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OPINION PAPER

Exploring new frontiers in forecasting forest growth, yield and wood property variation

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Abstract

• ***Key message*** **Modern forest managers operate in a world characterised by increasing variability in multiple factors impacting forest productivity, survival and product quality. Being able to predict, as accurately as possible, how forests will develop in the future is perhaps of more importance than ever before. At an international IUFRO conference held in Stellenbosch, South Africa, in September 2018, researchers and managers came together to present research and discuss multiple facets of this large and critical area of forest science.**

Keywords Forest growth and yield · Climate change · Forest management and planning · Forecasting forest attributes

Modern forest managers around the world face changing climate patterns, variable market conditions, the need for increasingly precise information, rapid genetic gains and serious risks posed by pests, diseases and natural disasters. In this context, forecasting how forests will develop into the future is increasingly challenging. Yet the ability to accurately predict future forest growth and structure, and the yields and quality of diverse products from these forests, remains an essential part of forest management, given the long timeframes over which planning must be done.

To address these challenges, an IUFRO-supported conference "New Frontiers in Forecasting Forests" was held in Stellenbosch, South Africa, in September 2018 to provide an opportunity to present research with wide-ranging perspectives on this problem. Delegates explored models predicting future forest attributes, including yield, forest structure and wood properties in diverse forest types, and approaches to making the measurements essential to initialising and calibrating models. The meeting aimed to mark the state-of-the-art, identifying emerging frontiers and exploring innovations and new technologies. Delegates also discussed how new frontiers in forest modelling research can be implemented to empower decision makers and deliver impact. Published in this special issue are a small selection of the papers presented at the conference. They covered three main themes.

The first dealt with the question of site quality. In any projection-based approach to predicting future yield, a quantitative understanding of site quality, or the inherent potential of a site to support forest growth, is an essential component of the modelling system. Molina-Valero et al. (2019) tackled the problem by considering the potential of the lesser-used "Site Form" (SF) as compared to much more widely utilised estimates of "Site Index" (SI). They showed that the two methods gave comparable overall accuracy and, given that SF does not require information on stand age, further research considering this lesser-used approach seems worthwhile.

In the research by Du Toit and Scheepers (2020), the important problem of understanding fertility as a key driver of site quality was addressed. They argued that volume growth responses to fertilisation in *Pinus elliottii* and *Pinus radiata* were most strongly associated with topsoil aerobic nitrogen mineralisation rates rather than just nitrogen content. Modelling responses to fertiliser addition, or considering site quality in terms of nutrient content estimates alone, will very likely lead to spurious predictions, and should be more explicit in process-based approaches.

The second theme, considered from several points of view, was the always-fascinating problem of models which

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give future estimates of more than just total yield. These complex modelling approaches, which consider the evolution of forest structure, and particularly growth of individual trees, need careful calibration and initialisation. But obtaining high quality, widely available and temporally repeated data at this level is still often a problem. Tian et al. (2020) proposed an individual tree modelling approach, linked to stand-level and diameter distribution models, which gave good results, even when initialised from temporary plot data only and with no further calibration. Such research is important, forcing forest scientists to continue to think about newer statistical methods for fitting, and novel ways of expressing increment and survival.

Fortunately, however, we have seen in recent years a revolution in the availability of tree-level data, so that calibration becomes more feasible. The more such detailed data can be quickly, cheaply and accurately obtained, the more feasible it becomes to run well-parameterised and calibrated fine-scale growth models in an operational context. The work by Mulverhill et al. (2019) provides an exciting demonstration of the real utility of a relatively simple photogrammetric approach to estimating tree-level diameter, height and volume. Airborne inventories are also becoming more routine and have great potential to be used to generate even tree-level data for forest modelling and decision support. Vauhkonen (2020), however, warns of the incorporation of systemic errors by this method in some forest types. As a result, under-detection of smaller classes of trees may lead to sub-optimal management decisions and losses of as much as 17% in future income.

The third theme that emerged was how to understand and model the drivers of wood property variation. The importance of models of wood formation, and wood property variability, has increased in importance in the last decades due to the need to understand carbon sequestration potential and because of an appreciation of wood quality as a major determinant of product value. Our understanding of the drivers of wood property variation, however, remains inadequate.

Two papers addressed this knowledge gap. Vaughan et al. (2019) showed in *Pinus ponderosa* that it is not growth rate, per sé, which is closely tied to variation in wood properties (in their case, focussing on wood density as an indicator) but rather annual climate peculiarities which lead to variation in the timing and extent of transitions into latewood production. Erasmus et al. (2020), looking at *Pinus patula*, found a clear effect of tree spacing. This was not just on wood density but also on the less-often measured but critically important, microfibril angle. How these properties change with the cambial age of the tree was modelled to allow the interaction between the potential age of the tree and its forest management to be projected.

The problem of "forecasting forests", i.e. predicting how they will develop into the future, is only becoming more important as we face a highly uncertain decision horizon. It is gratifying that scientists are giving consideration to this problem from multiple points of view leading, hopefully, to better outcomes for long-term planning and forest management.

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References

Du Toit B, Scheepers GP (2020) Modelling soil nitrogen mineralisation in semi-mature pine stands of South Africa to identify nutritional limitations and to predict potential responses to fertilisation. Ann For Sci 77:24. https://doi.org/10.1007/s13595-020-0923-y

Erasmus J, Drew DM, Wessels CB (2020) The flexural lumber properties of *Pinus patula* Schiede ex Schltdl. & Cham. improve with decreasing initial tree spacing. Ann For Sci 77:1–15. https://doi.org/10.1007/s13595-020-00975-9

Molina-Valero JA, Diéguez-Aranda U, Álvarez-González JG, Castedo-Dorado F, Pérez-Cruzado C (2019) Assessing site form as an indicator of site quality in even-aged Pinusradiata D. Don stands in north-western Spain. Ann For Sci 76:113. https://doi.org/10.1007/s13595-019-0904-1

Mulverhill C, Coops NC, Tompalski P, Bater CW, Dick AR (2019) The utility of terrestrial photogrammetry for assessment of tree volume and taper in boreal mixedwood forests. Ann For Sci 76:1–12. https://doi.org/10.1007/s13595-019-0852-9

Tian X, Sun S, Mola-Yudego B, Cao T (2020) Predicting individual tree growth using stand-level simulation, diameter distribution, and Bayesian calibration. Ann For Science 77:1–17. https://doi.org/10.1007/s13595-020-00970-0

Vaughan D, Auty D, Kolb TE, Sánchez Meador AJ, Mackes KH, Dahlen J, Moser WK (2019) Climate has a larger effect than stand basal area on wood density in Pinus ponderosa var. scopulorum in the southwestern USA. Ann For Sci 76:5. https://doi.org/10.1007/s13595-019-0869-0

Vauhkonen J (2020) Effects of diameter distribution errors on stand management decisions according to a simulated individual tree detection. Ann For Sci 77:21. https://doi.org/10.1007/s13595-020-0918-8