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## Combining dendroecology and remote sensing to assess how late spring frosts affect European beech forests

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Climate-extreme induced disturbances such as summer droughts and late spring frosts (LF), can affect productivity and tree growth in temperate forests. In this study we investigated how LFs affect canopy cover and radial growth in European beech (*Fagus sylvatica*) forests along an elevation gradient at four sites in the Italian Apennines. We combined tree-ring and remote-sensing data to analyse the vulnerability and recovery capacity of beech populations to LFs. We computed population and individual climate-growth relationships to test their responses at different elevation. Using climatic records, we reconstructed LF events and assessed their immediate and carry-over effects on growth. We also checked the role played by spatial and structural variables as drivers of LF rings occurrence at population and individual scales. We computed Normalized Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and LAI (Leaf Area Index) using satellite images to evaluate the post-LF canopy recovery. The growth reduction in LF-affected trees ranged from 36% to 84%. We detected a negative impact of LF on growth only during the year of LF occurrence, with growth recovery in 1-2 years after the event. Water deficit during the previous and current summers and cold spring temperatures are the main factors limiting beech growth. LFs affected stands feature low NDVI, EVI and LAI values until late June. Frost rings formation is enhanced at mid rather than low and high elevations, induced by spring leaf phenology. An increasing frequency of LF events could alter the resilience of mountain beech forests, but nowadays they show a high recovery capacity and no legacy effects. A broader geographic area, especially in marginal sites, and the use of other tree-ring variables (anatomy, isotopes), could improve the assessment of post-LF resilience in beech forests. Such improvement would help managers in preserving forest ecosystem services.