

Editorial

Simulation Models of the Dynamics of Forest Ecosystems

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The development of simulation models of the dynamics of forest ecosystems has been an active area of research. Paralleling a systematic increase in computational costs and computer size and power over time, these models have evolved considerably for the last six decades. The first forest dynamics model that required the use of a computer to perform simulations was developed in the 1960s by Newnham [1] at the University of British Columbia, Canada. This model was based on the computation of the intensity of competition between individual Douglas fir (*Pseudotsuga menziesii* (Mirbel) Franco) trees. This work was then followed by the development of individual tree models that tested different types of (1) distance-dependent competition indices, including zone of influence and the size/distance of competitors and crown interference and (2) distance-independent competition indices based on the size of competitors using the diameter, basal area, dominant height or number of competing trees [2]. Dynamics whole-stand models were also developed during this period to predict the growth of stand attributes, such as basal area, stand volume or stand density [2].

In the early 1970s, the development of forest succession models, also known as gap models, was introduced. This type of mechanistic model is based on processes intimately linked to species-specific ecological properties. They simulate individual tree growth and mortality, seedling establishment and the transition from sapling to tree status. JABOWA [3] was the first such model. More recently, from the 1980s, increased improvement in the development of process-based models, also known as ecosystem or mechanistic models, became an active area of research when a consensus among scientists highlighted the need to predict the extent that novel disturbances, such as particulate pollution or climate change, could affect the dynamics of forest ecosystems [4]. Process-based models build upon the development of cause-effect relationships within complex structures of interactions and feedback mechanisms of physiological and biogeochemical processes [4,5]. The incorporation of more mechanistic processes models with individual-based or stand-level models has been an ongoing synthesis since that time. Models simulating forest dynamics, species migration or niche habitat changes over landscapes or large regions have also been developed, particularly over the last three decades.

Models that simulate the dynamics of forest ecosystems contribute to maintaining their long-term sustainability and biodiversity, providing ecosystem services and optimizing management practices. There is an abundant literature on forest dynamics models. The literature differs in structures and objectives and strengths and weaknesses. Despite the rich achievements since the beginning of their development, there are still knowledge gaps that need to be addressed regarding these simulation models, including improved representations of ecological and physiological processes at the individual tree, ecosystem and landscape levels. In particular, these gaps include better understanding of competitive interactions among trees for resources, the effect of canopy spatial structure on ground vegetation and soil heterogeneity, the impacts of climate change on different ecosystem components, and synergies and trade-offs between ecosystem services, etc. New research questions require more complex ecosystem models at different scales, and new methodologies for model integration are needed, as well as methods for use in the calibration and



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validation of such models. Within this Special Issue, selected articles cover topics on the modelling of growth and succession, physiological and biogeochemical processes, carbon budget and climate change. This Special Issue includes 16 articles by 80 authors originating from nine countries – two from North America (Canada and the United States of America), four from Europe (the United Kingdom, Germany, Russia and Finland) and three from Asia (China, Australia and New Zealand).

Articles on growth and succession modelling reported on testing and comparing competition indices for spruce (*Picea abies* (L.) H.Karst.), pine (*Pinus sylvestris* L.), birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) and aspen (*Populus tremula* L.) forests in different spatial structures in Finland [6], comparing growth differences between loblolly (*Pinus taeda* L.) and slash (*Pinus eliottii* Engelm.) pine growing under different silvicultural intensities in East Texas using nonlinear models with fixed and random effects [7], evaluating the performance of a forest succession model using historical and experimental data and its applicability to predict yields and species composition in Ontario, Canada [8,9], developing a new modelling approach to improve the evaluation of site quality in Coast redwood stands (*Sequoia sempervirens* (Lamb. ex D. Don) Endl.) in New Zealand [10] and conducting a review of different models that can be used to develop management scenarios for small forests [11]. The complexity of modelling processes in forest ecosystems, which involve feedback between forest growth and environmental changes and from local to global scales and the development of “functional groups”, was highlighted by studying different aggregation strategies in the development of models [12].

Four articles focused on physiological and biogeochemical processes. A model of seasonal cambium development was developed as function climatic and phenological variables to predict cell production and sizes [13]. The process-based model APSIM was used as a modelling framework to simulate nitrogen uptake in radiata pine (*Pinus radiata* D.Don) and southern blue gum (*Eucalyptus globulus* Labill.) plantations in Australia [14]. Different process-based models were combined within the LandscapeDNDC framework to simulate carbon, nitrogen and water cycling at both ecosystem and regional levels and to compare simulation results with eddy covariance and soil chamber measurements in an 80-year-old oak (*Quercus* L.) forest in SE England [15]. Using repeated remote sensing measurements in the Changwu County in China, soil erosion as affected by land use/cover change was examined by applying different spatial analytical models [16].

Two articles concerned the use of carbon budget models. CBM-CFS3, developed by the Canadian Forest Service, was used to predict carbon dynamics in different forest types in Nova Scotia, Canada [17]. The simulation results were compared with those of locally developed empirical carbon models. The process-based model FORMIND was used to examine the extent to which the complexity of forest structure and composition may affect daily carbon fluxes [18]. The study took place in a forest mainly composed of sessile oak (*Quercus petraea* (Matt.) Liebl.), common beech (*Fagus sylvatica* L.) and hornbeam (*Carpinus betulus* L.) in Germany. Inventory and environmental data and eddy covariance measurements were used in the modelling exercise. These two studies were conducted to evaluate modelling methodologies aiming at addressing climate change issues. Three studies in the Special Issue specifically focused on the effects of climate change. Niche-based models based on climate, soil and human effect variables were developed to predict the impact of climate change on the habitat of *Ostrya rehderiana* Chun in the Tianmu Mountain, Southeast China [19]. A similar study was conducted for three *Carpinus* species that used a species distribution model based on climatic and human footprint variables [20]. MaxEnt algorithms were developed to identify conservation areas for *Cistanche deserticola* Ma, which is a parasite that lives on the roots of *Haloxylon ammodendron* (C.A. Mey) Bunge, in order to protect their biological diversity and ensure their survival under different climate change scenarios in the Xinjiang Uygur Autonomous Region, northwestern China [21].

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