Growth, isotope records and quantitative wood anatomy reveal species-specific couplings in three Mexican conifers inhabiting drought-prone areas

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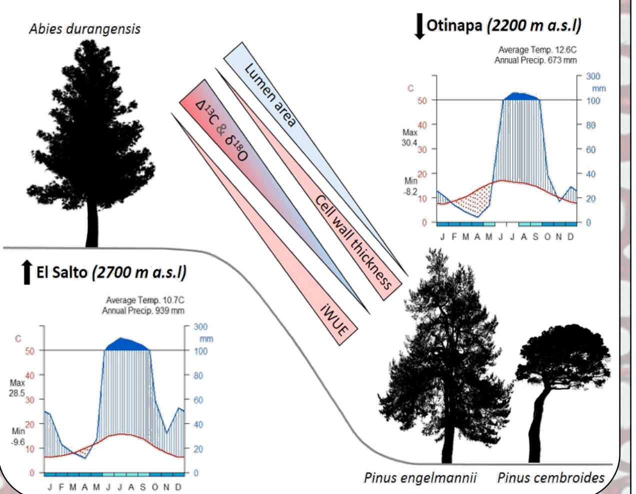
Introduction: Improving our understanding on how tree species will respond to warmer conditions and longer droughts requires comparing their responses across different environmental settings and considering a multi-proxy approach. This can be achieved by integrating tree-ring width, intra-annual density fluctuations (IADFs), wood anatomical traits, $\Delta^{13}C$ and $\Delta^{18}O$ records. We choose three conifer species inhabiting drought-prone areas in north-western Mexico to quantify these responses, focusing in a humidity and altitudinal gradient.

Objective: We aimed to test if the species growing on the more humid site present higher growth rate and develop different growth strategies (e.g. specific wood anatomical traits) that may suggest higher risk of hydraulic failure and dieback episodes caused by climate change, while the species growing on the drier site might cope better with it.

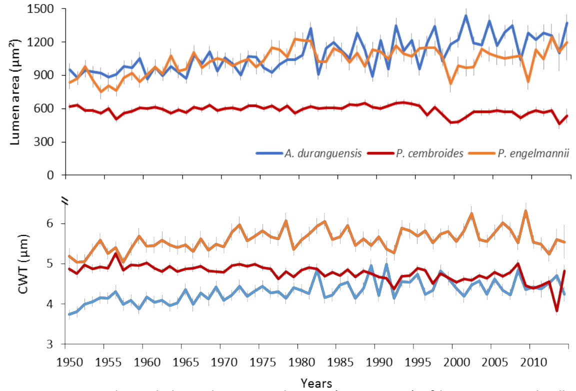
Experimental layout and expected outcomes



From: **A. Pacheco**, J.J. Camarero, M. Pompa-García, et al., Growth, wood anatomy and stable isotopes show species-specific couplings in three Mexican conifers inhabiting drought-prone areas, Science of the Total Environment **(2019)**, https://doi.org/10.1016/j.scitotenv.2019.134055

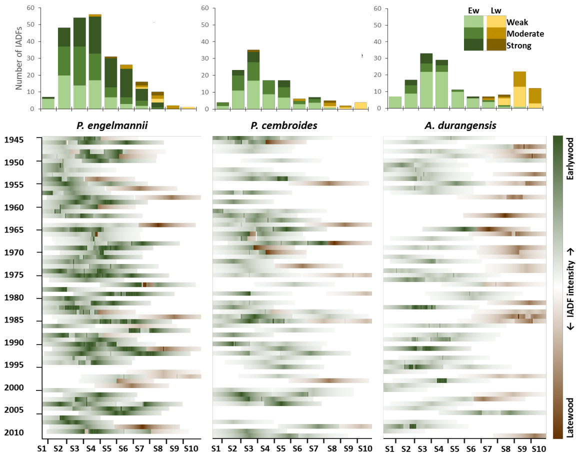
Results

Wood anatomy main traits



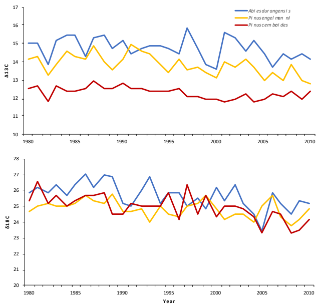
↘ Non-detrended wood anatomical series (means ± SE) of lumen area and cell wall thickness (CWT) for the common period of 1950-2014 in the three studied conifer species (wet site, *Abies durangensis*; dry site, *Pinus cembroides* and *Pinus engelmannii*).

Intra-annual density fluctuations



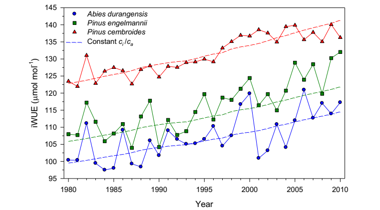
↘ Quantification and characterization of each intra-annual density fluctuations (IADF) present across all tree cores analyzed from the three conifer species (wet site, *Abies durangensis*; dry site, *Pinus cembroides* and *Pinus engelmannii*) along the 10 tree-ring radial sectors (x axes; radial sectors go from the early earlywood (S1) to the late latewood (S10)) from 1945 to 2010. Characterization is based on the location of the IADF within the earlywood (greens) or latewood (browns) areas and the intensity of its fluctuation. Top section indicates the overall totals of IADF's along all the study period.

Stable isotopes and intrinsic water-use efficiency



↘ Variability of cellulose-$\Delta^{13}C$ and cellulose-$\delta^{18}O$ in the three conifer species (wet site, *Abies durangensis*; dry site, *Pinus cembroides* and *Pinus engelmannii*). Values are shown for the period 1980-2010.

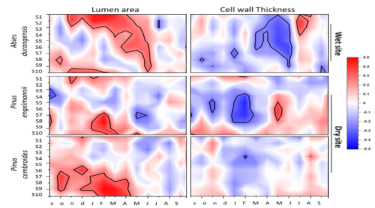
Species	iWUE models		
	Constant c_i	Constant c_i/c_a	Constant c_a–c_i
A. durangensis	1.88	0.88	1.72
P. engelmannii	1.53	0.98	2.01
P. cembroides	1.56	0.48	1.74



↘ Goodness-of-fit statistics (RMSE) for three different theoretical models of intrinsic water-use efficiency (iWUE) fitted to the iWUE data (1980-2010 period). C_a: atmospheric CO_2 concentration; c_i: CO_2 concentration in the internal sub-stomatal cavity of leaves.

↘ Trends in intrinsic water-use efficiency (iWUE) of the three species (wet site, *Abies durangensis*; dry site, *Pinus engelamannii* and *Pinus cembroides*) and selected iWUE model (constant c_i/c_a ratio, dashed lines).

Climate-wood anatomy relationships



↘ Climate-anatomy associations between lumen area or cell wall thickness and monthly precipitation for the two studied areas (wet site for *Abies durangensis*; dry site for *Pinus engelmannii* and *Pinus cembroides*) over the common period 1950–2014. Pearson correlations were computed from September of the previous year (months abbreviated by lowercase letters) to September of the next year (months abbreviated by uppercase letters), and they were calculated using the ten tree-ring radial sectors from the early earlywood (S1) to the late latewood (S10) (y axes). Correlation coefficients above |0.232| are significant at $p < 0.05$ and they are signaled by contour black lines.

Discussion and Conclusion: Matching tree-ring, wood anatomical and isotope analysis resulted in an efficient combination of methodologies that provided better insight on species-specific adaptation response to climate change. *P. cembroides*, with smaller cells, a compact morphology and an extremely high iWUE, stands as the species better adapted to its current environment and could be less affected by a future warmer and drier climate. On the other hand, it shows the lowest growth rates with a decreasing tendency over the last 30 years. *P. engelmannii* and *A. durangensis* show high plasticity at a wood anatomical level for a prompt response to seasonal water availability, but this plasticity likely gives no advantages under a climate with longer and more frequent drought spells. These findings provide a better understanding of the ecological mechanisms developed by the studied conifer species in northern Mexico. Our multi-proxy approach could be used in other forests to characterize the *in situ* functioning of trees, e.g. growth, water use, and development of strategies for forest management under new climate change scenarios.