PROJECT INFORMATION

Project title:	**DEFORSCEN - UNDERSTANDING CANOPY DEFOLIATION OF EUROPEAN FORESTS UNDER RECENT CLIMATE CHANGES TO PREDICT FUTURE ADAPTATION SCENARIOS**
Project ID:	137
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PROJECT DESCRIPTION

Executive Summary

There is increasing interest to identify patterns of current plastic and evolutionary response of plants to climate change. Since plasticity can be reflected by tree health, one possible investigation approach is the analysis of tree health (canopy defoliation) data collected on ca. 6000 plots across Europe since the 1980s and for which a fully convincing evaluation is still missing.
We will investigate if changes and trends in defoliation permit to identify species-specific response to climate change, also in view of future adaptation scenarios. We will do it according to novel methods, including Fast Fourier Transforms, selection of candidate variables, grouping of sites, optimal spectra (time window) and offset (time lag) for each variable, and response in relation to predictors within moving windows.

Objectives:

(1) To explore novel ways to evaluate how environment drives canopy leaf mass and year to year variation in canopy defoliation;

(2) to test elements of plasticity and integral or delayed responses in canopy defoliation to environmental stress

Context and Motivation

There is increasing interest to identify patterns of current plastic and evolutionary response of plants populations to climate change(1, 2): this has obvious relevance for adjusting forest management strategies and to maintain productive and healthy forests. Under the hypothesis that plasticity (i.e., the adaptability of an organism to changes in its environment) can be reflected by tree health status, one possible analytical approach is the analysis of long-term forest health data across species and regions in relation to climate change.
Available forest health data consist in defoliation, an estimate of relative lack of foliage mass on tree canopies as compared to an optimum. Defoliation has been assessed according to standardized methods by annual surveys on ca. 6000 plots across Europe since the 1980s(3). As a result, there is a large-scale, long-term coverage of European ecological gradients with fully documented, harmonized measurements. Defoliation was proven to be significantly related to tree growth(4, 5) and

driven by climate(6), although other factors (e.g. tree age, species-specific interactions and nitrogen deposition) may play a role. We learned, however, that considerable year-to-year variation in tree crown status may occur, with the amount available water playing a major role(7), and with considerable signal in the data remaining unexplained.
Recent climate change-oriented research in the field of forest health focused on tree mortality(8), disturbances(9) or catastrophic events(10). Here we want to investigate whether subtle changes in forest health condition and their time trends (as recorded by defoliation) permit identifying species specific responses to climate change and can therefore be used to project future conditions according to climate change scenarios. We will use novel methods (see below) and take advantage of a large set of available defoliation data.

Scope and Methods

The primary goal of this innovation project is to develop a novel method to analyze crown defoliation data as measured in monitoring campaigns since the late 1980s across Europe. We believe that novel analytical methods need to be developed because traditional methods to statistically relate direct environmental drivers (climate, atmosphere, soils) to the response (canopy defoliation) are performing poorly in explaining the behavior of tree canopies. After >30 years of measurements it is clear that canopies respond partly plastic, partly adaptive, and time lags cannot be excluded(11).
A novel analytical approach is therefore required that allows for decomposing the effect-response into time spectra of different length and lag. To our knowledge, no such complex analytical approach has been developed or applied to ecological time series data and certainly not to defoliation data.
The following steps are foreseen (see Figure 1):

1) Analyze possible response windows by means of Fast Fourier Transforms (FFT) of the response: analyze what spectra of responses are visible by decomposing the complex response into spectra of different length (in years).
2) Select and prepare important candidate variables to explain canopy defoliation: these will include information on water availability and atmosphere (climate, air pollution) at monthly resolution as well as trees, stand and soil data.
3) Select test-species and group sites across Europe by means of distance and climate: assemble sites with similar environment characteristics within meaningful distance in order to enlarge the pool of trees that can be analyzed in a comparable manner.
4) Analyze optimal spectra (time window) and offset (time lag) for each variable prior to analyses:testing for each variable, what is the best window (Figure 1, A) and time lag (Figure 1, B) of influence to explain canopy defoliation.
5) Analyze response of canopy defoliation in response to predictors within moving windows: the multivariate response is calculated in windows of 15-20 years in a moving window approach (Figure 1, C) in order to evaluate how the drivers have changed over time and to what degree the response shows adaptive, plasticity behavior.

We will use canopy defoliation data for selected species as measured on ca. 6000 ICP Forest Level I plots across Europe since the late 1980s.

Project History

Expected Results and Significance

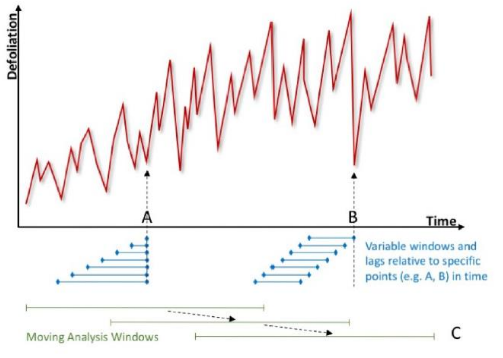

Figure 1: *Illustration of how single variables are tested to have best predictive power to explain defoliation, and how models are calibrated. Variables are tested for windows of influence (A) and lag effects (B) relative to each observation point in time, while models are calibrated in moving windows (C) of 15-20 years in order to assess adaptive behaviour.*

If successful, the novel approach developed here will provide new insights into both the general and the regional drivers of canopy defoliation in relation to environmental drivers in general and climate in particular. This will give insights into environmental constraints on forest productivity, since foliar biomass is one of the key elements (next to water availability and temperature) that drive forest productivity.
Understanding the constraints to the year-toyear foliar canopy biomass variation will help to optimize forest management in the adaptation to variation of these constraints.
The expected information output will therefore support climate-smart forestry, i.e. adaptive forest management in response to climate change and climate variability.
This project has not been submitted anywhere else. If successful, it is envisioned to submit a larger project to SNF with the aim to include all major tree species of Europe using ICP Forests data, to combine defoliation and growth analyses, to link ground measured point data with remotely sensed imagery across all of Europe, and to further project the found patterns to future conditions in order to explore the resilience of canopy and growth conditions under climate change. No sufficiently well established conclusion has been drawn after >30 years of measuring defoliation. It is likely that trees and canopies show a complex, adaptive and plastic behavior, with time lags in response. This requires novel ways of analyzing time series of defoliation, namely the decomposition of signals into temporal spectra of different length and of differing time-lags, as well as testing for adaptive behavior through time. With this innovation project, we seek to develop an analytical protocol for such a new method for selected species from ICP Forests plots. This can be of value also in view of the annual survey on defoliation conducted by WSL.

Project Team and Responsibilities

M. Ferretti is project leader, all co-applicants are members of the scientific project team that discusses ideas with the postdoc and the results originating from this project.

References

1. Franks SJ, Weber JJ, Aitken SN, 2014. Evolutionary Applications, 7, 123-139. **2.** Wheatley CJ, Beale CM, Bradbury RB, Pearce-Higgins JW, Critchlow R, Thomas CD. Glob Change Biol. 2017; 00:1–12. https://doi.org/10.1111/ gcb.13759; **3.** Ferretti M, Fischer R, editors, 2013. Forest Monitoring, Vol 12, DENS, UK: Elsevier, 2013, 507 ps. **4**. Dobbertin M, 2005. European Journal of Forest research, 124: 319-333. **5**. Solberg S., Tveite B. 2000. Scand J For Res, 15:1, 87-96. **6**. Carnicer, J., Coll, M., Ninyerola, M. et al., 2011. P. Natl. Acad. Sci. USA, 108, 4, 1474-1478. **7.** Eilmann B, Dobbertin M, Rigling A, 2013. Annals of Forest Sciences, 70: 685-693. **8.** Neumann M, Mues V, Moreno A, Hasenauer H, Seidl R, 2017. Glob Change Biol. 2017;00: 1–10. https://doi.org/10.1111/gcb.13724. **9.** Dale VH, Joyce LA, McNulty S et al., 2001. BioSciences, 9, 723-734.**10.** Kurz WA, Dymond CC, Stinson G et al., 2008. Nature, 452, 987-990. **11.** Ferretti M, Nicolas M, Bacaro G et al., 2014. Forest Ecol. Manage. 311, 56–69.

Schedule and Milestones

We propose to hire a postdoc for 6 months, which we believe is sufficient to explore the idea of optimizing temporal spectra and offsets (time windows and lags) of variables and to develop a novel way of explaining canopy defoliation. The schedule and milestones for this exploration project are as follows:

Milestones

The milestones of the project are as follows:

M1 (end of May 2018): finalized data structure and preliminary variables testing
M2 (end of August 2018): final model for explaining canopy defoliation
M3 (end of September 2018): final report and manuscript draft for a scientific paper.