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Modelling secondary tree growth of European forests based on high resolution satellite observations and climate data

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Under climate change, modelling forest productivity is gaining increasing attention since forests on the one hand contribute to climate change mitigation by carbon sequestration and provide wood as an important renewable resource, and on the other hand increasingly suffer from extreme events such as droughts, late-frosts, and other disturbances. Despite major advancements in tree-growth modelling over the past decade, we still lack observation-based (in contrast to simulated) high-resolution, gridded forest growth products that could help to provide a better mechanistic understanding of forest responses to climate change, potentially improving mechanistic model parameterization.

Within this context, tree-ring measurements render an invaluable source of information since they approximate annual above-ground tree growth – and thus net primary production (NPP) – fairly well. Yet, tree-ring records represent local tree growth, which implies the necessity to upscale these NPP-proxies to stand and landscape levels to achieve gridded products. A well-known means to model tree growth is based on climate data, since tree growth to a large degree is governed by environmental conditions. However, local site-conditions modulate how climate translates into growth, therefore site-specific information is required to improve models based on

gridded climate data. Here, earth observation from satellites (EOS) may render a valuable and relatively easy-to-obtain source of additional, site-specific information. This is because canopy reflectance in different bands (e.g. near infrared, red-edge, red) is closely related to the photosynthetic activity and thus NPP. Consequently, deploying gridded, open-access EOS data for improving growth predictions into space appears to be a promising research avenue. To date, the existing studies combining tree-ring data with EOS are mostly constrained to high latitudes (due to a very distinct growing season) and typically deployed EOS featuring coarse to moderate resolution. Consequently, assessing the potential of high-resolution (10 m – 20 m) remote-sensing missions such as Sentinel-1 and Sentinel-2 in mid-latitude forests will provide novel insights.

Within this framework, we recently assembled the TREOS-network. TREOS represents a sub-continental tree-ring network for eight common tree species in Central and Eastern Europe comprising 697 sites and spanning the region between 41.0 and 59.6° latitude and 5.6 and 27.9° longitude. For all sites, we extracted Sentinel-1 and Sentinel-2 time series of various bands along with gridded climate products and used various combinations of these explanatory variables to model tree growth as approximated by stand-level tree-ring chronologies. Species-specific models explained up to 70% of tree-growth variance, whereas clade-specific (i.e. gymnosperms vs. angiosperms) models performed worse (up to 30%), indicating the necessity to account for species-specific relationships. When implementing EOS data within multiple regressions model performance improved by up to 45%. In conclusion, these results indicate EOS- and climate-based gridded growth simulations to be generally feasible. Yet, problems related to species-specificity have to be solved, e.g. by deploying EOS-based tree-species classifications as a required source of information when projecting our models into space.

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