B2d: WOOD AND TREE-RING STUDIES OF FOREST ADAPTATION TO CLIMATE CHANGE; IMPLICATIONS FOR WOOD PRODUCTION

Functional role of *Eucalyptus* wood in terms of drought resistance traits: trends at interspecific and intraspecific levels

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Multispecies surveys have showed that there is a weak but significant tradeoff between xylem efficiency and safety in woody species, and that there are no species occupying the space with high efficiency and high safety. Large vessels and tracheids result in high vulnerability to xylem cavitation (VC) due to tension. Moreover, relationships between xylem structure and function are studied mostly at the interspecific level, with few studies considering the relationships at the intraspecific level, particularly in angiosperms. Recent studies in Quercus species, finding opposite trends in wood anatomy-function relationships considering the interspecies and the intraspecific levels, raises the question about the value of multispecies studies to shed light over what is adaptive within a given species. Eucalyptus species share with Quercus a xylem anatomy composed by solitary vessels surrounded and connected to imperforate tracheary cells and parenchyma, a type of wood anatomy which is poorly understood in functional terms. Contrary to results in that genus, our results in four Eucalyptus species revealed that the trends observed between vessel size (mean and distribution) and VC are similar at the interspecific and intraspecific (*E. globulus*) levels. No tradeoff was observed between xylem efficiency and safety: the largest the vessels, the lower the VC. The amount of cells around different size-vessels could be involved in this phenomenon. Trends observed in this important forestry genus challenge what we already know about xylem anatomy and function, and may help to widen our vision about the role of wood in adaptation to drought stress.

Wood anatomical traits reveal water constraints on black spruce xylem formation in the Boreal ecosystem

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One of the most evident effects of the rapid warming occurring recently in cold and high-latitude forests is the lengthening of the growing season, with the concurrent extension of the period of wood formation. In addition, the increase of evapotranspiration demand is starting to induce drought-stress conditions. By selecting the same black spruce (*Picea mariana*) trees (20 trees in 4 sites along a latitudinal gradient in Quebec, Canada) where xylogenesis analyses were performed in the last years, we investigatedlong-term series of wood anatomical traits and compare them to previous short-term findings. Time series of wood anatomical traits were correlated to chronologies of daily temperature, VPD and precipitation during the period 1936-2010. In all sites, tracheid area correlated negatively with June-September temperature and VPD, and positively with precipitation. Meanwhile, cell-wall thickness and the number of cells per ring in the northernmost site were positively affected by spring and summer temperature. While previous monitoring studies evidenced temperature as the key climate variable influencing the timing of xylogenesis phases, our results show that water availability plays a central role in shaping xylem cell features in boreal black spruce. This stresses the importance of an integrate approach to better understand the relationships between wood formation and climate variability at both intra-annual and long (decadal) time scales. This approach will hopefully reduce the uncertainties and skewed interpretations of models on how boreal forest will perform in the future.

Impact of drought on *Eucalyptus* wood chemistry by near infrared hyperspectral imaging

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The aim is to study tree development submitted to different water and mineral constraints. The objective is to correlate spatial distribution of wood chemistry with wood density, secondary growth. We sampled wood discs from 54 trees in rainfall exclusion design with *Eucalyptus grandis* at Esalq-USP, Itatinga Station, brazil. We felled the 5 years old trees growing under different water availability. For each disk, we acquired an image with a near infrared (nir) hyperspectral camera (hsi, specim, pixel size 625 x 625µm). The challenge here was to transfer our previous nir calibrations for total extractives built with a benchtop spectrometer (vector, bruker) to a hsi camera by using standard sample set measured on the two devices. An efficient model were built for the his camera with a prediction error of 10.3% compared to the prediction error of 11.6% for our previous calibration with benchtop spectrometer. Then, based on spectra from his image, we predicted extractive contents and built images. These allow us to compare their spatial distributions according to the growth conditions. In the absence or absence of fertilization, trees with higher water stress showed a higher heterogeneous distribution, from pith to bark, for the total extractive contents and a higher average mean value. In perspective, these data will allow us to study and refine the knowledge on cambium activity according to climatic variations by crossing variability of the chemical properties, x-ray micro-density and anatomy of wood, and diameter growth rate measured by electronic dendrometers.

Spatial variation of wood density for *Eucalyptus grandis* by near infrared hyperspectral imaging combined with X-ray analysis

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Most near-infrared spectroscopy (NIRS) studies for wood density use multiple spectral acquisitions taken manually at several points from pith to bark. Recently the use of near-infrared hyperspectral imaging (NIR- HSI) has shown good performance in predictions of wood properties, allowing build high spatial resolution predictive images. The combined use of NIR-HSI and X-ray microdensity imaging (X-ray MDI) could be more practical for evaluation of spatial variation of wood density. The aim was to develop a wood density calibration model for NIR-HSI (625 µm pixel size) from X-ray MDI (30 µm pixel size) and evaluate the spatial variation of wood density along stem cross-section in *Eucalyptus grandis* trees. Wood discs were collected from 18 trees of 6 years old, submitted to two different water availability, located in São Paulo, Brazil. The challenge here was to match the pixels of X-ray MDI to pixels of NIR-HSI (in 2 mm width radial region) to transfer accurate values of wood density to each pixel of NIR-HSI. The R^2 of the model was 0.72, while the root mean squared error was and 4.8×10^{-2} g cm^{-3} for the validation group. The prediction model allows comparing their spatial distributions according to the growth conditions. Trees with higher water stress showed higher wood density. Treatments showed a similar spatial variation of wood density, increasing from pith to bark. In perspective, these data will allow evaluating the spatial distribution of wood density inter and intra-tree rings in relation to meteorological variability.

A novel approach to understanding the formation of tree rings in tropical species by analyzing traces of elements

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After the initial division of the cambium and tree-ring formation, derivative cells are subject to cell expansion and secondary wall deposition. In this process, different chemical elements are allocated and translocated as part of tree metabolism and physiology. Both anatomical and chemical events, vary among the xylem cells according to their transport or storage functions. Here we analyze the anatomical and chemical pattern at the intra and inter ring level of two tropical species extensively used for dendrochronological studies, *Cedrella fisilis* and *Hymenaea coubaril*. The samples were them cut transversely (1.5 mm, thickness) with a parallel double circular saw for chemical analysis by X-ray fluorescence. And the rest of wood samples were used to prepare histological slides to evaluate the microscopic anatomical structure. Simultaneous multielemental and anatomical evaluation for each species-wood sample at different positions (five rings close to pith, in the sapwood and heartwood transition and close to bark) were performed. Elements such as Ca and K stood out in both samples. The highest K presence are observed in the developing xylem (rings close to the bark). While the highest Ca presence were found near to the pith. Furthermore, both elements were observed related to parenquimatic tissue. Elements content differences were observed between the rings of sapwood and heartwood. Altogether, this work shows interesting clues to understand the tree-physiology based on element traces related to their anatomical structures.

A simple and new method for enhance tree-ring visualization using fluorescence

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Tropical forests harbor about 50.000 tree species, out of which only few hundreds are used for dendrochronological purposes. One of the reasons is because only few species are known to produce annual tree rings. The other reason is the proportional diversity of wood anatomy that may result in less than clear tree-ring boundaries. In order to improve tree-ring visualization we evaluated the suitability of using fluorescence to enhance the contrast among wood cells. We tested three sets of fluorescence filters: GFP (green fluorescent protein), RFP (red fluorescent protein) and UV and compared with visualization under natural light. Overall, fluorescence enhanced the contrast among fibres, parenchyma and vessels on different tree species improving tree-ring visualization. For a few species tree-ring boundaries were highlighted by the presence of fibrous zones, by the presence of parenchyma bands, by presence of early-wood large vessels and/or narrow late-wood vessels, or by highlighting the content of secretory canals. For species known to have clear tree ring boundaries, fluorescence may aid visualization of false tree-rings. We also found this technique suitable for qualitative and quantitative wood anatomy studies. Therefore, tropical dendrochronologists may find this method useful for tree-ring counting, cross-dating and to expand the available set of species suitable for tree-ring investigations.

Geographical patterns and drivers of regeneration and growth dynamics of *Quercus variabilis*

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Impending climate warming is expected to influence plant regeneration, growth and distribution ranges. However, synchronous comparisons of regeneration and growth dynamics associated with biotic factors across latitudinal, longitudinal and altitudinal gradients at a single species'level have received little attention. In the present study, we investigated regeneration (seedling and sapling) and growth variations (radial and height growth) of Quercus variabilis along latitudinal, longitudinal and altitudinal gradients; meanwhile, the effects of environmental factors (climate, soil and stand conditions) on regeneration and growth across the three geographical gradients were ranked and apportioned using linear mixed-effects models. Our results indicated that the regeneration of Chinese cork oak decreased from middle to the range limit, the radial growth of ringwood and latewood increased with latitude, and latewood and height growth decreased with longitude; furthermore, the growth sensitivity to climate were less in the southern and eastern populations than the northern and western. When pooling all sites' data, we found that climate variables were not solely decisive factors to drive the geographic variations in the regeneration and growth of *Q. variabilis*, stand conditions (stand density and total basal area) and soil properties (pH, Ca, Mg, N and N/P) also played important roles in shaping large geographical patterns of the oak regeneration and growth.