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Modelling forest productivity in a changing climate: uncertainties and challenges

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Forest productivity models are the focus of active research in many jurisdictions. The three main model categories, empirical growth and yield, gap and process-based, were designed and are being further developed to meet specific needs. Growth and yield models, based on the empirical use of stand inventory data, focus on the prediction of annual allowable cut and the effects of silvicultural treatments. Gap models, characterized by representations of intermediate complexity of stand dynamics processes, can be used to evaluate the potential long-term effects of small-scale disturbances on forest succession. Process-based models contain relatively detailed descriptions of the ecophysiological processes that govern tree and stand growth. They are the most effective to evaluate the impacts of major disturbances, such as climate change. Despite the fact that major accomplishments have been achieved in the last few decades, uncertainties in the predictions of forest productivity models still remain important. Several difficulties are specifically associated with their development. These include dealing with natural variability, representing the complex interactions inherent to forest ecosystems, and integrating the longevity factor. Also, in order to make sound decisions about natural resource management, users expect a high degree of accuracy in the predictions. These issues are particularly important more than ever before as there is an urgent need to improve the capacity of different model types to predict the effects of climate change on forest productivity. Although the natural inclination might be to add more code or increase the complexity of statistical methods, these are not necessarily the answer. The fact is that the changing climate poses new challenges that can best be met by returning to significant and relevant basic research questions related to the mechanisms affected by climate change, including ecophysiological processes, carbon allocation, disturbance rate and/or forest succession. But this time, the lack of understanding identified by existing models can contribute to improving the design of research protocols and field and laboratory experiments can be intimately linked to garner significant and relevant information. Specifically, there is a need to improve the biological consistency of the mathematical representations of the complex nonlinear interactions within forest ecosystems and to address in more depth different time and spatial scale issues. As a consequence, it is likely that the complexity of the next generation of forest productivity models will increase appreciably. Modellers will have to rely more on specific methods to deal with complexity, such as hierarchy theory or systems analysis, to avoid developing models that require too much data to calibrate them, a common complaint of model users. Also, more importance should be put on the computation of uncertainty estimates. These will allow the users to (1) evaluate the errors in the predictions and (2) compare the predictions of different model types. Even though process-based models have the most potential to predict the effects of climate change, they are not necessarily suitable for predicting short-term and small-scale management interventions or simulating forest succession. However, their output can be used to adjust growth and yield or gap models to account for the effects of climate change. The cycle of modelling can then be extended and the information used in the most efficient way.