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

## Short-Term Scientific Mission

**COST Action**: FP1106
**STSM reference code**: COST-STSM-ECOST-STSM-FP1106-210714-047021
**Beneficiary**: Maxime Cailleret, Forest Ecology Group, ETH Zürich
**Host**: Jordi Martínez-Vilalta, Centre for Ecological Research and Forestry Applications, Universitat Autonoma de Barcelona
**Period**: 2014-07-21 to 2014-08-08

# Growth patterns as early warning signals of tree mortality

## Introduction

Extreme climatic events have the potential to induce tree mortality episodes and cause sudden changes in forest ecosystems. There is some evidence that such episodes are increasing as a result of global environmental change, at least in some regions (Allen et al. 2010. In this context it is important to determine which forests, or which trees within a forest, are more likely to suffer mortality which can be assess focusing on radial growth dynamics (e.g., Bigler & Bugmann, 2004). If the number of studies comparing the growth dynamics of (coexisting) dying and surviving trees has increased dramatically over the last decade, they only focus on single species located on few different sites. We feel that time is ripe for synthetizing this literature to compare multi-specific patterns (in terms of magnitude, trends or variability) in the growth of dead trees from those of surviving trees.

## Aim of the STSM

The aim of the STSM was to compile a global database of tree-ring increment from both living and dead trees and to analyse growth-mortality relationships across forest tree species.

## Description of the work carried out during the STSM.

51 published or unpublished tree-ring datasets were available at the beginning of the STSM. We firstly filtered the data to consider only (i) living and dead trees that had been growing together in the same area, (ii) tree-ring chronologies with accurate cross-dating, and (iii) sites in which dieback was caused by drought or other stress factors that are comparable or usually interact with drought (basically pests and pathogens and competition). Finally, four datasets (out of 51) were rejected and we end up with 2550 and 3778 ring-width chronologies for dead and living trees respectively, covering 33 species (Fig. 1) located in 160 different sites.

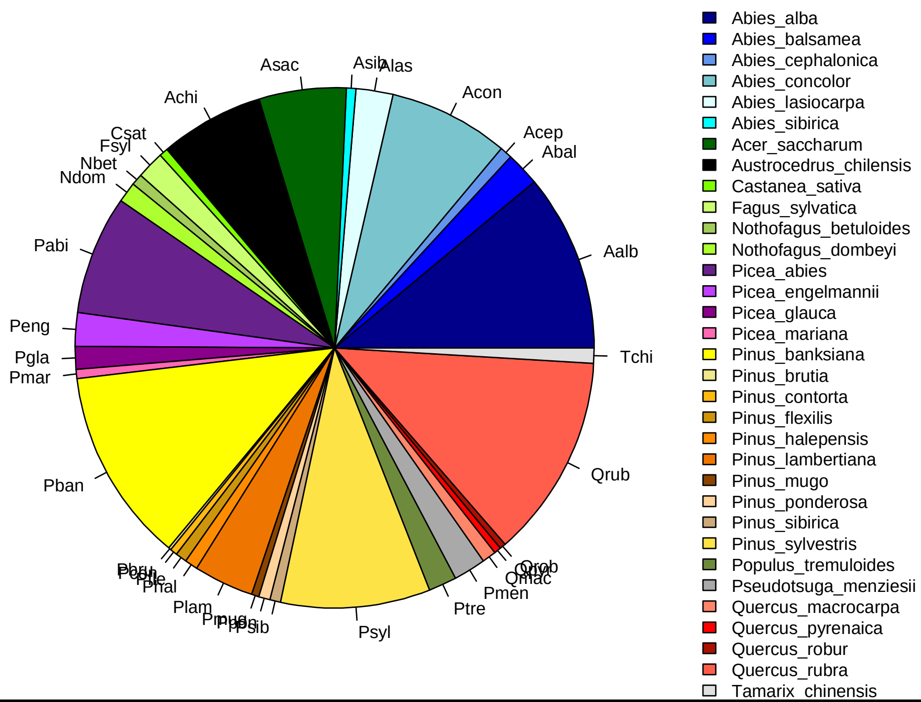


**Figure 1**: Repartition of the tree-ring database (number of trees) according to the study species.

We then designed the methodological approach to use in order to accurately analyse growth-mortality relationships for each species. In a first approach, we decided to use logistic mixed models to predict the survival probability of a tree *i* at time *t* ($Psurv_{i,t}$; Bigler and Bugmann 2004):

$$Psurv_{i,t}(Y_{i,t} = 1|X_{i,t}) = \frac{exp(\alpha * X_{i,t})}{1 + exp(\alpha * X_{i,t})}$$

where $Y_{i,t} = 0$ indicates that tree is dead at time *t*, while $Y_{i,t} = 1$ indicates that the tree is alive. The matrix $X_{i,t}$ contains the variables of the tree *i* (size, past radial growth, site characteristics…) and α a vector containing the parameters of the regression.

To reduce the prevalence of the "living events" in the input data (see Lawson et al. 2014), we followed a "paired sampling methodology", *i.e.* for each dead tree that dies at a time *t*, we sampled one living tree from the same site/plot and used its growth characteristics at the same time *t*. Different variables were included to reflect the different aspects of radial growth dynamics: growth level, growth trend, juvenile growth and growth variance variables. All these growth variables were calculated using *n* rings with $1 \leq n \leq 50$ for growth level variables and $2 \leq n \leq 50$ for growth trend variables.

Mixed-effects generalized linear models were then used to consider the potential effect of tree size and of the study site on survival probability ($Psurv_{i,t}$):

$$glmer\left(Psurv_{i,t} \sim growth_{i,t,n} + DBH_{i,t} + DBH_{i,t}^2 + (1|site) + (growth_{i,n}|site)\right)$$

**Description of the main results obtained.**

As preliminary result, we found that the performance (AUC) of logistic models that consider Basal Area Increment (BAI) of the last years and tree size strongly depends on the study species (Fig. 2). AUC of the best models ranges from 0.61 to 0.99 indicating that in some species additional variables should be included in the model to accurately predict mortality (AUC<0.7; *e.g.* for *Pinus flexilis*), while the model is almost perfect for other species (*e.g. Quercus pyrenaica*). Mean BAI of the last years usually has a positive effect on tree survival, *i.e.*, the higher is the growth rate during the recent years, the lower is the mortality probability. However, this effect is more important for some species (e.g. *Pinus banksiana*) and can also be negative for others (e.g. *Pinus sibirica*). The model that maximizes AUC usually uses mean BAI of the recent years (in most cases from last year [*n*=1] to the last 3 years) and usually considers an effect of tree size on Psurv.

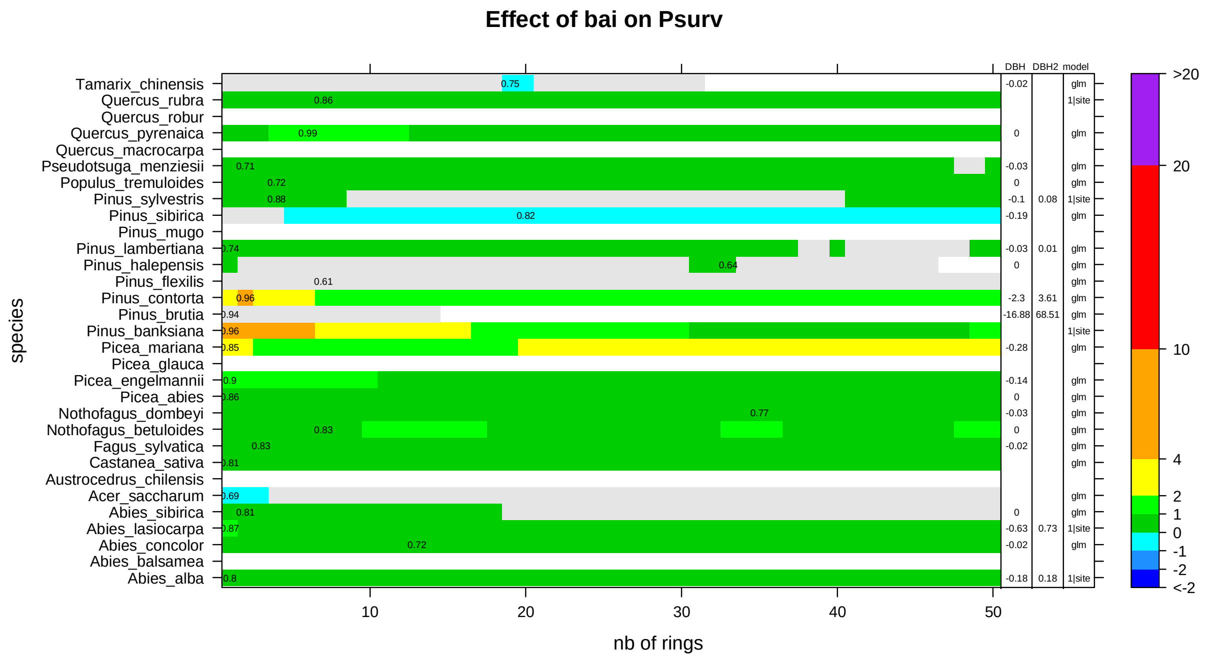


**Figure 2**: Change in the effect of mean Basal Area Increment of the last years ($BAI_n$) of tree survival probability (Psurv) according to the number of outermost rings (*n*) used to calculate this average, and to the study species. Positive values (from green to purple) indicate a positive and significant ($p<0.1$) relationship between BAI and Psurv while negative values (blue colors) indicate a negative relationship. Grey cells reveal not significant effect of growth on Psurv ($p>0.1$). White cells indicate that the model could not be fitted (number of dead trees below 7 or BAI could not be calculated). For each species, we determined for which *n* the logistic model maximizes the AUC (Area Under the Receiving Operator Characteristics Curve, which reflects model prediction accuracy). The AUC value of this model is included for each species at the corresponding *n*. Values on the right reveal the structure of this best model: (1) if DBH and/or DBH2 have an effect on Psurv, (2) and if it includes site as a random effect on Psurv (*1 | site* if yes; *glm* if not).

## Description about how the results contribute to the Action aims

Cleaning and compiling this multi-specific multi-site tree-ring dataset was an important task to reach objectives of the COST action, i.e. to analyze growth-mortality relationships but also for future analyses (test different modelling approaches to predict mortality based on radial growth…). The statistical approaches used for these purposes are now well defined, and the first results are quite promising. Based on them, a scientific manuscript is in preparation which will be submitted before the end of the year.

## 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.

## References

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