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Stress response and transformation processes initiated by the summer drought 2018 – a multi-scale study from the Hainich forest

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More frequent and intense drought events pose one of the greatest threats to forests under climate change with substantial consequences for tree growth, ecosystem stability, and climate change mitigation. A better understanding of drought-related stress response and adaptation mechanisms is paramount to assess the adaptative capacity of forest ecosystems and deduce supportive management actions.

Here, we report on the stress effects and transformation processes initiated by the 2018 summer drought in the Hainich Nationalpark, an old-growth beech-dominated forest in Central Germany (DE-Hai). We deploy a multi-scale approach encompassing long-term eddy covariance measurements for stand-level CO_2 exchange, concurrent surveys of tree increments, and satellite imagery that covers the core zone of the National Park. Thus, we can provide a comprehensive picture of the response mechanisms that occur in a mixed old-growth forest in the wake of a severe drought.

After a 15-year reference period of relatively stable net CO_2 uptake of 535±73 g m^2 yr^{-1} on average, the summer drought 2018 persistently lowered the forest's CO_2 sink function down to 333-395 g m^2 yr^{-1} (2019-2021). The lowered CO_2 sequestration was primarily due to a sustained reduction in photosynthetic CO_2 uptake and went along with an increase in tree mortality from 1 to 6%. We observed a substantial shift in growth patterns among the surviving trees: *Fraxinus excelsior*, which in its role as competitor tree had contributed substantially to stand-level growth for a long time, showed significantly lower increments from 2018. At the same time, increments of *Fagus sylvatica* increased markedly after 2018. Especially younger, suppressed *Fagus* individuals benefitted in the post-drought period and pushed stand-level growth to a new record in 2021. On larger spatial scale encompassing the National Park core zone, drought response was overprinted by topographic effects that reflect landscape water availability, particularly altitude and routing of

waterways.

Tree growth response to extreme water stress in a mixed, old-growth forest varies with regard to species-specific drought tolerance levels and/or the tree's role in the forest structure. The natural growth dynamics emanating from drought events in unmanaged forests are modulated locally by landscape water availability, and can cumulate into profound structural change. At the early stage of transformation captured by our study, a reduction in productivity and climate change mitigation potential must be expected.