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Spatiotemporal Changes in Drought Sensitivity Captured by Multiple Tree-Ring Parameters of Central European Conifers

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Abstract : Environmental changes have increased the frequency and intensity of climatic extremes, particularly hotter droughts, leading to altered tree growth patterns and multi-year lags in tree recovery. The effects of shifting climatic conditions on tree growth are inhomogeneous across species' natural distribution ranges, with large spatial heterogeneity and inter-population variability, but generally have significant consequences for contemporary forest dynamics and future ecosystem functioning. Despite numerous studies on the impacts of regional drought effects, large uncertainties remain regarding the mechanistic basis of drought legacy effects on wood formation and the ability of individual species to cope with increasingly drier growing conditions and rising year-to-year climatic variability. To unravel the complexity of climate-growth interactions and assess species-specific responses to severe droughts, we combined forward modeling of tree growth (VS-lite model) with correlation analyses against climate (temperature, precipitation, and the SPEI-3 moisture index) and growth responses to extreme drought events from multiple tree-ring parameters (tree-width and blue intensity parameters). We used an extensive dataset with over 1000 tree-ring samples from 23 nature forest reserves across an altitudinal range in Czechia and Slovakia. Our results revealed substantial spatiotemporal variability in growth responses to summer season temperature and moisture availability across species and tree-ring parameters. However, a general trend of increasing spring moisture-growth sensitivity in recent decades was observed in the Scots pine mountain forests and lowland forests of both species. The VS-lite model effectively captured nonstationary climate-growth relationships and accurately estimated high-frequency growth variability, indicating a significant incidence of regional drought events and growth reductions. Notably, growth reductions during extreme drought years and discrete legacy effects identified in individual wood components were most pronounced in the lowland forests. Together with the observed growth declines in recent decades, these findings suggest an increasing vulnerability of Norway spruce and Scots pine in dry lowlands under intensifying climatic constraints.

Keywords : dendroclimatology, Vaganova–Shashkin lite, conifers, central Europe, drought, blue intensity
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