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Divergent temporal shifts in climate sensitivity of Norway spruce along an elevational and continentality gradient in the Carpathians

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Climate change is affecting forest ecosystems all around the globe, through warming as well as increased drought frequency and intensity. Across much of Europe, climate change has caused a major dieback of Norway spruce (*Picea abies* L.), an economically important tree species. However, the southeasternmost fringe of this tree species – the Eastern Carpathians – has not yet suffered large-scale dieback. In recent decades, temporal shifts of climate sensitivity (TSCS) have been observed on a global scale. Thus, studying TSCS over time may elucidate the degree to which Norway spruce may be vulnerable to climate-change induced decline in upcoming decades.

Under this framework, we analyzed a regional tree-ring network comprising more than 3,000 trees, with the aim of quantifying TSCS since 1950. We mathematically defined TSCS as the slope parameter of the regression of climate sensitivity (the correlation coefficient) over time. Given the often-observed contrasting shift of climate sensitivity at low versus high elevations, we were particularly interested in studying potentially divergent TSCS along elevational and spatial gradients. Our results revealed several indications of TSCS for Norway spruce in the Eastern Carpathians. First, at high elevations (>1,100 m a.s.l.), we found that the positive link between summer temperature and spruce growth decreased significantly over the study period. In turn, these trees, over time, featured an increasing positive relationship with late winter temperatures. At low elevations (<800 m a.s.l.), the signal of positive summer Standardised Precipitation-Evapotranspiration Index (SPEI) correlation became more frequent among sites. Our results revealed that TSCS was driven significantly by an elevational climate gradient and a longitudinal continentality gradient. Overall, our findings indicate that Norway spruce is increasingly affected by water limitations under climate change at low elevations, highlighting a potentially rising risk of decline of this species in the Eastern Carpathians.

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