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Large scale assessment of post-drought climate sensitivity of tree-growth

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Hotter droughts will have an increasingly influential role in shaping forest ecosystems in the future. Risks include decreases in species richness, altered species distributions, forest dieback and changed function as carbon sink. A common method to study the impacts of droughts on forests is the quantification of reductions in biomass productivity via secondary growth – approximated by ring-width measurements –, including duration until growth rates return to pre-drought levels, so-called legacy periods. However, while these metrics are practical and relatively easy to measure, the underlying governing mechanisms are not, and thus poorly understood. Consequently, it is uncertain if drought-induced reductions in secondary growth are due to corresponding decreases in total physiological function or high plasticity, and if recovery times are due to lasting damage or adaptation with more carbon allocated to drought-mitigating structures.

The principle of the most limiting factor for tree-growth can be used to track temporal variations in climate-growth relationships. Similarly, the considerable strain hotter drought constitutes for tree-growth, and the need to repair damaged structures or alter carbon allocation, may imply temporary climate sensitivity deviations during legacy periods. Identifying their existence and quantifying subsequent differences in these deviations can help to shed light on strategies used by trees to respond to droughts.

Here, we detect and quantify deviations in climate-growth relationships during hotter drought legacy periods and assess how they differ according to clade (angiosperms – gymnosperms), site aridity and hydraulic safety margin. We do this by applying a linear mixed model on all ring-width indices (RWI) in the global-scale International Tree-Ring Data Bank (ITRDB) which exhibit a positive correlation with Standardized Precipitation-Evapotranspiration Index (SPEI). We apply a combined climatological and ecological definition for drought events and use site-dependent SPEI time-scales to allow for specific climate dependencies.

Results show heterogeneous post-drought climate sensitivity deviations, which are broadly categorized in three groups: 1) angiosperms growing in arid sites become increasingly sensitive to climate for 2 – 4 years; 2) angiosperms in mesic sites and or with high hydraulic safety margin show abrupt and complete disruption of the climate-growth relationship for the first year after droughts, which turn into a decrease in climate sensitivity for an additional 1 – 3 years; 3) gymnosperms in arid sites become less sensitive to climate for 2 – 4 years, although without the abrupt disruption seen in group 2. We discuss these results and their implications in an

ecophysiological context, including future research avenues.

In conclusion, the results clearly show a functional legacy effect that is not detected through measurements of reductions in biomass accumulation alone, hinting at differential strategies employed by trees to cope with hotter droughts. This is a first step towards a better understanding of the mechanisms underlying hotter drought legacies which may help to improve ecosystem models and better predict how trees will respond to drought in a warming future climate.