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The cascade of uncertainty in modeling the impacts of climate change on Europe's forests

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Projecting the impacts of global change on forest ecosystems is a cornerstone for designing sustainable forest management strategies and paramount for assessing the potential of Europe's forest to contribute to the EU bioeconomy. Research on climate change impacts on forests relies to a large extent on model applications along a model chain from Integrated Assessment Models to General and Regional Circulation Models that provide important driving variables for forest models. Or to decision support systems that synthesize findings of more detailed forest models to inform forest managers. At each step in the model chain, model-specific uncertainties about, amongst others, parameter values, input data or model structure accumulate, leading to a cascade of uncertainty. For example, climate change impacts on forests strongly depend on the in- or exclusion of CO_2-effects or on the use of an ensemble of climate models rather than relying on one particular climate model. In the past, these uncertainties have not or only partly been considered in studies of climate change impacts on forests. This has left managers and decision-makers in doubt of how robust the projected impacts on forest ecosystems are.
We deal with this cascade of uncertainty in a structured way and the objective of this presentation is to assess how different types of uncertainties affect projections of the effects of climate change on forest ecosystems. To address this objective we synthesized a large body of scientific literature on modeled productivity changes and the effects of extreme events on plant processes. Furthermore, we apply the process-based forest growth model 4C to forest stands all over Europe and assess how different climate models, emission scenarios and assumptions about the parameters and structure of 4C affect the uncertainty of the model projections.
We show that there are consistent regional changes in forest productivity such as an increase in NPP in cold and wet regions while decreasing trends are mostly found in already warm and dry regions despite large differences in model structure, model parameters and climate change scenarios that induce considerable uncertainty into future projections. We also show that there are data assimilation techniques available to assess some types of uncertainties but also that many climate change impact assessment in forest ecosystems (including those presented here as well as observational and experimental studies) have focused to a large extent on testing the response of plants to changes in mean climate rather than climatic extremes. The latter may however ultimately shape the responses to a driving variable in reality. Finally, we highlight how these uncertainties culminate in increasingly complex management of natural resources in coupled social-ecological systems.