The impact of silvicultural strategies and climate change on carbon sequestration and other forest ecosystem functions

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Abstract

Forests are a key resource serving a multitude of functions such as providing income to forest owners, supplying industries with timber, protecting water resources, providing habitat for wildlife, and maintaining biodiversity. Recently much attention has been given to the role of forests in the global carbon cycle and their management for increased carbon sequestration is seen as a possible mitigation option against climate change. Furthermore, the use of harvested wood can contribute to the reduction of atmospheric carbon and other greenhouse gases through (i) carbon sequestration in wood products, (ii) the substitution of non-wood products with wood products, which in most cases are less energy intensive during their life cycle, and (iii) through the use of wood as a biofuel to replace fossil fuels. Forest resource managers are challenged by the task to balance these multiple and often conflicting forest functions while simultaneously meeting economic requirements and taking into consideration the demands of stakeholder groups. Additionally, risks and uncertainties with regard to uncontrollable external variables such as climate have to be considered in the decision making process.

In this study a scientific stakeholder dialogue with forest-related stakeholder groups in the Federal State of Brandenburg was accomplished offering a valuable opportunity to bring together the specific knowledge of scientists, forest service personnel, and environmentalists and thereby provide a link to real life in a scientific study. The main results of this dialogue were the definition of major forest functions (carbon sequestration, groundwater recharge, biodiversity, and timber production) and priority setting among them by the stakeholders using the pair-wise comparison technique.

Following the stakeholder dialogue, the impact of different forest management strategies and climate change scenarios on the main functions of forest ecosystems were evaluated at the stand level and forest management unit level. The study was based on the current forest conditions in the Kleinsee management unit in south-east Brandenburg, which is dominated by Scots Pine (*Pinus sylvestris* L.) and oak (*Quercus robur* L. and *Quercus petraea* Liebl.) stands. Forest management strategies were simulated over 100 years using the forest growth model 4C and a newly implemented wood product model (WPM). A current climate scenario and two climate change scenarios based on global circulation models (GCMs) HadCM2 and ECHAM4-OPYC3 and the IS92a emission scenario were applied. The climate change scenario positively influenced stand productivity, and hence increased carbon sequestration (up to 27%) and income. The impact on the other forest functions was small.

Furthermore, the overall utility of forest management strategies were compared under the priority settings of stakeholders by a multi-criteria analysis (MCA) method. Significant differences in priority setting and the choice of an adequate management strategy were found for the environmentalists on one side and the more economy-oriented forest managers of public and private owned forests on the other side. From an ecological

perspective, a conservation strategy would be preferable under all climate scenarios, but the business as usual management would also fit the expectations under the current climate due to high biodiversity and carbon sequestration in the forest ecosystem. In contrast, a forest manager in public-owned forests or a private forest owner would prefer a management strategy with an intermediate thinning intensity and a high share of pine stands to enhance income from timber production while maintaining the other forest functions. The analysis served as an example for the combined application of simulation tools and a MCA method for the evaluation of management strategies at the stand and management unit levels under multi-purpose and multi-user settings with changing climatic conditions.

Another focus of this study was set on quantifying the overall effect of forest management on carbon sequestration in the forest sector and the wood industry sector plus substitution effects over 50 years. To achieve this objective, the carbon emission reduction potential of material and energy substitution (S_{mat} and S_{en}) was estimated based on data extracted from the literature. On average, for each tonne of dry wood used in a wood product substituting a non-wood product, 0.71 fewer tonnes of fossil carbon are emitted into to the atmosphere. Based on S_{mat} and S_{en} the calculation of the carbon emission reduction through substitution was implemented in the WPM. Carbon sequestration and substitution effects of different management strategies were simulated at three local scales using the WPM and the forest growth models 4C (management unit level) or EFISCEN (federal state of Brandenburg and Germany). An investigation was conducted on the influence of uncertainties in the initialisation of the WPM, S_{mat}, and basic conditions of the wood product sector on carbon sequestration plus substitution effects. Results showed that carbon sequestration in the wood industry sector plus substitution effects exceeded sequestration in the forest sector. In contrast to the carbon pools in the forest sector, which acted as sink or source, the substitution effect continually reduced carbon emission as long as forests are managed and timber is harvested. The main climate protection function was investigated for energy substitution which accounted for about half of the total carbon sequestration plus substitution effects, followed by carbon storage in landfills. In Germany, the absolute annual carbon sequestration in the forest and wood industry sector plus substitution effects was 19.9 Mt C. Over 50 years the wood industry sector contributed 70% of the total carbon sequestration plus substitution effects.