STReESS: Studying Tree Responses to extreme Events: a SynthesiS. Cost Action FP1106

Short-Term Scientific Mission

COST Action: FP1106
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University of Coimbra.
Host: Maxime Cailleret, Forest Ecology Group, ETH Zürich
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Growth recovery following drought events as early signal of tree mortality

Introduction

Current climate variability have been increasing the vulnerability of terrestrial ecosystems as it was revealed by the impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones and wildfires (Settele et al. 2014). Particularly, increased forest dieback has been observed in many places worldwide and has been attributed to increases in the frequency or intensity of ecosystem disturbances such as droughts, wind storms, fires, and pest outbreaks (Williams et al. 2013). Therefore, drought events associated with increasing temperatures have the potential to prompt tree mortality episodes and cause sudden changes in forest ecosystems (Allen et al. 2010, Reichstein et al. 2013). Nevertheless, the lack of long time series and confounding factors hamper the absolute attribution of forest dieback to climate change (Anderegg et al. 2013). In fact, tree mortality is just the ultimate symptom of a long-term process of vitality loss and hence, it is extremely difficult to determine the stressors, the mechanisms triggering mortality or even the traits which enable trees to survive. Drought events may not only reduce tree growth but also may compromise vitality and thereby the capacity of trees to recover from subsequent, even minor, droughts during tree life. Therefore, the study of the growth recovery following drought events will allow us to evaluate the tree ability to survive to future droughts and eventually, might be used as early signal to predict tree mortality. Our working hypothesis is that trees with lower recovery capacity to drought events would be more prone to die afterward.

Aim of the STSM

The aim of the STSM was to establish the initial computational assumptions to compare drought sensitivity and recovery rates between dead and living trees.

Description of the work carried out during the STSM

This work was based on 58 tree-ring datasets included in either published or unpublished scientific articles collected by the Topic Group 7 “Tree mortality” (TG7). TG7 collected tree-ring and mortality data all over the world (5,003 and 3,258 ring-width chronologies for living and dead trees, respectively, located in 199 sites) and compile them in a big dataset (here after TG7 database) with the aim to use the appropriate statistical procedures to detect the growth patterns prior to mortality. This TG7 database was previously filtered and checked by Dr. Cailleret. Within this first selection, only living and dead trees that had been growing together in the same area and tree-ring chronologies with accurate cross-dating were considered. Then, we selected only the sites in which the cause of death was drought or drought-related effect (bark beetle, competition etc.). Finally, 52 datasets of 31 species (12 Angiosperms species and 19 Gymnosperms species) located in 169 different sites compounded our database.

Since we aim to explore the effect of drought events, we first considered the coordinates of the sampling sites to get the corresponding Standard Precipitation Evapotranspiration Indices (SPEI, Vicente-Serrano et al. 2010). SPEI is a multi-scale drought index based on climatic data from 1901-2013 with a spatial resolution of 0.5º. SPEI data are calculated using the monthly difference between precipitation and potential evapotranspiration. Positive and negative SPEI values correspond, respectively, to wet and dry conditions. The SPEI can be computed at different time scales between 1 and 48 months to characterize the duration and intensity of droughts.

We considered three different monthly SPEI (August, September and October in North Hemisphere and February, March and April in South Hemisphere) for two different scales 5- and 6-month windows. For example, the first time window to calculate the SPEI is focus on August with a 5-month scale (from April to August). We initially considered SPEI < -2 as a standard value of a severe drought event for all the sites.

Then, we graphically explored the relationship between SPEI and growth. Growth was considered either as Basal Area Increment (BAI) or Tree Ring Width (TRW). We wanted to confirm that the SPEI < -2 can be a good indicator of BAI or TRW suppressions due to drought. The effect of the drought may vary between species. For instance, in some conifers the drought year may not correspond with the release of growth, which occurs the subsequent year. After selecting the SPEI value for severe drought events, we will assess the recovery.

Description of the main results obtained

For the 169 sites, we graphically compared growth of living and dead trees and SPEI for the different time windows and scales. Several suppressions of growth were simultaneous with the lowest SPEI values in each population (see the example in Fig. 1). However, in many sites the minimum SPEI values were higher than -2. Therefore, the lowest SPEI value (lower than -1.5) for each site will be use as the indicator of the severe drought event. Then, we will analyse the growth recovery in those target years.

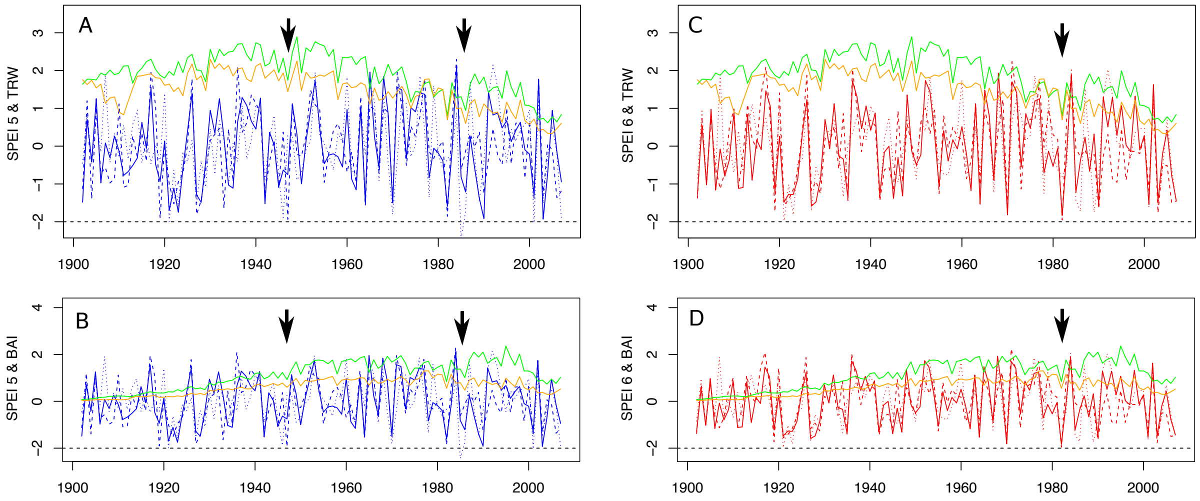

Figure 1: Example of the relationship between radial growth and Standard Precipitation Evapotranspiration Index (SPEI) for the site Vesubie 3 (43º51'N, 7º11'E, France). SPEI is displayed for August (dashed line), September (solid line) and October (dotted line) for two different scales 5-month window (A, B; blue lines) and 6-month window (C, D; red lines). Mean tree-ring widths (A, C; TRW) and Basal Area Increment (B, D; BAI) are showed for living (green line) and dead (orange line) trees. Arrows indicate SPEI < -2.

Description of the next working steps

The next step will be to compare recovery rates between dead and living trees of the TG7 database. Since this STSM was benefited from a meeting on the September the 16th with the core group of the TG7, we have the opportunity to discuss about the main issues of the study. We agreed that the use of the indices developed by Lloret et al. (2011) would be the most simple and promising approach. Lloret and collaborators considered three indices: Resistance (i.e. inverse of the growth reduction during disturbance), Recovery (i.e. ability to recover to the damage experienced during disturbance) and Resilience (i.e. capacity to reach the performance previous to the disturbance). The indices were mathematically expressed as:

Resistance = Dr/PreDr
Recovery = PostDr/Dr
Resilience = PostDr/PreDr

For our study, we will consider:

PreDr= mean BAI (or TRW) of the preceding 4(or 5)-year period
Dr= BAI (or TRW) of the drought year
PostDr= mean BAI (or TRW) of the subsequent 4(or 5)-year

Note: We will either compare four or five years before and after the drought event, regarding the legacy effect in Anderegg et al. (2015) or the period establish by Lloret et al. (2011), respectively.

We expect that dead trees showed lower recovery, resistance and resilience to drought than living trees, particularly. For the analysis we will consider two alternative response variables Basal Area Increment (BAI) or Tree Ring Width (TRW) and several fixed and random effects (see Table 1).

Table1. Full Model

A. With TRW:
Resilience, resistance or recovery ~ Fixed: status + DBH + SPEI + (SPEI_PostDr - SPEI_PreDr) + Delta_time + Climate Index + Species Family +
Random: species + site + tree + species / status

B. With BAI:
Resilience, resistance or recovery ~ Fixed: status + SPEI + (SPEI_PostDr - SPEI_PreDr) + Delta_time + Climate Index + Species Family +
Random: species + site + tree + species / status

status, dead or living; DBH, diameter at breast height at the year of the drought; SPEI, Standard Precipitation Evapotranspiration Index at the time of the drought; SPEI_PostDr - SPEI_PreDr, differences between the average of SPEI 4 years after the drought event and average of SPEI 4 years before; Delta_time, time between drought and death; Climate Index, climate zone or biome (e.g. Köppen Climate Classification System); Family, Family of the tree species.

Description about how the results contribute to the Action aims

In the context of the of the COST Action FP1106 STReESS, recovery to drought is one of the main objectives of the TG7. The aim of the STSM was to establish the initial computational assumptions to compare recovery rates between dead and living trees. The results of this study will be presented in the next TG7 meeting in Slovenia (November 2015). Furthermore, an abstract presenting the ideas and the preliminary results of this study has already been accepted for the Special Issue "Studying Tree Responses to extreme Events" of the Journal Frontiers in Plant Science, hence a manuscript will be sent to be considered for publication in January 2016.

Confirmation by the host institution of the successful execution of the STSM

The letter of confirmation by the host institution of the successful execution of the STSM is attached in a separate file.

Acknowledgements

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This report can be posted at the COST Action website.

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