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From process to proxy: Ecological challenges and opportunities of tree-ring based environmental reconstructions

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Trees are sessile, long-living organisms and as such constantly need to adapt to changing environmental conditions. Accordingly, they often show high phenotypic plasticity (the ability to change phenotypic traits, such as allocation of resources) in response to environmental change. This high phenotypic plasticity is generally considered as one of the main ingredients for a sessile organism to survive and reach high ages.

Precisely because of the ability of trees to reach old age and their in-ability to simply run away when conditions get worse, growth information recorded in tree rings has long been used as a major environmental proxy, covering time scales from decades to millennia. Past environmental conditions (e.g. climate) are recorded in i.e. annual tree-ring width, early- and latewood width, wood density, isotopic concentrations, cell anatomy or wood chemistry. One prerequisite for a reconstruction is that the relationship between the environmental variable influencing tree growth and the tree-growth variable itself is stable through time. This, however, might contrast the ecological theory of high plasticity and the trees ability to adapt to change.

To untangle possible mechanisms leading to stable or unstable relationships between tree growth and environmental variables, it is helpful to have exact site information and several proxy variables of each tree-ring series available. Although we gain insight into the environmental history of a sampling site when sampling today, this is extremely difficult when using archeological wood. In this latter case, we face the additional challenge of unknown origin, provenance and (or) site conditions, making it even more important to use multiple proxy time-series from the same sample.

Here, we review typical examples, where the relationship between tree growth and environmental variables seems 1) stable and 2) instable through time, and relate these two cases to ecological theory. Based on ecological theory, we then give recommendations to improve the reliability of environmental reconstructions using tree rings.