Acronyme : IsotopeANA

Water use efficiency in beech trees following the 2018 extreme drought in northeastern France

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Collaborations : Département de la Santé des Forêts (DSF)

Thematic action concerned : *WP2*

Context **—**

Extreme drought events are responsible for widespread forest dieback and large-scale tree mortality events across the globe, which can have detrimental effects on both short-term forest functioning and long-term ecosystem dynamics. An unprecedented decline of European beech (*Fagus sylvatica* L.) has been observed in central Europe following the 2018-2020 drought event, and beech trees may have reached a tipping point where many individuals are no longer able to survive. A better understanding of the physiological mechanisms that allow beech trees to resist and to cope with severe water deficits and those that lead to the tree death is essential.

Objectives **—**

The main objective of this study is to gain insight into the physiological properties involved in the resilience or mortality trajectories of the beech trees in response to an extreme and prolonged drought episode.

We retrospectively analysed multi traits including tree-ring carbon isotope composition ($\delta^{13}C$), used to calculate intrinsic water use efficiency (iWUE), and oxygen isotope composition ($\delta^{18}O$), closely related to leaf transpiration and evaporative demand, to assess the effects of drought on beech trees.

Approaches —

A total of 60 trees were selected, distributed in four stands in north-eastern France with different levels of soil water deficit which were quantified retrospectively by the BILJOU© water balance model. Tree cores were taken at 1.3 m in spring 2023 for retrospective radial growth analysis over the last 10 tree rings (rings before, during and after drought). $\delta^{13}C$ and $\delta^{18}O$ were also measured in these rings to determine, respectively, the annual iWUE and the water and carbon constraints on iWUE variation. Tree resistance, recovery and resilience to drought were quantified for cambial growth and iWUE.

Key results —

So far, we have completed the sampling and data collection.
- The annual soil water deficits at the stand level were precisely quantified by BILJOU© model. In addition to 2018-2020 being drought years, we also identified 2015 as a drought year.
- Decreased tree growth and increased $\delta^{18}O$ and iWUE were observed due to soil water deficit.
- $\delta^{13}C$ and iWUE were not significantly related to tree ring width index, but positively related to $\delta^{18}O$.
- In the severe drought site, recurrent drought severely affected the resistance of tree growth and the post-drought recovery of water use efficiency.

Main conclusions including key points of discussion —

Our results demonstrate that beech xylem isotopic traits and iWUE show obvious sensitivity to drought, and that increased iWUE due to stomatal closure does not lead to enhanced tree growth. Our study highlights the impact of consecutive or recurrent droughts in reducing beech tree resistance and xylem iWUE resilience, particularly in sites with higher drought intensity. This work contributes to the understanding of how drought-sensitive trees cope with extreme drought events in terms of their carbon-water relations in the context of climate change.

Perspectives —

It would be interesting to explore the overall relationships among non-structural carbohydrates, wood anatomy and isotopes under drought conditions by integrating the results of three projects (DEPHETRE, RiskForBeech and IsotopeANA) funded by Labex ARBRE, since these projects worked on the same sample tree species and plots. In addition, recent studies have highlighted the potential of hydrogen isotope ($\delta^{2}H$) analysis as a proxy for plant metabolic function. Combined with conventional proxies for leaf gas exchange in the context of climate change, $\delta^{2}H$ analysis will improve our understanding of the underlying physiological mechanisms by which trees cope with extreme drought events.

Valorization —

The results of this research have been written up in a first draft of a paper and will be published in a high-level journal. At the same time, the project leader will give a talk at the upcoming EGU conference.

Leveraging effect of the project—

This project can be seen as a companion to the RiskForBeech project, also funded by Labex ARBRE and region Grand-Est. The two “twin projects” have independent scientific questions, but strong links and complementarities between them.