Assessing potential of sun-induced chlorophyll fluorescence for early detection of forest decline using a 3-D radiative transfer model accounting for forest structure

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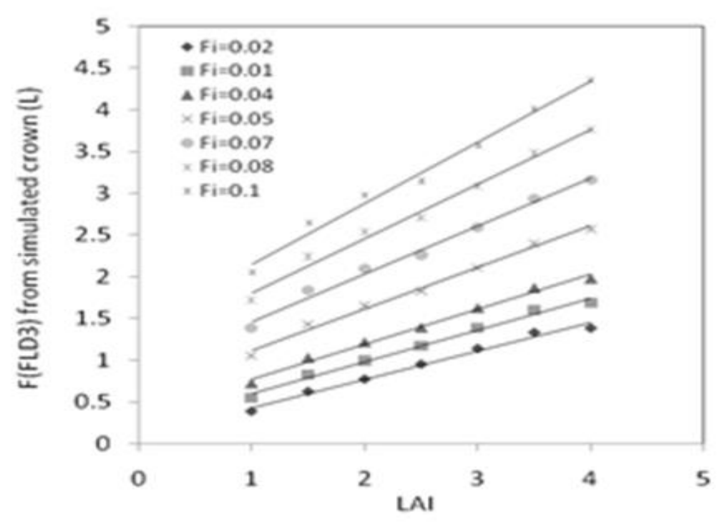
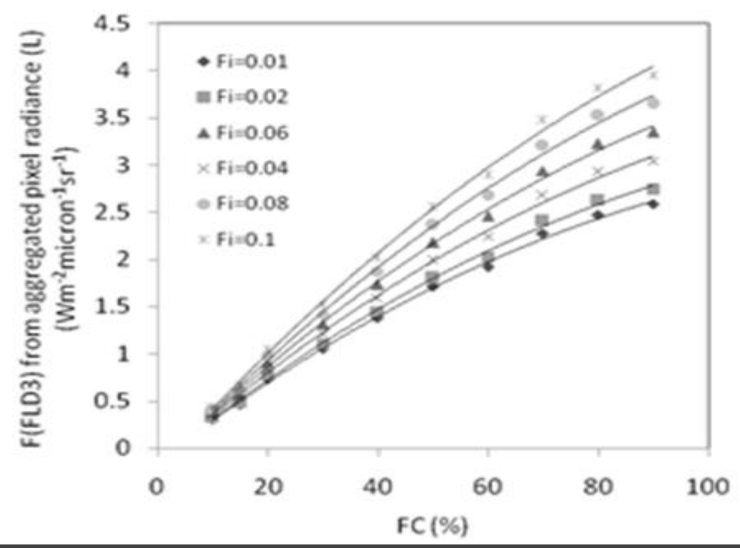
Sun-induced fluorescence (SIF) has been proven to serve as a proxy of photosynthesis activity and therefore, as an early indicator of physiological alterations for global monitoring of vegetation. However, the interpretation of SIF over different spatial resolutions is critical to bridge the existing gap between local and global scales. Here we present new field experiments and model simulations aimed at understanding the influence of scene components, forest structure and composition on the quantification of the fluorescence signal as an early indicator of forest decline.

Field data collection and airborne image acquisitions

Experiments were conducted over an oak forest (*Quercus ilex*) affected by water stress and *Phytophthora* infection in the southwest of Spain. The robustness of the SIF quantification through the Fraunhofer Line Depth (FLD) principle with three spectral bands F (FLD3) was assessed using high resolution (60 cm) hyperspectral imagery extracting sunlit crowns, pure tree crowns and aggregated pixels.

Effects of forest structural variables on simulated canopy fluorescence (FLD3).

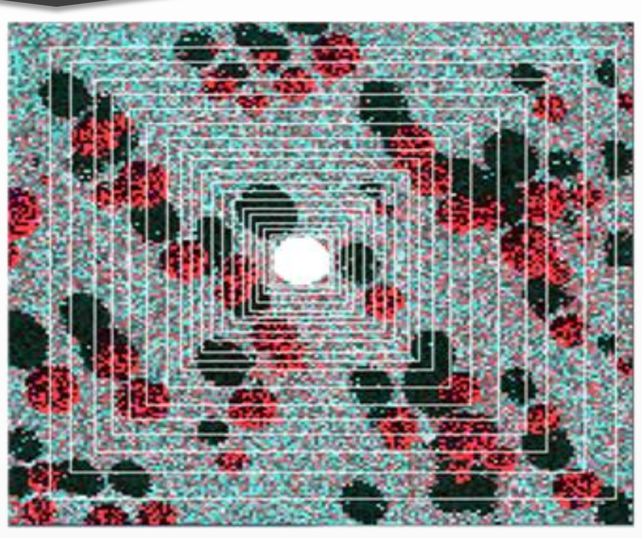


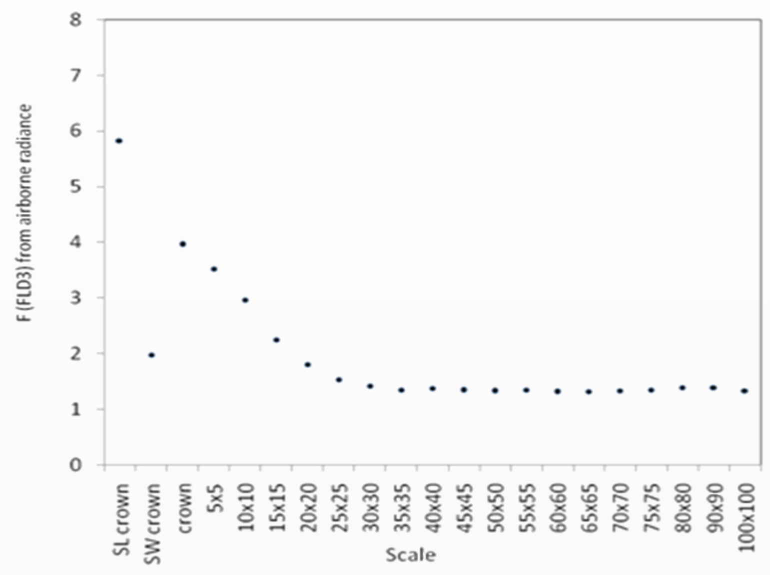


FluorFLIGHT: a canopy fluorescence model based for remote sensing of forest health and productivity

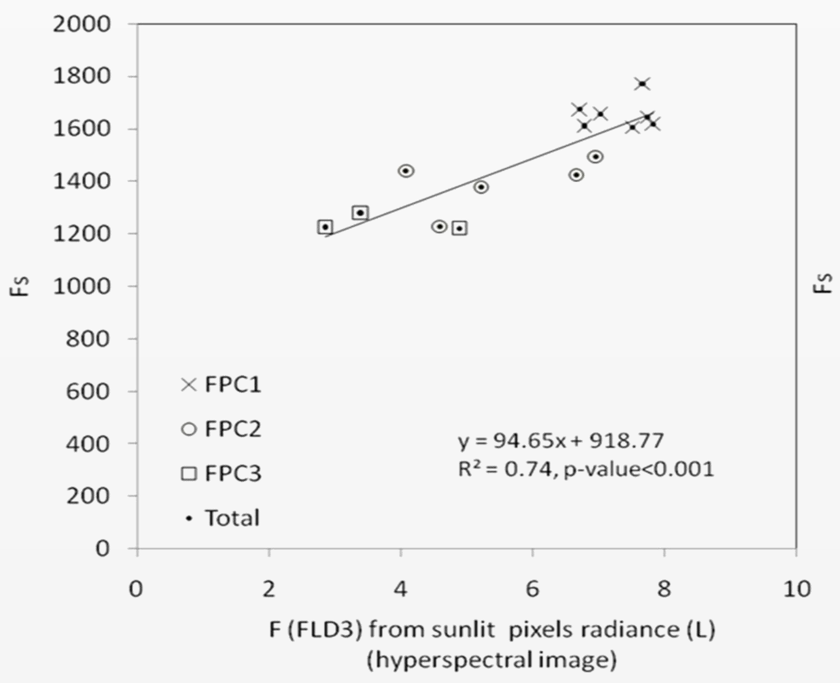
FluorFLIGHT, a modified version of the 3-D radiative transfer model FLIGHT was developed to enable the simulation of canopy radiance and reflectance including fluorescence effects from different spatial resolutions and percentage cover levels. The FluorFLIGHT model was specifically developed to assess the sensitivity of the fluorescence signal on heterogeneous forest canopy images.

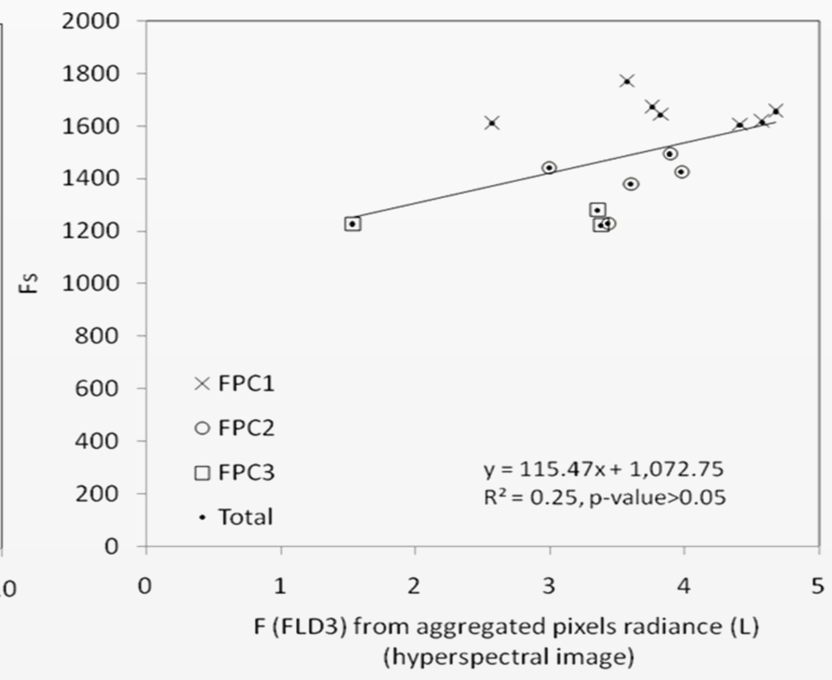
FluorFLIGHT model simulation to analyse the aggregation effects due to the spatial resolution



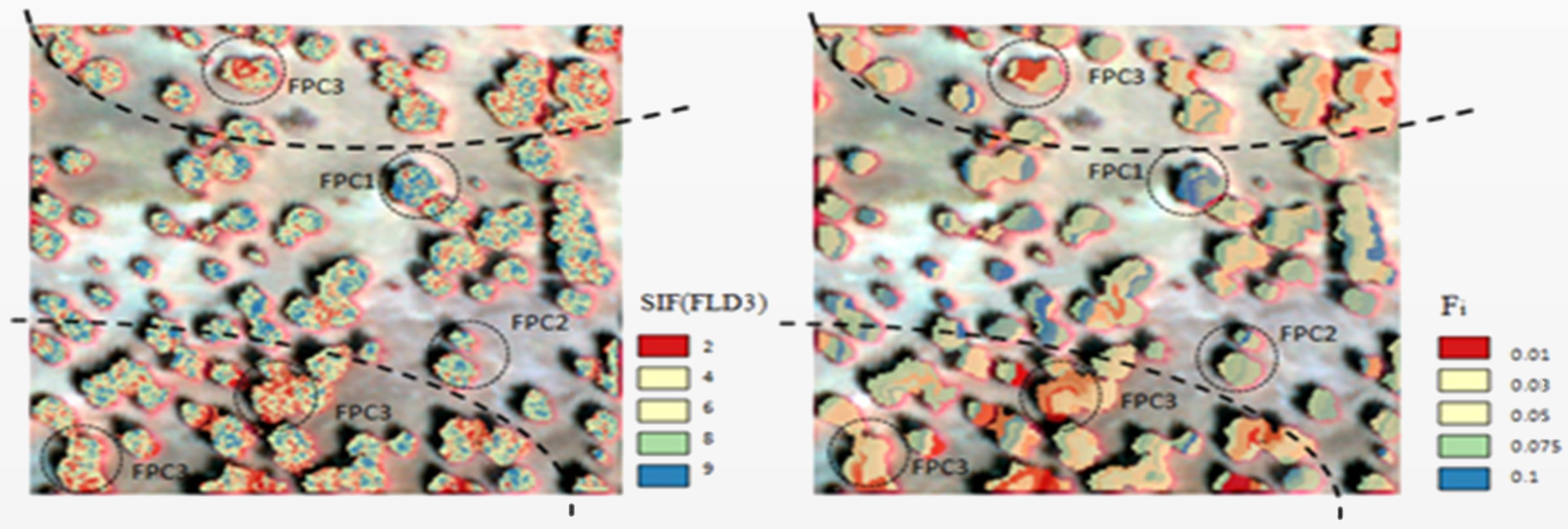


Results





Relationship between de-epoxidation state of the xanthophyll cycle (DEPS) and water potential against FLD3 from sunlit pure crown L.



SIF retrieval at the crown level estimated from the 60-cm hyperspectral image using the fluorescence in-filling method within the oak forest.

Conclusions

Sun-induced fluorescence imaging (SIF) provides early and precise stress diagnosis. SIF was quantified from imagery acquired over a oak forest and related with decline processes induced by water stress and *Phytophthora* infections. SIF emission was added to FLIGHT to account for forest structural effects which permitted the quantification of SIF from coarse-resolution imagery. The 3D modelling approach significantly improved the relationship between F_s and F (FLD3) extracted from aggregated pixels, and enabled the quantification of SIF as a function of fractional cover, leaf area index and chlorophyll content yielding significant relationships between F_s ground-data measurements and fluorescence quantum yield estimated with FluorFLIGHT. The methodology also demonstrated its capabilities for mapping SIF at the tree level for single tree assessment of forest physiological condition in the context of early disease detection.