ModPhenWood

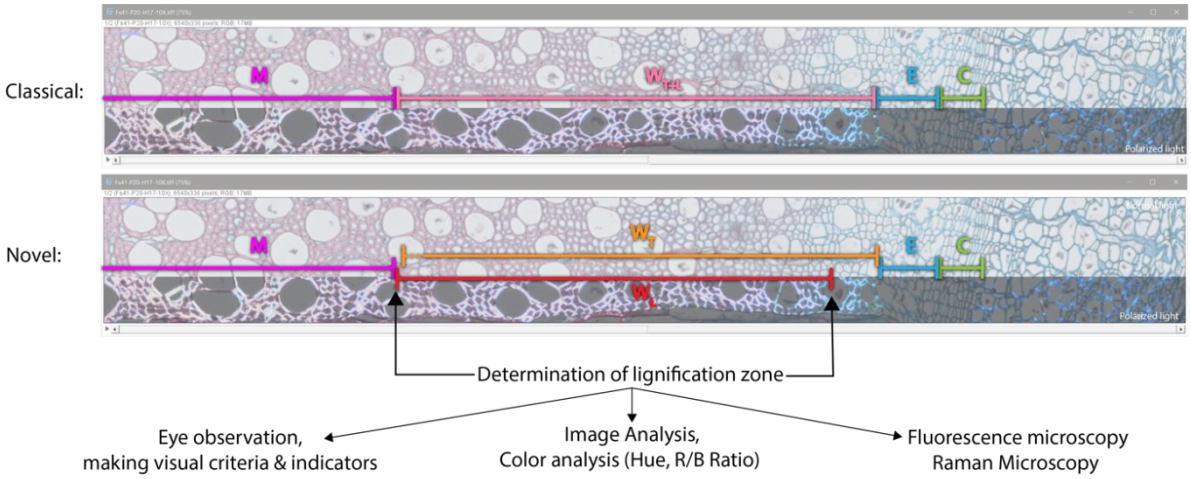

Figure 1. *Determination of the wood formation zones and the lignification zone in particular. The top picture illustrates the classical zonation of wood formation bands: C, Cambial division; E, enlargement; W_{T+L}, secondary cell wall thickening and lignification; and M, mature zones. Bottom picture 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. However, wood formation is a complex process, and it has now been established that its seasonality does not depend solely on carbon assimilation processes. Environmental factors and tissue development have a crucial influence on the dynamics of wood formation. These findings run counter to the current representation of this process in vegetation models, which assume that xylogenesis depends solely on photosynthesis.

Objectives **—**
The ModPhenWood project aims to extend 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 in wood formation (resumption of cambium divisions, start and end of enlargement of new xylem cells, start and end of deposition of secondary walls and lignification) is being developed. These models 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, comprising more than 300 data points (year-site pairs) for each critical date in wood formation and for more than 20 conifer species located in the northern hemisphere. At the same time, the database will be extended to hardwoods, with a set of more than 30 data points already identified for sessile oak and European beech. The project also aims to improve the criteria for observing the different stages of wood phenology and cell wall lignification dynamics in particular (Figure 1).

Key Results — The project has produced the following results:

- The use of band dendrometers provides unreliable information on the phenology of wood formation. The discrepancy with phenological observations decreases with increasing growth rate, but increases with greater heterogeneity in ring structure (from diffuse porous rings to coniferous and porous rings) and bark roughness (from smooth or scaly bark to cracked bark).
- Temperature is the main determinant of wood phenology in angiosperms and gymnosperms. However, these temperatures do not control the start of wood formation through a simple threshold effect (as assumed in many publications), but through a more complex process that involves both warm spring temperatures (forcing) and cold winter temperatures (chilling), during specific periods (photoperiod effect) that depend on the species.
- Our results indicate that, even in temperate forests, water stress plays 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 micro-cores only in very specific cases, and this is precisely the case at our emblematic site in Hesse (beech stand in favourable hydric conditions).
- We have a validated ecophysiological model for the start of wood formation in conifers, but we have not yet succeeded in developing an ecophysiological model for the cessation of wood formation.
- We are now able to distinguish between the deposition of cellulose and the lignification of the walls during our observations.

Perspectives —
We are going to integrate the data from the band dendrometers into our work at our Hesse site to improve the characterisation of wood formation phenology, extend the series and relate them to other biological factors (leaf phenology, reserve levels, 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) in the CASTANEA vegetation model and carry out a sensitivity study to see how this influences the CASTANEA outputs. We will explore how drought influences the dynamics of the lignification process.

Valorization —
The project gave rise to four presentations at international conferences (1 TRACE2023, 1 EGU2023 and 2 EGU2024) and several scientific articles (1 published article, 3 manuscripts in preparation) on the main themes of the project. Ignatius Adikurnia unfortunately did not defend his PhD thesis, but Jianhong Lin should defend his at the end of 2024.

Leveraging effect of the project —

With the help of LabEx ARBRE funding, which consisted of half a PhD grant, we were able to attract additional funding from the INRAE ECODIV department, which enabled us to launch an international recruitment. We attracted two excellent candidates, including a Chinese candidate (Jianhong Lin), who, through a partnership between the Université de Paris Sud and the Chinese Ministry of Research, was awarded an individual doctoral grant. This project has also enabled us to play an active role in an international project (LEAF-FALL, led by Matteo Campioli from the University of Antwerp in Belgium) on autumn phenology (leaves and wood) in angiosperms and the relationship with carbon sequestration.