ModPhenWood

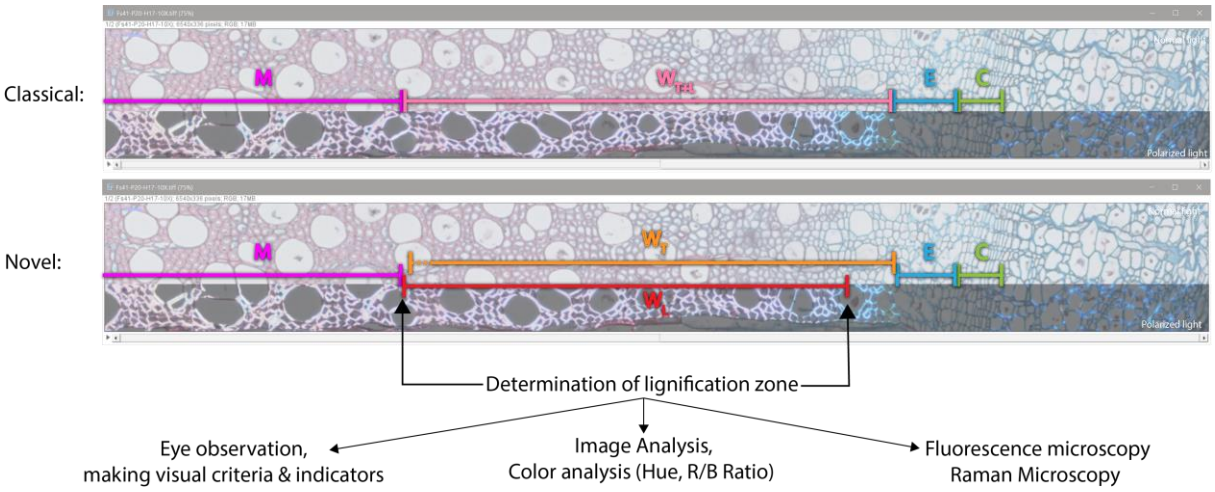

Figure 1. *Determination of the wood formation zones and the lignification zone in particular. The top picture illustrates the classical zonation of wood formation bands: C, Cambial division; E, enlargement; W_{T+L}, secondary cell wall thickening and lignification; and M, mature zones. Bottom picture illustrates the new proposed zonation adding lignification (W_L) to cell wall thickening (W_T).*

Ecophysiological modelling of the phenology of wood formation in temperate and boreal forest trees

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Collaborations:

- Jianhong LIN, Nicolas DELPIERRE *(ESE, Université Paris-Sud)*

Thematic action concerned: WP2

Context — Wood is the second largest stock of continental biomass on Earth. Its production by woody plants helps to mitigate the current accumulation of anthropogenic CO_2 in the atmosphere. Wood formation is, however, a complex process, the seasonality of which is now known to depend not only on carbon assimilation processes. Indeed, environmental factors and tissue development have a crucial influence on the dynamics of wood formation. These findings go against the common representation of this process in vegetation models which assume that xylogenesis depends only on photosynthesis.

Objectives — The ModPhenWood project aims to deepen our knowledge of the role of environmental and ontogenetic constraints on the phenology of wood formation. A set of statistical and ecophysiological models simulating the occurrence of key stages of wood formation (resumption of cambium divisions, start and end of enlargement of new xylem cells, start and end of secondary wall deposition and lignification) will be developed. These models will explore the role of both environmental factors (temperature, water balance, photoperiod) and tree characteristics (species, size, vitality).

Approaches — The models will be developed and tested using an existing database of over 300 data points (year-site pairs) for each critical date of wood formation and for more than 20 conifer species located in the northern hemisphere. In parallel, the database will be extended to hardwoods, with a set of over 30 data points already identified for sessile oak and European beech. In addition, the project will also aim to improve the criteria for observing the different stages of wood phenology and cell wall lignification dynamics in particular (Figure 1).

Key results —

- The use of band dendrometers gives reliable information about the phenology of wood formation in smooth-barked species such as beech and fir, but not in species with scaly or fissured bark.
- Temperature is the main determinant of wood phenology in angiosperms and gymnosperms. However, temperature do not control the initiation of wood formation through a simple threshold effect (as assumed in many publications), but through a more complex process involving both warm spring temperatures (forcing) and cold winter temperatures (chilling), during particular periods (photoperiod effect) that depend on the species.
- Our results indicate that, even in temperate forests, water stress has an important role in the cessation of cambial activity, wood formation and lignification in particular.

Main conclusions including key points of discussion —

- Band dendrometers can be used to compensate for the lack of monitoring of wood formation by taking microcores in certain very specific cases, and this is the case at our emblematic site in Hesse (beech stand in favorable hydric conditions);
- We developed a validated ecophysiological model for the start of wood formation in conifers;
- But we did not succeed in developing an ecophysiological model for the cessation of wood formation.
- We are now able to distinguish cellulose deposition from wall lignification in our observations.

Perspectives — We will integrate the band dendrometer data into our work at our Hesse site to improve the characterization of wood formation phenology, extend the series and relate them to other biological factors (leaf phenology, reserve level, etc.) and climate (effect of the 2018 drought). We will include the wood phenology module (ecophysiological model at the beginning and statistical model at the end) to the CASTANEA vegetation model and do a sensitivity analysis to see how it influences the CASTANEA outputs. We will explore how drought influences the dynamics of the lignification process.

Valorization — This project will lead to several participations in international conferences (presentations accepted at EGU2023 and TRACE2023) and to several high-level scientific articles (1 article submitted, 3 articles in preparation) on the main themes of the project, which are very original (phenology of wood lignification, influence of climate and drought on lignification, ecophysiological model of wood phenology for gymnosperms, then for angiosperms, etc.). This project will also enable the defense of two doctoral theses, the thesis of Jianhong Lin at the University of Paris Sud and the thesis of Ignatius Adikurnia at AgroParisTech.

Leveraging effect of the project — With the help of LabEx funding, which consisted of a half thesis grant, we were able to attract additional funding from the INRAE ECODIV department, which allowed us to launch an international recruitment. We attracted two excellent candidates, including a Chinese candidate (Jianhong Lin), who through a partnership between the University of Paris Sud and the Chinese Ministry of Research was able to benefit from an individual doctoral grant. So, with half a thesis grant financed by the LabEx, we were able to launch two PhD thesis projects in parallel. This project also enabled us to actively collaborate in an international project (LEAF-FALL, led by Matteo Campioli from the University of Antwerp in Belgium) on autumn phenology (leaf and wood) in angiosperms and the relationship with carbon sequestration.