Remote Sensing of Fluorescence, Photosynthesis and Vegetation Status
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Chlorophyll fluorescence signature of European forests is affected by latitude, and tree species composition and species-specific features. Insights from a terrestrial survey

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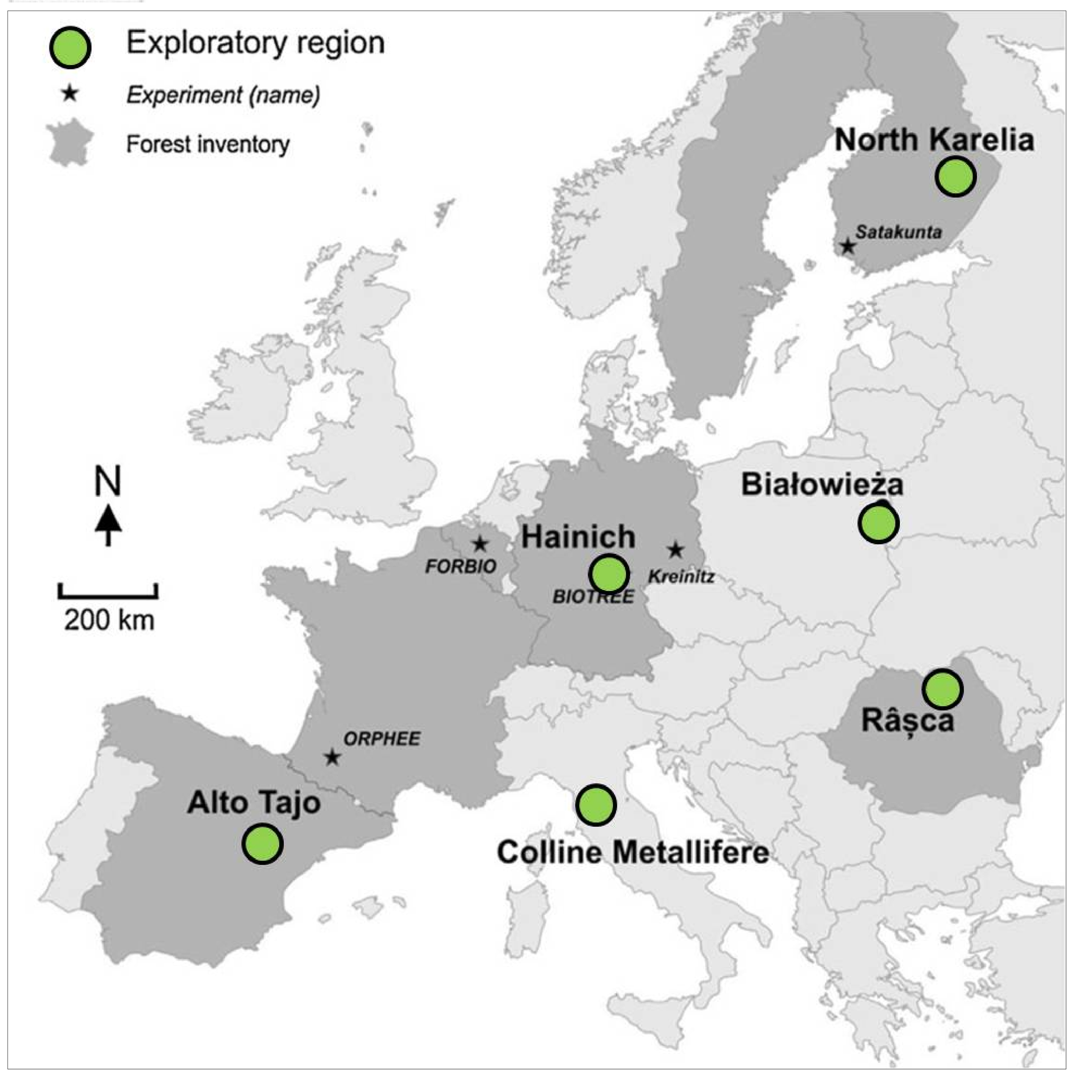

Figure 1

FunDivEUROPE project

The physiological features of forest trees are influenced by several factors, including development stage, leaf age, environmental conditions and reciprocal interactions among tree species. Tree diversity may have positive or negative effects on the physiological functioning of trees, depending from belowground and aboveground mechanisms of facilitation and or competition for water, nutrient and light. The effects of forest biodiversity on ecosystem functioning and services in Europe were studied in the FP7-project **FUNctional significance of forest bioDIVersity in Europe (FunDivEUROPE)**. 209 forest stands distributed in six countries, from Mediterranean to boreal regions (exploratory regions, Figure 1), representative of the main European forest types, were assessed during 2012-2013. Sixteen forest tree species (three to five in each region) were selected according to a diversity gradient (monospecific and mixed stands - for a detailed description of the project see Baeten et al., 2013). The photosynthetic responses of European tree species to climate parameters, structural characteristics of the stands and to diversity are presented here.

Photosynthetic efficiency of forest tree species

A leaf sampling in all forest stands of the FunDivEUROPE project was carried out (Figure 2 A, B). In each forest stand, six (in monospecific stands) to 15 (in mixed stands) canopy trees were sampled. The photosynthetic efficiency of forest trees were analyzed by means of chlorophyll fluorescence (ChlF) (prompt fluorescence, OJIP-fluorescence transient (Figure 3) parameters, Strasser et al., 2004). The following chlorophyll fluorescence parameters were measured:

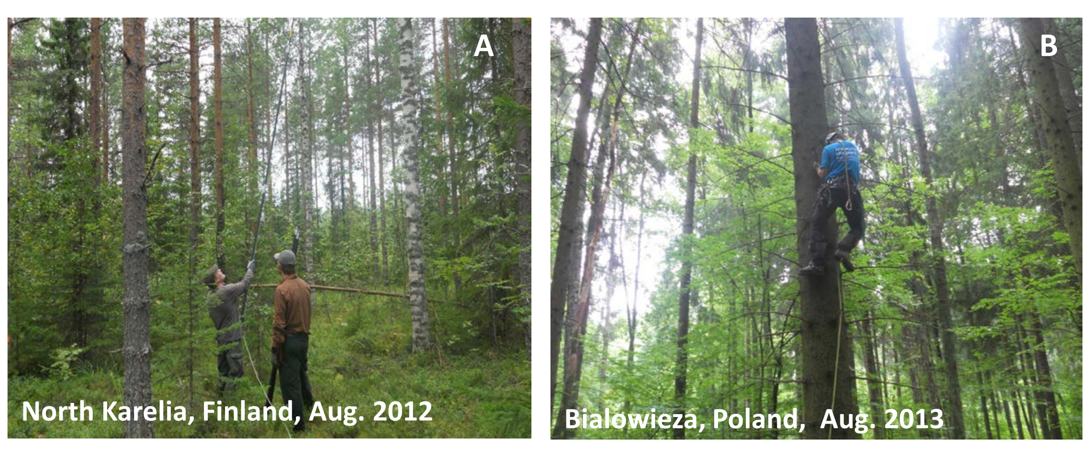

Figure 2

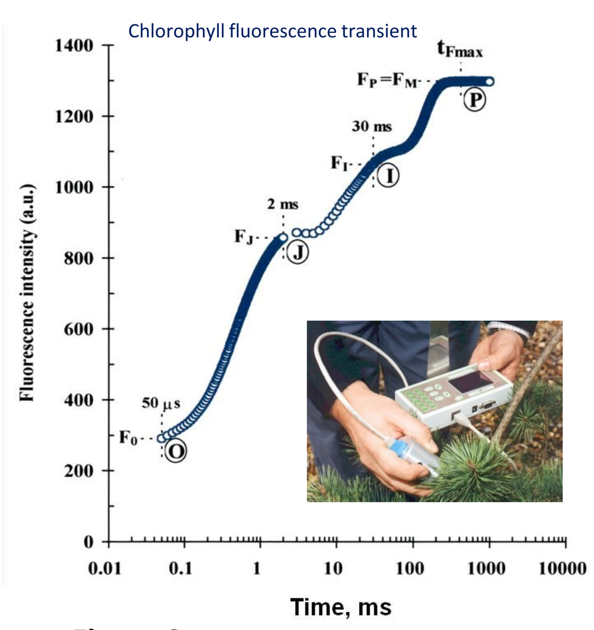

Figure 3

F_V/F_M: maximun quantum yield of photosystem II (PSII) in dark-adapted leaves. It expresses the capacity of the reaction center to trap a photon absorbed from the PSII antenna. It is an indicator of stress (especially sensitive to high solar radiation - *photoinhibition*)

I-P phase: efficiency of the electron flux through the photosystem I (PSI). It describes the phase of the fluorescence transient related to the reduction of PSI end-electron acceptors, such as $NADP^+$

PI_{ABS}: performance index on absorption basis. It is a index for potential energy conservation of photons in the intersystem between PSII and PSI. It is a synthetic expression of the overall photosynthetic efficiency of leaves (from the light-capture processes, to electron acceptors and carriers between PSII and PSI, to the final electron acceptors and their reduction).

Results

Photosynthetic efficiency of forest tree species

ChlF parameters varied significantly across the tree species: conifers showed the highest overall photosynthetic efficiency (Figure 4), whereas Mediterranean oaks (*Q. faginea* and *Q. ilex*) had the lowest ability of light-capture.

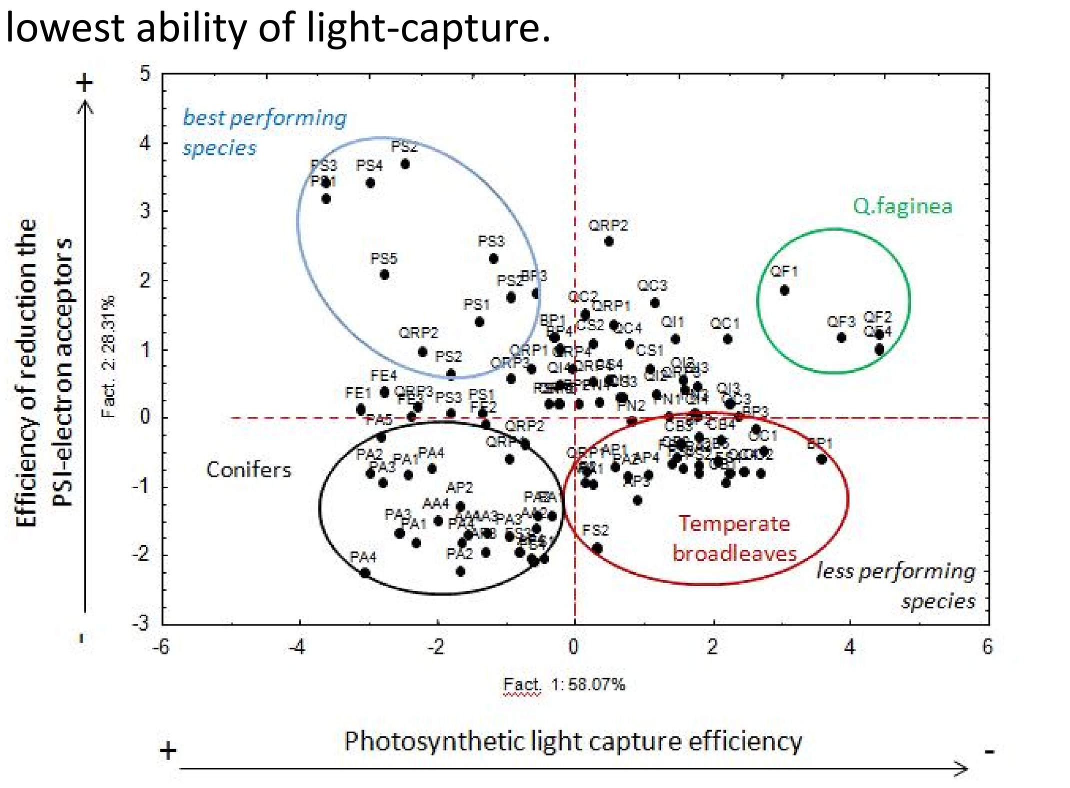

Figure 4. Photosynthetic efficiency of all tree species across the six countries. The species are indicated as following: *Abies alba* (AA), *Acer pseudoplatanus* (AP), *Betula pendula* (BP), *Carpinus betulus* (CB), *Castanea sativa* (CS), *Fagus sylvatica* (FS), *Fraxinus excelsior* (FE), *Ostrya carpinifolia* (OC), *Picea abies* (PA), *Pinus nigra* (PN), *Pinus sylvestris* (PS), *Quercus robur* (QR), *Quercus* spp. (*Q. robur-Q. petraea*, QRP). The number close to the name of the species indicates the species mixture level (forest stands with 1 to 5 species).

Effects of climate factors

The photosynthetic efficiency of the tree species increased with latitude (Figure 5), with exception of the northermost forest stands (boreal forest in Finland).

The effect of climate parameters on tree species photosynthetic efficiency was different if we consider the photosynthetic processes of the light-capture (measured by F_V/F_M) or the processes of reduction of the end-electron acceptors of PSI (measured by I-P phase), separately (Figure 6).

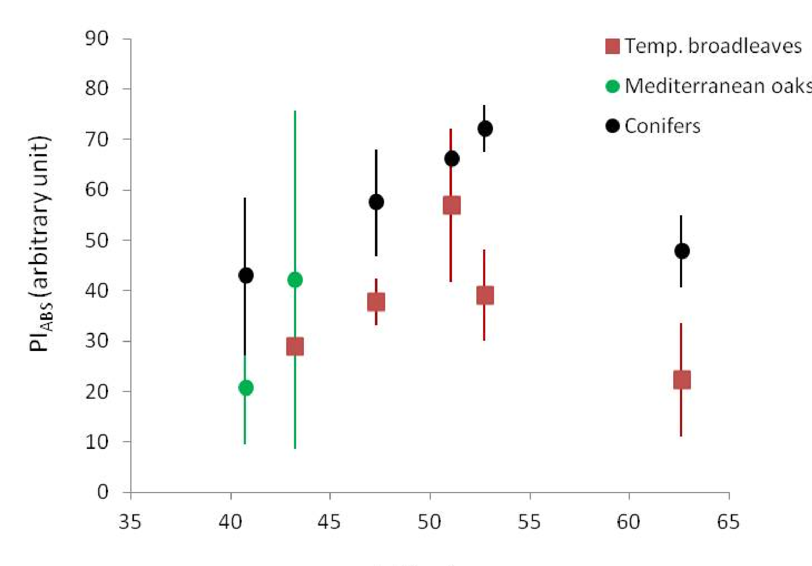

Figure 5

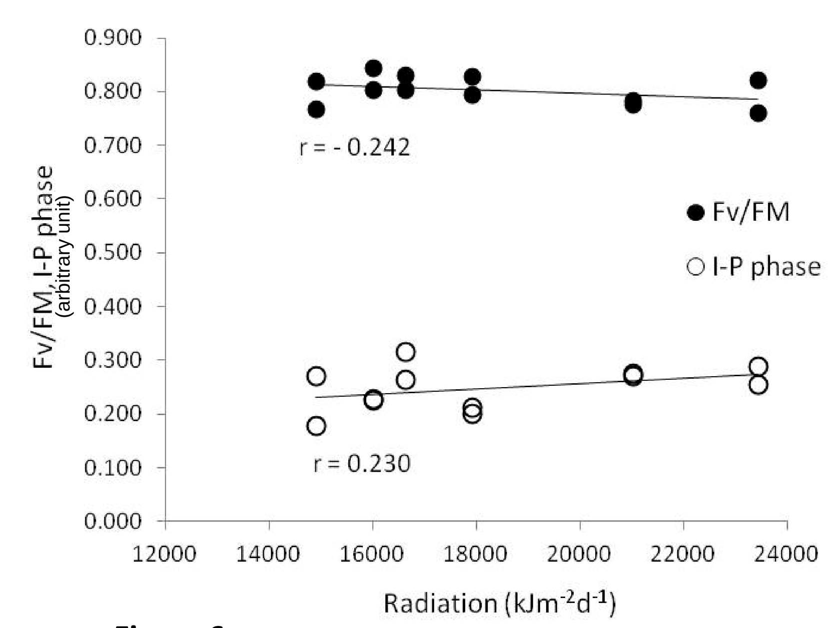

Figure 6

Effects of structural characteristics of forest stands

The overall photosynthetic efficiency of the tree species (PI_{ABS}) is positively correlated with structural characteristics of the stands, such as the basal area (Figure 7) and the leaf area index. This last parameter showed a similar pattern in relation to the latitudinal distribution of the functional groups of species (Figure 8), respect to the PI_{ABS}

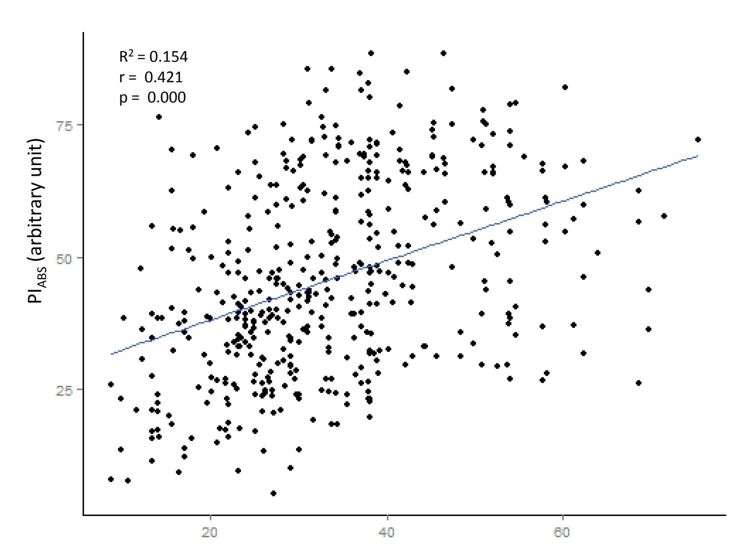

Figure 7

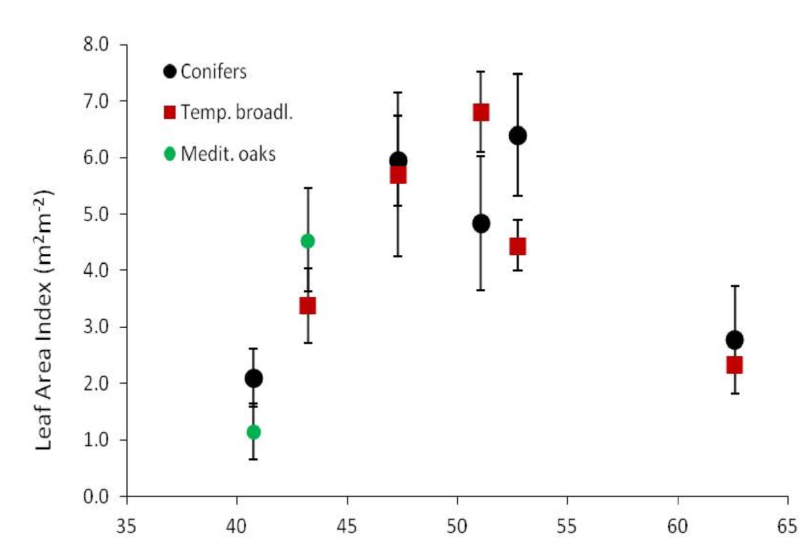

Figure 8

Effects of tree diversity

Tree species richness and tree species composition of the stands influenced the photosynthetic efficiency of trees . We found species-specific and site-specific effects of the forest diversity (measured by Shannon diversity index). *Picea abies*, the most common tree species in the FunDivEUROPE sites, showed an opposite photosynthetic response in Romania and in Finland (Figure 9 and 10).

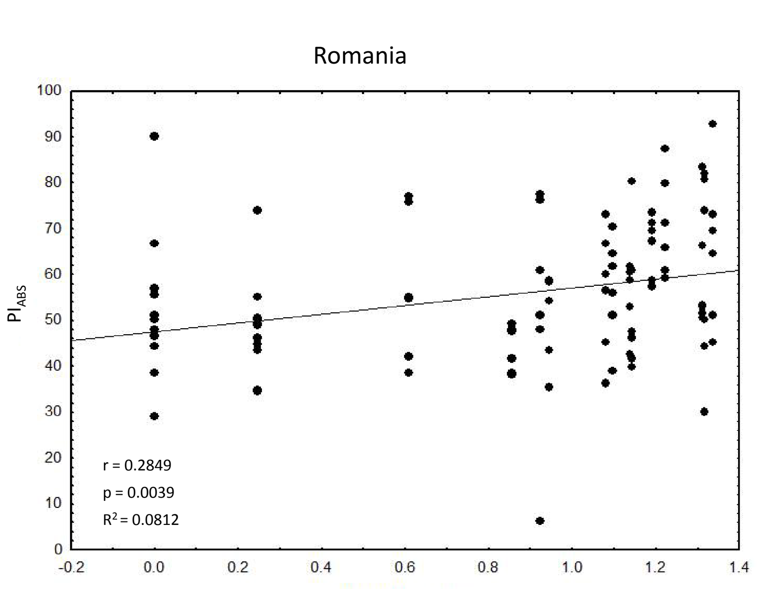

Figure 9

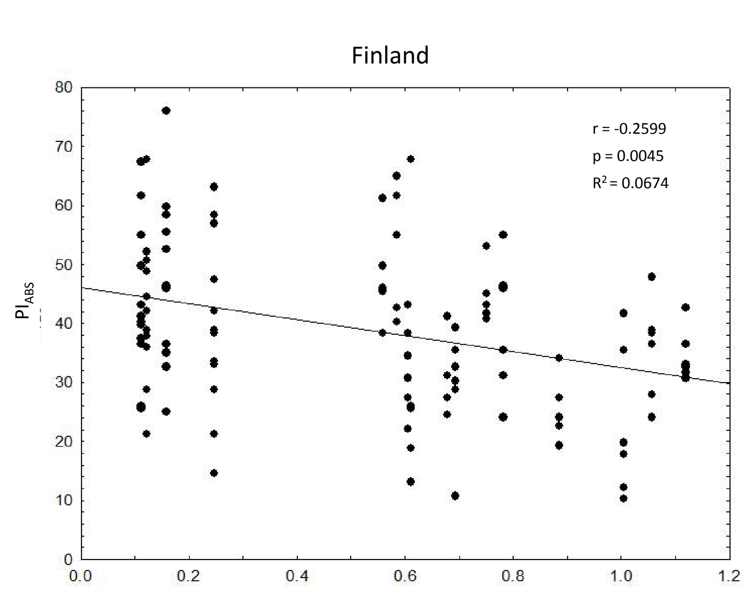

Figure 10

Conclusions

- At European scale forest tree species are distributed in groups according to their photosynthetic properties. And functional groups of species (conifers, broadleaves, Mediterranean oaks) are identified and characterized by means of chlorophyll fluorescence parameters.
- The photosynthetic properties of tree species are affected by ecological factors, that at local scale may be described as site-factors.
- Tree diversity, both tree species richness level and species combination, play a role of modifying factor, with species- and site-specific effects.
- The knowledge of tree species responses to climate, ecological and diversity factors allow to identify the forest stand structure and tree species assemblage more appropriate to cope with environmental changes.

Reference

Baeten L, Verheyen K, Wirth C, Bruelheide H, Bussotti F, Finér L, Jaroszewicz B, Selvi F, Valladares F, Allan E et al. 2013. A novel comparative research platform designed to determine the functional significance of tree species diversity in European forests. *Perspectives in Plant Ecology, Evolution and Systematics* 15(5): 281-291

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