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EDITORIAL

Linking Inventory and Forest Optimisation: Information and decision-making in forest management

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Introduction

Forest management planning used to be a well-developed and acknowledged discipline in forest science of German-speaking countries (Mantel 1949). Looking back to a long tradition, this discipline had achieved a prominent position in forest science. Well-elaborated planning techniques and theoretical forest models, such as the famous fully regulated forest (also called "normal forest" according to Hundeshagen 1826), fundamental forest management textbooks by Hartig (1795), Judeich (1871), Wagner (1928), Baader (1945), or Richter (1963) and a manifold of deductive formulas to derive the mean allowable cut, formed the basis for the rise of forest management planning in the past. Forest management planning continued its straightforward development in English-speaking countries, which is indicated, for example, by up-to-date and high-standard textbooks, such as Rideout and Hesseln (2001), Davis et al. (2001), Buongiorno and Gilless (2003), and Bettinger et al. (2009). In these countries, forest management planning greatly benefited from the integration of operations research and management science methods. In contrast, the status of forest management planning in German-speaking countries seemed to remain at a standstill or even declined in recent decades. The last highly acknowledged textbook with a strong planning focus dates back to Speidel (1972). Sagl (1995) confirmed this decline with his evaluation of Austrian forest management planning as being poor and unprogressive. According to him, the formerly comprehensive and integrative character of forest management planning had been lost. Other scientists criticised the performance of scientific forest management planning, while feeling a serious lack of innovations in this discipline (Pretzsch 2003). The absence of a serious scientific perspective has been suggested for all classical forest science disciplines (Schanz et al. 1999). A certain loss of scientific orientation is thus not limited to the discipline of forest management planning (see for example Knoke 2010 for a critical approach to the role of science in silviculture). However, the briefly outlined background establishes a strong requirement for new and innovative research approaches particularly within forest management planning and especially for German-speaking countries.

This context formed the challenge to bring back forest management planning in German-speaking countries to an internationally acknowledged and scientifically well-founded position; a challenge which had been accepted by Technische Universität München, founding the Institute of Forest Management in October 2005. It was thus our belief that an international conference on forest management planning located in Germany would be of great benefit (1) for a better exchange between the internationally existing "sub-communities" in forest management planning (such as research communities in sustainability, inventory, optimisation or controlling), who largely carry out their research initiatives independent from another, (2) to generally strengthen exchange and learning between countries, and (3) to present current research of new

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impetus in German forest management planning. Hence, we found several reasons to initiate the LIFO ("Linking Inventory and Forest Optimisation") conference, held at the Center of Life and Food Sciences Weihenstephan, Technische Universität München (TUM), in Freising (April 2008). The conference was organised by the Institute of Forest Management (TUM) in collaboration with the IUFRO groups "4.02.00 Forest Resources Inventory and Monitoring" and "4.04.00 Forest Management Planning".

To form a platform for the LIFO Special Issue, we shall view forest management planning as a decision-making process in which to coordinate management activities at the forest enterprise level over a medium to long-term period. The result of this process is typically a management plan that contains all activities that can be used to best meet the objectives of the landowners (Bettinger et al. 2009). In addition to this, the integration of stakeholder interests and sustainability goals has become a central objective in forest management planning, a topic which addresses ecological and social aspects in addition to economic objectives (Knoke and Weber 2006). As a result of a typical decision-making process, forest management planning often follows several steps, starting with the outlining of management objectives, followed by the identification of management alternatives, and finally the selection of the preferred approach. However, this planning procedure is only meaningful, if adequate information of the conditions of the particular management area are available and if predictions about the resource development under different management strategies are possible.

During the planning process, the selection of the "best" planning alternative is controlled by the values and preferences of the decision-maker. Decision-making in forest management planning may thus have a distinct subjective component, because values and preferences show considerable variation among various persons and institutions. In summary, the steps in decision-making for forest management planning constitute a circle where monitoring and updating the management plan feed back to the system of goals, to the inventory concepts and to the formulation of management alternatives (Fig. 1).

The complex process indicated by Fig. 1 establishes the demand for research strategies and information concepts adequate to best support high-quality decision-making in forest management. Accordingly, various fields of research can be identified (Fig. 2). These include sustainability concepts as a part of the management objectives, optimisation approaches and related information needs. Applying inventory and monitoring concepts will feed the decision-support, providing data to decide on the goals identified previously. Against this background, we distinguished five research areas along the decision-making process in forest management planning to structure the papers collected for the LIFO Special Issue (Fig. 2).

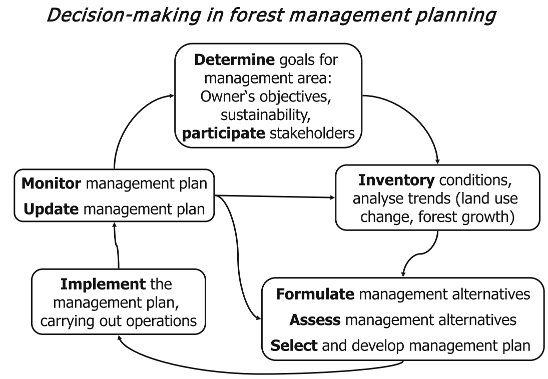

Fig. 1 Steps in decision-making which constitute the process of forest management planning (following Bettinger et al. 2009, with alterations)

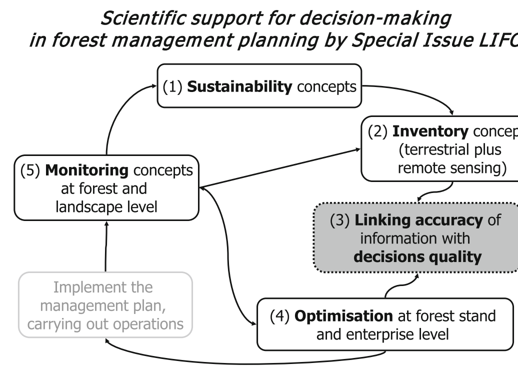

Fig. 2 Identified areas of research as a structure to classifying the papers in this issue (aside from the step "implementation of the management plan", all steps in forest management planning will be addressed)

Compared to the steps that form forest management planning (Fig. 1), our identified scientific research areas (Fig. 2) contain an additional integrative part, where the accuracy of data and information obtained by inventory concepts is linked with the quality of the decisions outcomes. Information accuracy thus controls decision-outcomes in the considered approaches (research area 3). Although occasionally addressed in the past (for example, Eid 2000), the quality of decision-outcomes forms a comparatively new and innovative field of research—an additional aim of the LIFO conference and this Special Issue: Forming a bridge between the manifold of sub-communities in forest management planning, where often isolated research philosophies and languages are imperfectly communicated, placing all planners at a disadvantage.

Included papers

Sustainability concepts

The topic of sustainability may be addressed at various temporal (intragenerational and intergenerational aspects) and spatial scales (local, enterprise scales or regional, national or worldwide scales). The paper by Irland (2010, this issue) on assessing sustainability for global forests starts with the UN's Millennium Developments Goals and thus obtains a worldwide perspective to compare two approaches to sustainability assessment. It contrasts the "Criteria and Indicators approach" to monitor change in the forest conditions over time with approaches that compare nations at a given point in time, such as the "Yale Environmental Performance Index". Irland (2010, this issue) identifies severe data weaknesses and calls for an entirely new discipline to supply this information. To bring more clarity into the often heterogeneous discussion about sustainability, Hahn and Knoke (2010, this issue) review studies concerned with sustainability concepts. They identify the concept of precaution as a dominating approach, with an inherently risk-avoiding attitude incorporated into the decision-making. However, a view concentrating only on potential losses through management actions might miss integration opportunities which are also connected with an uncertain future. The paper by Hahn and Knoke (2010, this issue) thus guides our view to a sustainability concept that is built upon the idea of future options and the ability to respond to changing social and biophysical circumstances, allowing enough flexibility to adapt forest management approaches to changing future demands and developments.

Terrestrial and remote sensing based inventory concepts

We included five papers related to the direct acquisition of data for management issues. Two of them explore the opportunities of Remote Sensing to collect information, two other papers address regionalisation of sample-based terrestrial data with the k-nearest neighbour method and the last paper is on statistical methodology and focuses on ratio estimators.

Information about tree species distribution in forests is fundamental for forest management. However, Remote Sensing methods are generally not able to deliver high-resolution information on tree species, which is also true for airborne laser scanning (ALS). With their paper on ALS-based forest inventory, Vauhkonen et al. (2010, this issue) make a successful attempt to use 3D point clouds to discriminate between three groups of tree species. With a lower requirement for details, Breidenbach et al. (2010a, this issue) test TERRASAR-X data to distinguish forests from other land cover classes, such as agriculture, built-up, and water bodies. Land cover classification was carried out with logistic regressions, where classification success was improved when using differently polarised images and including terrain slope as an explanatory variable. However, transferring the classification model to another area than the "training" area caused a loss in accuracy by 7–9%.

A typical method of information collection for forest management planning is terrestrial sampling on inventory plots. However, this method delivers only point related data. Often, sufficient information is unavailable for the silvicultural management units. In this line, Scheuber (2010, this issue) shows potential and limitation when regionalising sample-based data by means of the k-nearest neighbour method. Comparing three nearest neighbour approaches, Breidenbach et al. (2010b, this issue) show potential for upscaling of plot level data when using airborne laser scanning. With a contribution to statistical methodology, Salas and Gregoire (2010, this issue) conclude the section related to inventory concepts. They explore the effect of errors in auxiliary variables on precision and bias of ratio estimators.

Linking accuracy of information with decision quality

The value of information is non-consumptive by its nature. Rather, information generates value, because it enables efficient decisions that reach the management objectives. With good information at hand and a wise use of this information, the opportunity costs of drawing poor decisions may be minimised. However, the acquisition of good information is usually not costless. With the background of this framework and extensions, four papers connect the accuracy of information with decision consequences, and thus constitute a decision-oriented approach in forest inventory, which is so far often lacking when surveys are conceptualised.

A review paper by Kangas (2010, this issue) on the value of forest information opens this section. She starts from the platform of the already established, so-called "cost-plus-loss" analyses and shows how it is possible to go further when utilising Bayesian decision theory. Based on multi-source information, Kotamaa et al. (2010, this issue) combine field sampling, ALS data, aerial photographs and optimal bucking to support stand-level decision-making. Mäkinen et al. (2010, this issue) investigate the effects of input data errors on the accuracy of forest growth projections and how different growth models behave, when erroneous data is used. The authors find that tree-level ALS data results in more precise growth projections compared to using stand-wise field inventory data. Moreover, tree-level growth simulation proved less sensitive to errors in input data. The former approach was then extended by Holopainen et al. (2010, this issue) to demonstrate the effect of tree-level ALS measurement accuracy on timing and expected economic value of harvest decisions. They show that accuracy greatly affects both timing and relative expected economic value. Here also, tree-level ALS produced greater accuracy than stand wise estimations and tree-diameter based information was most important as input data for simulations.

Optimisation at forest stand and enterprise level

In this LIFO Special Issue, we are able to present five papers related to optimisation techniques in forest management, three of which address the stand-level, one focusing on the forest enterprise level and the final paper combining stand and forest level optimisation. With a comparative paper on different management systems under the risk of wildfire, the contribution by Hyytiäinen and Haight (2010, this issue) values the economic efficiency of even-aged and uneven-aged forestry systems. In line with other studies on uneven-aged management (see Knoke 2009 for an overview), the authors confirm that uneven-aged management is generally superior with increasing interest rates, with and without fire risk. However, higher fire risk increases the relative efficiency of even-aged management. Based on the theory of optimal portfolio selection, Beinhofer (2010, this issue) tests whether or not the production of softwood provides risk compensation, if it is carried out as a systematic mixture of management strategies to produce different log qualities. The tested silvicultural options include pruning to obtain high-quality timber and stand-level optimisation of rotation periods and planting densities. The results showed that diversifying the production into different log-quality grades is effective particularly if this is done in combination with stand-level optimisation. Although not focussing on log qualities, Hildebrandt et al. (2010, this issue) extend the approach by Beinhofer (2010, this issue) when including growth interdependency between mixed tree species. They consider a changed volume growth for Douglas fir (*Pseudotsuga menziesii*) and Rauli (*Nothofagus alpina*) which were in mixed plantations in Chile. Due to the fact that only the fluctuation of timber prices was considered, the results showed that the effects of diversification are comparatively low. Intensive tree by tree mixtures showed rather inferior results compared to block by block mixtures of tree species due to unfavourable growth of Douglas fir in tree by tree mixtures. Rojas et al. (2010, this issue) employ linear programming to set up a multiple-use forest planning model for second-growth forests in Chile. The model considers constraints on timber yield flows, biodiversity levels and limitations on clear cutting in high-visibility areas and enables computing the opportunity costs of the constraints. Finally, Strimbu et al. (2010, this issue) present an interesting approach in combining optimal stand and forest level planning. This study uses the perfect bin-packing theorem to achieve this.

Monitoring concepts at forest and landscape level

Focussing dynamics at the landscape level, Zhang et al. (2010, this issue) address spatial scales beyond forest enterprises. Based on a case study of Yong'an City, the authors use a Markov model fed by sample-plot survey data from Continuous Forest Inventory. The model was applied at the county level to understand the dynamics of a forest landscape. The authors show a net increase in forests, while conversion processes between landscape elements were frequent. Whereas primary forests are on the decline, degraded forests recover to secondary forests. The authors conclude that the Markov model is a suitable means to analyse forest landscape dynamics.

Conclusion

The LIFO Conference in Freising brought together around 90 forest scientists of different research areas and from almost every continent, establishing an effective exchange. Selected papers, which resulted from this conference, have been included in this Special Issue to reflect the actually great innovative potential inherent in forest management planning. Consequently, we can conclude that this discipline is certainly no longer on the decline, neither internationally nor among the German-speaking community of forest science.

However, for the future the presented approaches may well be extended on various scales, spatially and thematically. From our perspective, it seems to be essential and promising to enlarge current optimisation approaches from the forest management unit to the landscape level, integrating physical and socio-economic interconnections between various kinds of land use. This consideration of alternative land use options together with forestry options appears to be extremely fruitful in addressing international problems with sustainable land use (e.g. Knoke et al. 2009a). Additionally, the integration of further social needs besides market goods, by example aspects of ecosystem services, such as carbon sequestration to mitigate climate change (e.g. Knoke et al. 2009b) or biodiversity assessments, opens up another commendable field of research. A future conference to address these topics, possibly to be held again at the Center of Life and Food Sciences Weihenstephan, could be an idea with merits.

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