WatFlux

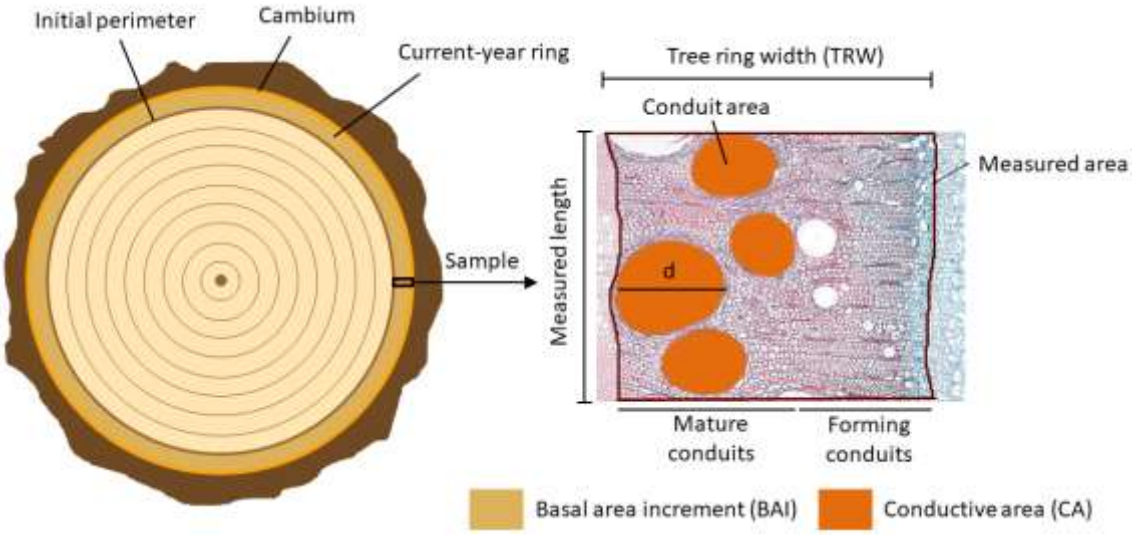

Figure 1. *Diagram showing the different variables measured for each sample. d: conduit diameter, calculated from conduit area*

Understanding water flux in the xylem, from seasonal dynamics to long-term variations, from xylem cell maturation to forest ecosystems

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Context — Leaf and xylem water potentials directly influence cell turgor pressure, which in turn affect xylem cell division, expansion and maturation, and thus radial growth and wood properties. Potential xylem hydraulic conductivity, on the other hand, depends on the size and number of conduits, as well as on the properties of the pits that connect them. Xylem formation may therefore have long-lasting consequences for whole canopy water and carbon fluxes. However, much is still unknown about how trees adjust xylem structure to meet transpiration needs.

Objectives — The aim of this project was to model intra-annual dynamics of water fluxes between the canopy and the atmosphere as a function of xylem conductivity and climatic conditions.

Approaches — The project WatFlux allowed us to add two years (2018, 2019) of wood formation monitoring data to our current dataset of three years (2015, 2016, 2017). This unique dataset has/will allowed us: (1) to explore the relationships between xylem anatomy, sap flow density, and eddy covariance flux measurements; (2) to understand the adaptation of xylem conductivity to variations of climatic factors; and (3) to model the water flux through the xylem in relation to the development of the tree and its physiological state. The high-resolution sap flow measurements have been compared to the xylem conductivity estimates calculated from the wood-formation-monitoring data. In addition, we have performed high resolution anatomical measurements using scanning electron microscopy (SEM). The collected data are currently used to obtain a better estimate of the conductivity of the xylem and its resistance to the transport of water.

Key results — The results of this project provide new insights into the biological processes governing the carbon and water cycle of forest ecosystems, improving our understanding of its responses to climatic variability at short (growth and transpiration dynamics), medium (legacy effects), and long-term (forest functioning).

- Conduits started to be potentially active earlier in oak (early May) than in beech and spruce (late May or June). In the three study species, the gain in basal area (BAI) was slower than the gain in conductive area (CA) and theoretical xylem hydraulic conductivity (K_h). This uncoupling among the intra-annual dynamics of BAI, CA and K_h was greater in oak than in the other two species.
- In beech, canopy transpiration (E_c) started in mid-April, before current-year vessels started to be potentially active, thus relying on previous-year vessels for water transport to the canopy. E_c peaked in June, before maximum current-year K_h was achieved. There was a strong decrease in transpiration rates in response to summer drought in 2015 and 2018, but no higher presence of tyloses (i.e., no significant difference between total and functional K_h) in those years. This may indicate that early stomatal closure protected the xylem from significant functional loss due to cavitation.
- So, current-year vessels did not support sap flux (J_s) early in the season, while maximal K_h was achieved when J_s was low. This suggests that current-year vessel contribution to J_s may be negligible compared those of the whole sapwood.

Main conclusions including key points of discussion — Wood monitoring methods can be effective to account for intra-annual changes in xylem conductivity in species with different anatomical structures. This approach may be particularly interesting for ring-porous species, which mostly rely on current-year vessels for water transport. Our results imply that the date of measurements have a significant effect on the values obtained, particularly considering that hydraulic conductivity and percentage loss of conductivity measurements are performed in small branches containing very few rings, and thus the forming ring may have a significant weight on total sapwood conductivity. Due to the lag between xylem growth and function, there is an uncoupling between canopy and stem water fluxes and xylem formation processes. Xylogenesis may thus not respond to current-year canopy transpiration needs.

Perspectives — Our results provide a better understanding of the interplay between canopy and stem processes, which could help improve whole-tree mechanistic models of tree response to climatic variability. They also provide new insights into the biological processes governing forest water and carbon cycles. The knowledge gathered through this project could help to better simulate the impact of climatic change on the terrestrial biosphere.

Valorization —

Publications

- Fernández de Uña L., Rathgeber C. B. K., Pérez-de-Lis G., Andrianantenaina A. N., Cuntz M. Intra-annual dynamics of xylem formation and water conductivity in three tree species presenting contrasted tree-ring structures. In prep.
- Fernández de Uña L., Rathgeber C. B. K., Cuntz M. Analysis of inter-annual variability in wood anatomy and the soil-tree-atmosphere water fluxes. In prep.

Conferences and Communications

- Fernández de Uña L., Rathgeber C.B.K., Cuntz M. Intra-annual dynamics of vessel formation and water fluxes in beech trees. 4th Xylem International Meeting, September 25-27, 2019, Padua, Italy. Poster communication
- Fernández de Uña L., Cuntz M., Rathgeber C.B.K. Intra-annual xylem formation and water flux dynamics in Fagus sylvatica L. Gordon Research Conference Multiscale Plant Vascular Biology, June 17-22, 2018, Mount Snow (VT), USA. Poster communication
- Fernández de Uña L., Cuntz M., Rathgeber C.B.K. Intra-annual xylem formation and water flux dynamics in Fagus sylvatica L. Gordon Research Seminar Multiscale Plant Vascular Biology, June 16-17, 2018, Mount Snow (VT), USA. Oral and poster communication
- Fernández de Uña L., Rathgeber C.B.K., Cuntz M. Intra-annual dynamics of xylem conductivity in three tree species presenting contrasted tree-ring structures. Wood formation and tree adaptation to climate, May 23-25, 2018. Orléans, France. Oral communication

Leveraging effect of the project — This project benefited from the data and methods developed in a previous PhD Thesis (Anjy Andrianantenaina), which was not founded by the LabEx. In turn this project fuelled three other projects that are currently under development:

- Richard Peters, Swiss National Fondation | Project Inter- and intra-specific water-use strategies of European trees: towards a better mechanistic understanding of tree performance during drought and warming;
- Matteo Campioli European ERC Grant | Project: LEAF-FALL;
- Ignatius Kristia Adikurnia PhD Thesis (INRAE + LabEx fundings) | Project: Intra-annual dynamics of carbon sequestration and lignin deposition in soft- and hard-wood species of temperate forests.