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Species-specific responses to drought have strong long-term consequences at the ecosystem scale

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Future climate-induced changes in soil moisture conditions will influence ecosystems, which in turn partly control and/or facilitate evapotranspiration and hence have a direct feedback effect on the regional climate. Small-scale experimental data from a mature deciduous forest suggest species-specific reductions in transpiration during drought. We used these data to investigate the long-term consequences of the differential drought responses of trees at the ecosystem scale by incorporating two alternative mechanisms in the ecosystem model LPJ-GUESS. According to the first mechanism, tree species differ physiologically, i.e. in their water uptake capacity under drought conditions. According to the second mechanism, they differ morphologically by featuring different vertical root distribution patterns.
We performed simulations for temperate deciduous forest ecosystems in central Europe, using mixed forests and single species stands. Predictions on long-term trends in tree diversity differed strongly depending on the type of drought response that was used, leading to either strong suppression of the most sensitive tree species in the case of differences in water uptake capacity, or to a mixed-species forest in case of differential root distribution patterns. The reduction in ecosystem evapotranspiration on days with low soil moisture was considerable for the drought sensitive species, but less important for the other species and for mixed forests. This pattern could be reversed during prolonged droughts, because reduced water uptake earlier in the drought may result in higher water availability later on. This implies that, paradoxically, drought sensitive tree species may be able to maintain a positive carbon balance during longer drought periods.
We scale up these vegetation changes for a whole inner alpine catchment, characterized by a strong gradient of both temperature and precipitation, where drought stress was shown to be of high importance in the lower elevations. As it is anticipated that drought periods are likely to become more frequent and/or longer in many parts of the world, projections of ecosystem responses will be sensitive to the processes investigated here, and therefore ecosystem models should be upgraded to take them into account.