DEPHETRE

Study of the beech decline in the Northeastern of France

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Thematic action concerned: WP2

Context —
Since 2019, beech forests in the North-East of France have been showing massive decline leading to the death of some adult trees in the centre of the species' distribution area, induced by the exceptional drought episode from 2018 to 2020. Biotic attacks have also been observed on some individuals according to the typical cascade of risks. Understanding the vulnerability factors and resilience capacities of species to these extreme drought events is crucial to help foresters better manage crises, understand risks and adapt the forest management to future climate.

Objectives —
The main objective the DEP-HETRE project will be to have a better understanding the physiological dysfunctions that cause a tipping point towards death or, conversely, favour the resilience of beech trees. Particularly, the DEP-HETRE project will take the opportunity of this large-scale field decline to investigate the role of carbon reserves in the résistance and recuperation capacities of trees, their susceptibility to pathogens and their ability to defend themselves against secondary pathogen attacks.

Approaches — Two experiments were set up:

1. Study of a stand with declining beech trees subjected to attacks by secondary pests

In 2020, a stand with declining beech trees in Bliesbruck (57) has been selected. Parameters needed to apply the Biljou© water balance model were described. Tree health status (leaf loss, branch mortality and branching deficit) and the level of fruiting of 32 hammered trees were described by the DSF (Forest Health Division). Following the felling of these trees, two agents, from ONF and DSF, described the level of biotic attacks along the trunk and branches. Wood samples of trunk, branches and roots were taken to quantify and to map the carbon reserves (starch and soluble sugars) at the whole tree scale. Cores in the heart of trees at 1m30 were also taken to determine the age of the trees and to measure the cambial growth by dendrochronological analysis.

2. Study of a network of semi-permanent plots on a large geographical scale

In 2019, a network of 30 semi-permanent plots of 15 trees with contrasted crown condition was set up by the DSF to monitor the evolution of the health status of beech stands in the GE and BFC regions for 5 years. Since 2019, the DSF has noted the annual crown condition and since 2020 we collected wood cores at the base of trees which to follow the carbon reserves of trees. At the end of 2022 we have taken also a core sample at 1.3m to know the age of trees and for dendrochronological analysis.

Key results —

1. Study of a stand with declining beech trees subjected to attacks by secondary pests

- Starch concentrations were very low in all organs of trees and the concentrations in roots and trunks were negatively correlated with the level of biotic attack. Preliminary results of the dendrochronological analysis showed a mean age of 160 years for the trees. After a standardisation of the age effect on the radial growth, the ring width and area showed a decreasing trend of the tree growth from 2003 suggesting a weakness of trees in the last twenty years. A decreasing exponential relation was observed between the leaf deficit observed in 2020 on trees and the mean ring area over the last 10 years.

2. Study of a network of semi-permanent plots on a large geographical scale

- Tree health monitoring over a 5-year period (2019 to 2023) shows a gradual deterioration in crown condition across the network, with an increase in average leaf deficit from 55.6% to 66.1% in GE and from 49.7% to 60.4% in BFC between 2019 and 2021, followed by a slight improvement in BFC in 2022 (57.7%), which stabilized in 2023, whereas the deterioration continued in GE in 2022, reaching 68.5% defoliation, and then stabilized in 2023. Contrasting situations are observed according to trees and plots.

- 7.2% of trees died in GE between 2020 and 2022, with the highest annual mortality rate reached in 2022 (3.6%). 9.2% of trees died in BFC between 2020 and 2022, with the highest annual mortality rate in 2021 (5.8%).

- When carbon reserve concentration in the trunk went below the threshold of 10% of dry matter, trees presented a greater risk of mortality in the following 3 years. Thus, 52% of trees reaching this threshold in 2020 died within 3 years.

- Pierre Antoine Gaertner (PhD student on the project) spent 2 months in Switzerland to image the cores using more powerful and high-throughput tools for dendrochronological analysis. Although a general trend towards a decrease in radial tree growth has been observed over the past 10 years, trees with a defoliation level of over 75% in 2019 have shown significantly lower radial growth since 2007 than trees with less than 25% defoliation. Trees with higher wood starch reserves at the end of the drought (2020) showed, in 2022, better cambial growth resilience to the 2018-2020 drought.

Main conclusions including key points of discussion —

The initial results suggest a general weakening of the trees as a result of recent recurrent droughts. The low starch concentrations measured in the Bliesbruck's trees show that critical and irreversible thresholds of carbon stock shortage could be reached with a high risk of mortality. This conclusion will have to be confirmed in the multi-annual monitoring of trees in the DSF beech network.

Perspectives —

Bliesbruck stand: completion of soluble sugars, phenolic components, sol chemical analysis, and dendrochronological analyses to analyze the impact of different levels of health status and biotic attacks. The publication of these results is planned in 2024.

- DSF network: The soil descriptions produced following the opening of soil pits at the end of 2023 will be used to parameterize the Biljou© water balance model, which will enable retrospective quantification of water deficits on each plot. All these results will be presented in a publication currently in preparation.

These results will also be put into perspective with those obtained within the framework of the Labex projects RiskForBeech (22PN02) and IsotopeANA (23PN04) to globalize our understanding of the underlying physiological mechanisms by which beech trees cope with extreme drought events.

Valorization —

-*Gaertner PA, Massonnet C, Breda N* (2021) Sur-mortalités de hêtre depuis 2018 : une cascade d'aléas climatiques et biotiques ? Colloque de lancement du réseau scientifique RisqFor, Nancy.

-*Massonnet et al.* (2021) Vulnérabilité des forêts face aux changements climatiques. Colloque scientifique de la SNHF : le dérèglement climatique : un défi pour les plantes.

-*Massonnet et al. (2022)* Vulnérabilité des arbres aux évènements climatiques extrêmes. Colloque AgroParisTech et ProSilva - Changement climatique : les hommes et les forêts au pied du mur ? Verdun.

- *Gaertner et al. (2023) Réponse du hêtre à des sécheresses extrêmes et récurrentes : Partie 2-Rôle des réserves carbonées dans la résilience d'arbres adultes à la sécheresse de 2018-2020 dans le Nord-Est de la France. Colloque SOERE TEMPO - 4/10/2023.* Présentation orale

- *Massonnet et al (2023) Etude du dépérissement et de la resilience du hêtre suite à la sécheresse extrême de 2018 dans le Nord Est de la France. Colloque annuel du Labex Arbre-1/12/2023.* Présentation orale

- Jade Stucky (2023) Comparaison de la dynamique pluriannuelle des réserves glucidiques entre hêtres présentant différents états sanitaires. Rapport de stage de 2eme année de BUT Genie biologique Thionville/Yuts.

- Massonnet et al. (2024) Recherche d'indicateurs de résilience du hêtre suite à la sécheresse extrême de 2018 dans le Nord-Est de la France. Journée INRAE – DSF.2/02/2024. Présentation orale.

- Massonnet et al. (2024) Recherche d'indicateurs de résilience du hêtre suite à la sécheresse extrême de 2018 dans le Nord-Est de la France. Lettre du DSF – Bilan du Hêtre en France

- Gaertner et al. (2024) Relationships between non-structural carbohydrates reserves and growth resilience of Fagus sylvatica to extreme drought events. EGU, Vienne, 14/04/2024-19/04/2024. Présentation orale

- Gaertner et al. Growth resilience of Fagus sylvatica to extreme drought events: complementary implication of carbohydrate reserves, soil water intensity and past growth. En preparation pour New Phytologist

Leveraging effect of the project—

-A thesis grant funded by DG INRAE (ECODIV division) has been allocated for this subject in 2021.

-Funding from DSF has been also obtained to cover the costs of this thesis work in complement of the DEP-HETRE project.

-Collaboration with researchers from the WSL (Swiss research institute, Georg Von Arx and Yann Vitasse) and obtaining grants (INRAE Ecodiv, LUE DREAM program and DEESSE Eira program) to send the PhD student for 2 months to this laboratory.

- A post-doc (Guangqi Zhang) has been recruited co-funded by the innovative RiskForBeech project (Labex project) and by the Grand-Est region to work on a complementary approach to this project.