



Accelerated drought-induced resilience decline across European forests

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The recent intensification of hotter droughts due to climate change has resulted in a reduced resilience of forests at global scale. This response is not only mirrored by increasing rates of tree dieback, but also reflected in a reduced canopy greenness (Buras et al., 2021) as well as emerging statistical early-warning signals of declining forest resilience (EWS, Forzieri et al., 2022). Yet, a systematic investigation on how atmospheric water demand, canopy greenness decline, and EWS are linked across European forests and including the most recent extreme droughts of 2022 and 2023 is missing. To overcome this research gap, we 1) deployed time series of remotely sensed canopy greenness (NDVI) at moderate spatial resolution (6.25 ha) over the period 2001–2023 for the European continent, 2) derived three independent statistical indices of forest resilience, and 3) related these data streams to atmospheric water demand (VPD).

Over the study period, VPD displayed an increasing trend over most of Europe, which was mirrored in a concurrent decline of forest canopy greenness. Moreover, we found a clear and significant non-linear negative impact of rising VPD on canopy greenness for 75% of European forests. The grid-specific frequency of identified EWS was significantly linked to VPD and featured a record extent in 2023 with about one fifth of European forests being affected. This observation was independently supported by a strong increase in the spatiotemporal memory of canopy greenness since the extreme drought of 2018 (Buras et al., 2020). Finally, in the years following 2018 VPD-based predictions increasingly overestimated canopy greenness, hinting at forests decreasing ability to recover from extreme drought impacts. In conclusion, our study underscores the enhanced vulnerability of European forests during the extraordinarily dry period 2018–2023 with important implications for forestry, land-based mitigation plans, and regional climate feedbacks.

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