FOREVERS

FOREsts Vulnerability to climate Evolution using Range Shifts of species

Principle investigator: Christian PIEDALLU, UMR Silva- AgroParistech

LabEx partners/collaborations: SILVA : Josep M.SERRA DIAZ, Jean-Claude GEGOUT, Myriam LEGAY, Celia BRESSON, Eric LACOMBE, Jean Luc DUPOUEY, Vincent BADEAU, Joseph LE VILLAIN, Ingrid SEYNAVE,: INRAE-BEF : Laurent SAINTANDRE, IGN: Stephanie WURPILLOT, CRPF : Sylvain GAUDIN, Juliette BOIFFIN, Sabine BARETS, Cyril VITU, DSF : Romaric PIERREL

Thematic action(s) concerned: WP2

Context —

Increases of tree mortality were recorded all around the world, in temperate, boreal, and tropical forest. They were correlated in different studies to the increase in temperatures or decrease of water availability. Currently, foresters mainly based the choice of the species on site type recommendations provided by catalogues or simplified guides but these studies don't exist everywhere and maps are costly to realize. Even in cases where such document exist, climate change effects are taken into account in a very simplified way due to the lack of information about species vulnerability. The spatial risk assessment according to local climate and soil properties over broad areas remains an important challenge. Species Distribution Models (SDM) require easy to collect information (presence

and/or absence of the species), and relate species occurrence to environmental factors that explain their distribution, mainly linked to climate and soil characteristics. The climatic parameters selected in SDM allow to calculate the probability of presence (also called 'habitat suitability') of the species for different periods, and then to determine areas with changes in probability of presence by comparing different period.

Objectives —

The aim of this study is to evaluate SDM relevance to predict tree mortality and thus anticipate climate change effects. The availability of observed species occurrence at different dates, time series describing climate over the 50 previous years, soils properties predictive maps, and the presence of important diebacks for coniferous species in the Vosges Mountains, represent an opportunity to evaluate the interest of the SDM approach to map species vulnerability in the context of climate change.

Approaches —

We focused on the Vosges Mountains in the North East of France, to study the vulnerability of Silver Fir and Norway spruce. We selected these species because they are among the most important in this region and they show important decline symptoms. We use the IGN dataset from the forest inventory collected before 2005 (IGN old method dataset) to extract the presences and absences of the studied species at the French scale. We consider climatic information for the 1961-1987 period (here called "reference period") to describe climatic conditions prior to climate warming in France. Using models calibrated at the French scale, probabilities of presence are mapped for the Vosges mountains, with a dataset of high spatial resolution environmental variables (50m cell size) existing for this area. The climatic variables selected in the models for the reference period are calculated for the contemporary climatic conditions (the 2010-2020 period, here called "contemporary climate") and mapped. The evolution of presence probability between the reference period and contemporary climate depict the possible consequences of the recent climate change in habitat suitability for the species. We then evaluate if the decrease in probabilities of presence correspond to areas with important dieback. We use "sentinel 2" remote sensing images at 10 m resolution to identify mortality patterns at the Vosges mountains scale. Dieback patches are delimited using automatic classification. To determine the species names, we use stand maps identifying the dominant species produced by the ONF for the public forests, and ancien aerial photographs allowing to identify the stand composition for 2000 plots scattered on the studied area.

Key results —

- Retrospective distribution models and maps were made with 2 different statistical methods, for fir and spruce (total distribution and native area only) for the periods 1961-1987, which were projected for the periods 2014-2019, 2009-2019, 1999-2019 and 1989-2019. Differences were calculated between the period 1961-1987 and each of the contemporary projections.
- Dieback was collected by classification on sentinel-2 images from 2019.
- The link between the observed decline and the decreases in the probability of presence is generally weak for the 2 species tested, these having resisted better than expected in a certain number of areas.
- However, differences appear depending on the location, the link is stronger in the south of the massif where dieback is greater.
- A model was produced for each species to explain the overestimates of mortality induced by the models, highlighting a strong effect of the history of the local climate and its evolution to explain these differences.

Main conclusions including key points of discussion —

- Globally a weak link between the retrospective models and the current decline of fir and spruce
- This weak link is due to an adaptation of stands in hot and dry environments which are more resistant to the effects of climate change. In these areas the climate has evolved less rapidly than in areas the most affected by dieback.
- This work emphasizes the importance of taking into account the temporal dynamics of climate change, dieback being caused by an intensity of change over a given time period.
- This work illustrates the limits of the use of SDMs to predict dieback, which must be used with vigilance in a prospective vision for future periods.
- These results are only an image of the situation at a time t, the areas where the stands resist better can undergo a sudden deterioration in the health of the trees if physiological thresholds are reached. Monitoring of these stands will be necessary to assess their ability to persist over time.

Perspectives **—**

- Similar work has just started using process-based models, and will allow the remaining time of this project to assess whether predictive performance is better compared to retrospective empirical SDM. This work is carried out in collaboration with Xavier Morin at the CEFE in Montpellier and involves the FORCEEPS, PHENOFIT and SUREAU models, the coupling of which is currently being carried out by CNRS teams. The results will be included in the final report.

Valorization —

- The M2 internship report of Héloise Benoit, AgroParisTech student
- Two meetings between all team members, in March 2022 and June 2022
- Writing of a scientific article concerning the first part of this work in progress
- A second scientific article on the use of coupled mechanistic models is planned

Leveraging effect of the project—

- Development of collaborations with the CEFE of Montpellier and the INRAE of Avignon on the theme of model coupling
- Development of collaborations with the UMR Tetis on the subject of remote sensing