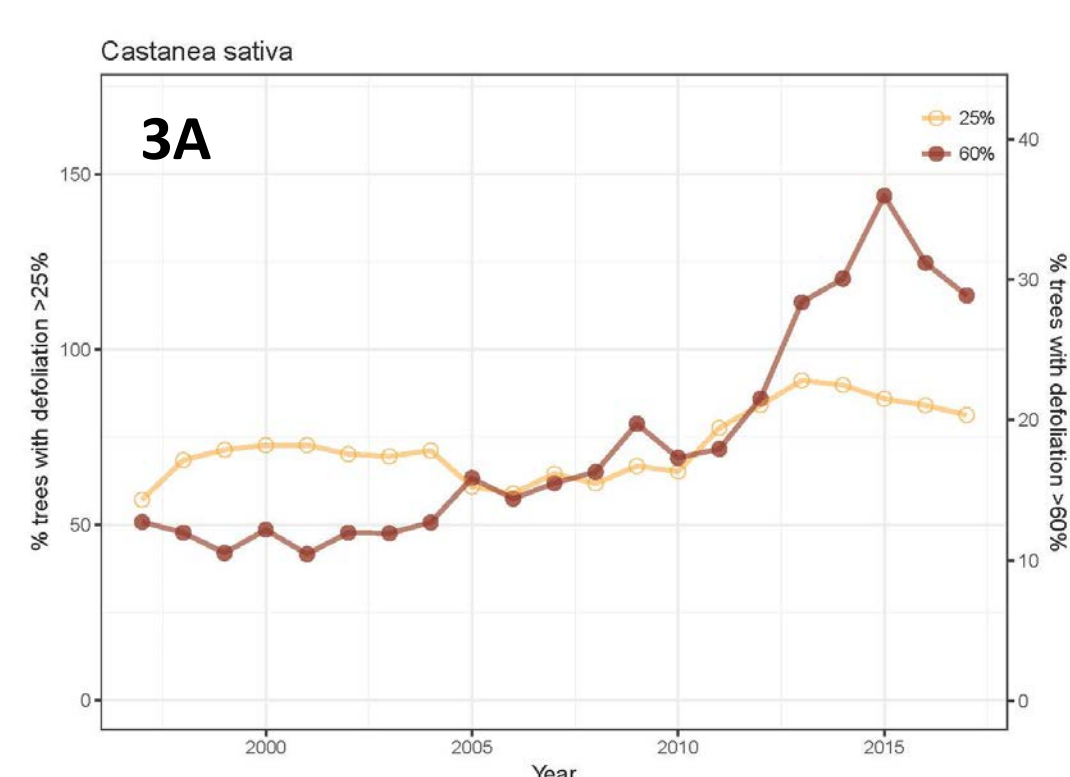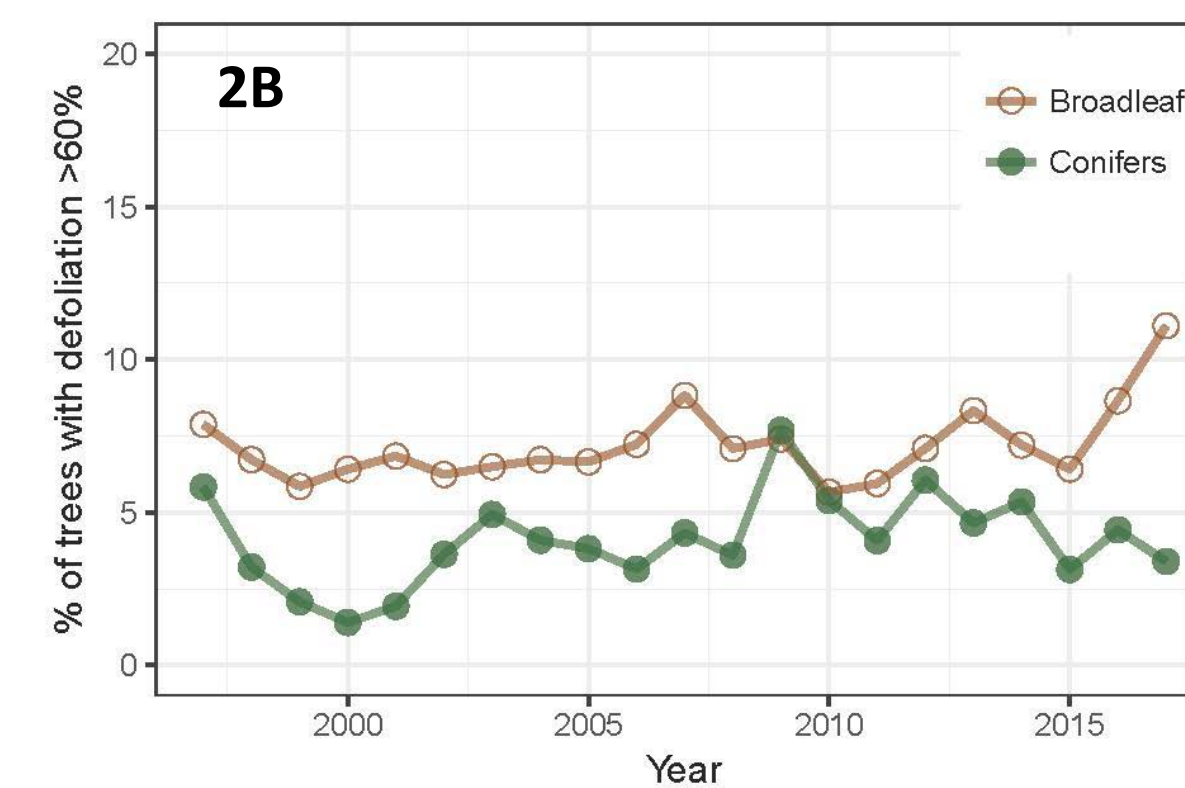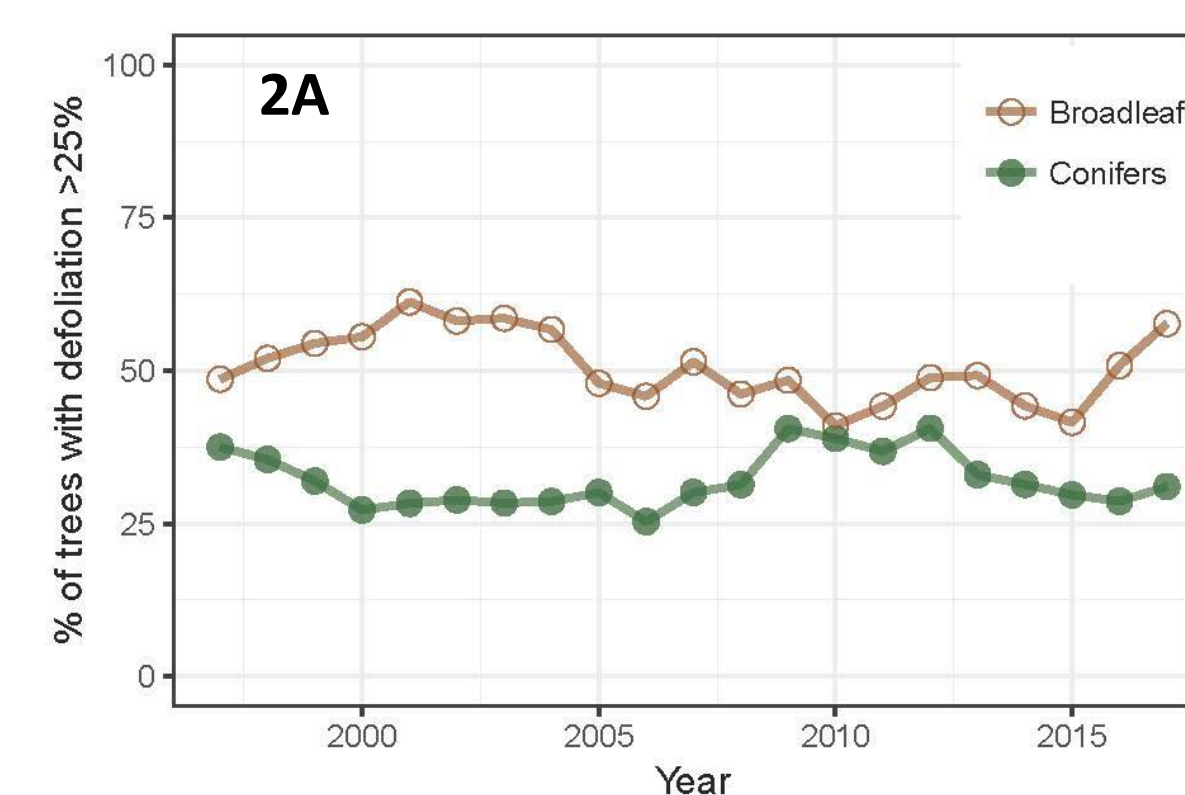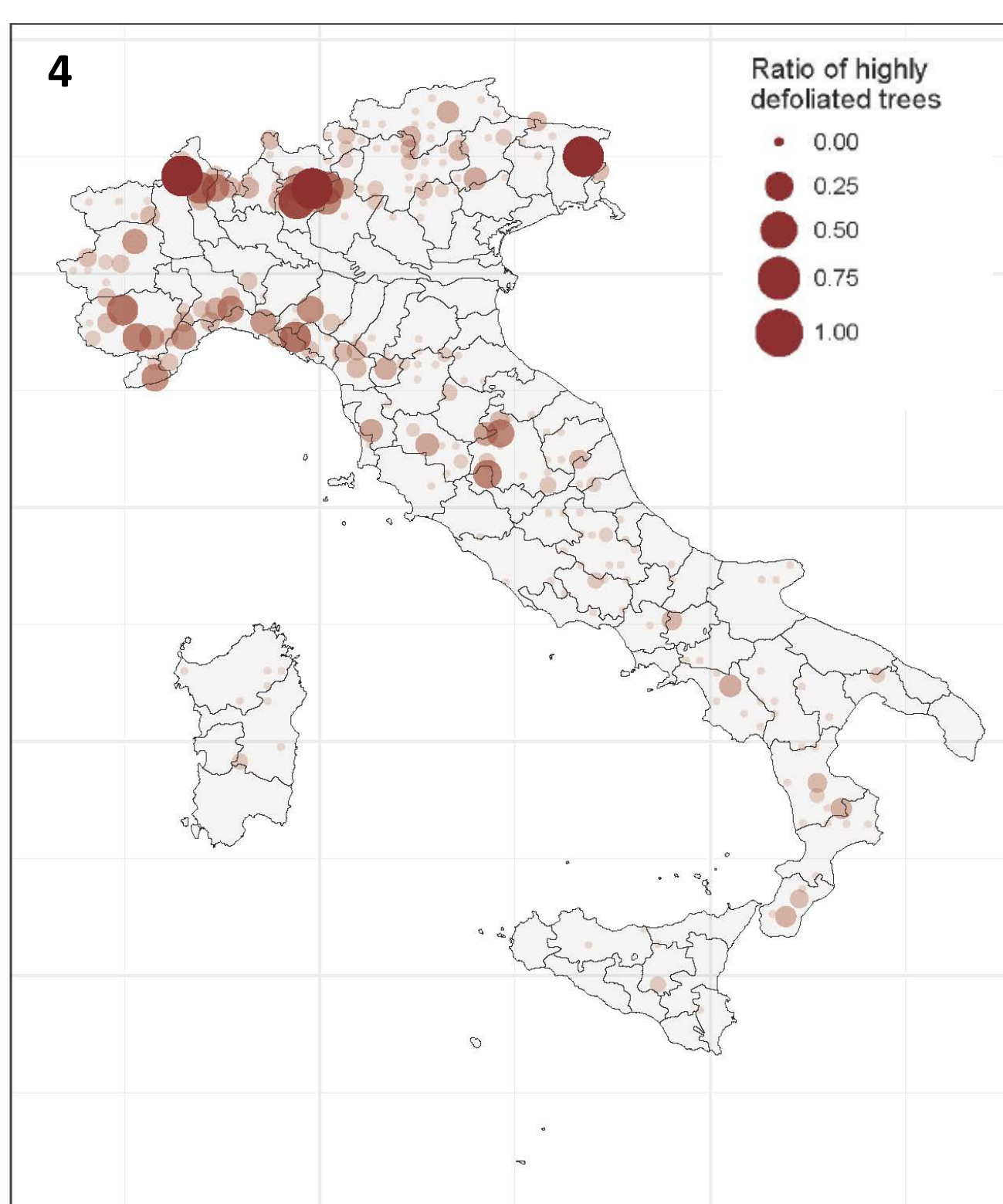**Cluster 1.** Mixed forests on the sub-mountain (Alpine and Apennine) belt, with a prevailing composition on deciduous broadleaved trees. Main species are: *Castanea sativa*, *Fagus sylvatica*, *Ostrya carpinifolia*, *Quercus pubescens*

Cluster 2. Forest with similar distribution respect to the Cluster 1, but at lower altitude and with lower degree of diversity. Main species are: *Quercus pubescens*, *Picea abies*, *Quercus cerris*, *Fagus sylvatica*, *Larix decidua-*

Cluster 3. Monospecific or low diversity forests (broadleaves and/or conifers) at the highest elevations in Alps and Apennine. Main species are: *Fagus sylvatica*, *Picea abies*, *Larix decidua*.

Cluster 4. Mediterranean and supra-Mediterranean broadleaved forests (evergreen and deciduous), in xero-thermic conditions and with low levels of diversity. Main species are: *Quercus ilex*, *Quercus pubescens*, *Quercus cerris*, *Castanea sativa*.

2A
Broadleaf
Conifers

2B
Broadleaf
Conifers

3A — Castanea sativa

3B — Fagus sylvatica

3C — Quercus ilex

3D — Picea abies

4 — Fagus sylvatica

Picea abies

Quercus ilex
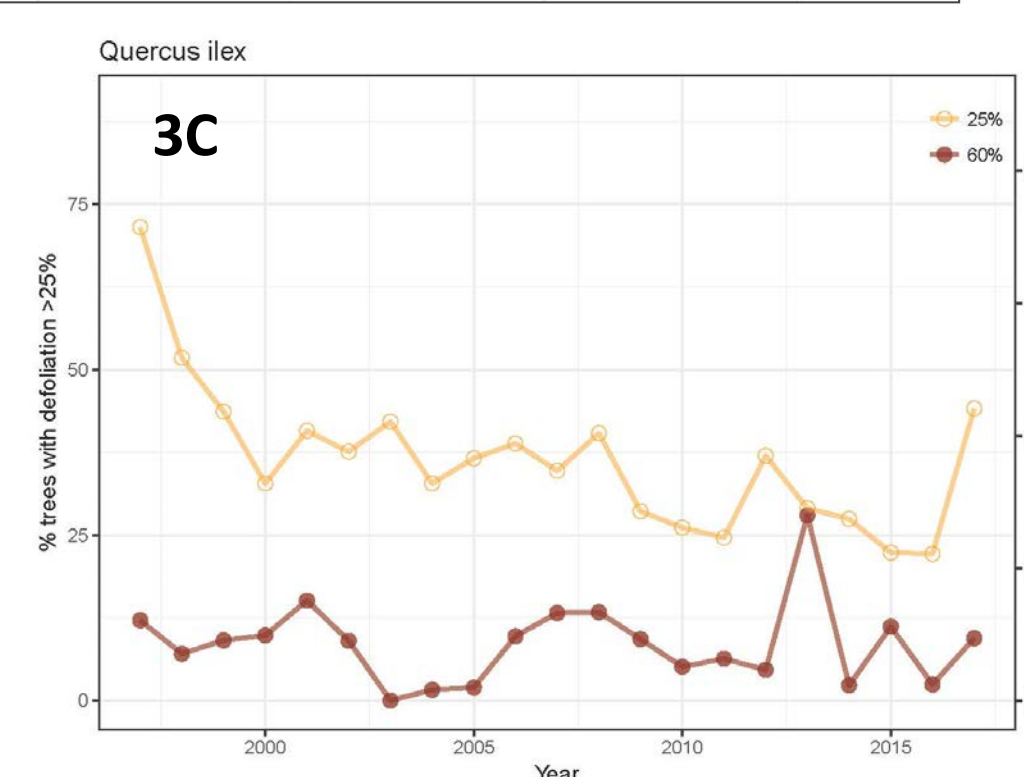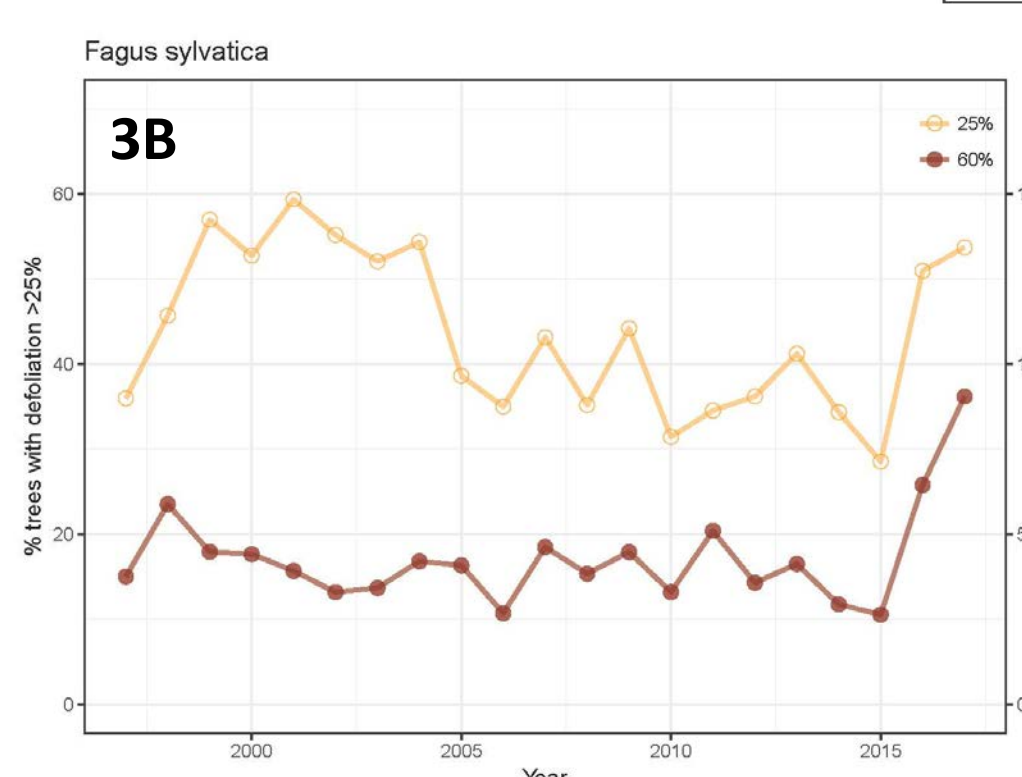
Relationships of defoliation with tree diversity

The country-wide analysis for the main tree species revealed a general trend of increase of defoliation in the more diverse stands (positive correlations). This behavior can be considered as the effect of the interaction between different ecological and vegetational conditions.

Relationships between defoliation and tree diversity, however, may vary in different clusters of plots. Whereas no special behaviors was observed for beech, spruce and holm oak showed significant negative correlations respectively in the clusters 3 and 4, between the years 2008 and 2013 (Fig. 4).

Crown conditions worsened in spruce monospecific plots in the 2008-2012 period, whereas remained relatively stable in mixed plots (Fig. 5). This behavior suggests that in this species tree diversity at plot level exerts a stabilizing role.

In holm oak the correlation between tree diversity and defoliation was always negative but became significant in some specific years depending on the relative fluctuation of defoliation in monospecific and mixed plots. Tree diversity, therefore, is more beneficial in Mediterranean stressful conditions.

Conclusions

In a heterogeneous context forest tree assemblage and diversity are strictly dependent from the varying ecological conditions, consequently any analysis at country scale may be severely biased. It was therefore necessary to limit the analyses to more homogeneous conditions. The results of the Italian survey indicate that forest diversity can modify the responses of trees subjected to fluctuating environmental pressures, but correlations between crown conditions and tree diversity may change in relation to tree species and ecological context.

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Fagus sylvatica – cluster 3
Monospecific
Mixed

Picea abies – cluster 3
Monospecific
Mixed

Quercus ilex – cluster 4
Monospecific
Mixed