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Trade-offs and synergies among ecosystem services under different forest management scenarios – The LEcA tool

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ABSTRACT

Forests provide a multitude of ecosystem services. In Sweden, the goal to replace fossil fuels could induce substantial changes in the current management and use of forests. Therefore, methods and tools are needed to assess synergies and trade-offs between ecosystem services for policy and planning alternatives. The aim of this study was to develop methods for integrated sustainability assessment of forest management strategies for long-term provisioning of various ecosystem services. For this purpose, the Landscape simulation and Ecological Assessment (LEcA) tool was developed to analyse synergies and trade-offs among five ecosystem services: bioenergy feedstock and industrial wood production, forest carbon storage, recreation areas and habitat networks. Forest growth and management were simulated for two scenarios; the EAF-tot scenario dominated by even-aged forestry (EAF), and the CCF-int scenario with a combination of continuous-cover forestry (CCF) and intensified EAF. The results showed trade-offs between industrial wood and bioenergy production on one side and habitat, recreation and carbon storage on the other side. The LEcA tool showed great potential for evaluation of impacts of alternative policies for land zoning and forest management on forest ecosystem services. It can be used to assess the consequences of forest management strategies related to renewable energy and conservation policies.

1. Introduction

Forests play an important role for climate change mitigation by providing bioenergy feedstock to substitute fossil fuels, as well as carbon storage to counteract greenhouse gas emissions. At the same time, they are also important for other ecosystem services and biodiversity. To limit the increase in temperature to well below 2 °C according to the Paris Agreement (UNFCCC, 2015), emissions of greenhouse gases worldwide need to be halved by 2050 and to be close to zero by 2100 (IPCC, 2014). Sweden is a country with relatively good preconditions for both switching to renewable energy sources (water, wind and forest biomass) and for climate change mitigation through carbon sequestration in forests and substitution of fossil-based materials by forest products. In Sweden, the Parliament has declared that the vehicle fleet should be independent of fossil fuels by 2030 (IEA, 2014) and adopted a vision for Sweden of zero net emissions of greenhouse gases by 2050 (Ministry of the Environment, 2014).

By the year 2013, around 34% of the final energy consumption in Sweden still depended on fossil fuels, which would equal to 131 TWh (SEA, 2015), so, to fulfil the goal, the same amount of renewable energy would be needed to replace the fossil fuels. A similar share (34%) of the domestic energy consumption came from bioenergy in 2013 (SEA, 2015). Other sources that can be seen as carbon neutral and that also have a large share of the energy generation in Sweden are hydropower and nuclear power (SEA, 2015). However, the opportunities for expanding these sources are limited (SEPA, 2009; SOU, 2014), and the latter is even planned to be phased out (SEPA, 2011), which are factors that together with the climate-related goals may lead to an increased demand for forest bioenergy feedstock in Sweden (e.g., Börjesson et al., 2017). This could induce substantial changes in the current management and use of forests.

According to the Swedish environmental quality objective “Reduced climate impact”, climate-related goals should be

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achieved without jeopardizing other goals of sustainable development, such as, biological diversity should be preserved and food production should be assured (Govt. prop. 1997/98:145 and 2004/05:150; SEPA, 2012b). According to another Swedish environmental quality objective, "Sustainable forests", the value of forests for biological production must be protected, at the same time as biodiversity, cultural heritage and recreational values are safeguarded (Govt. prop. 1997/98:145 and 2004/05:150). However, according to SEPA (2015), it will not be possible to achieve these objectives by 2020 under current development and policies. On EU level, to combat climate change, the EU Renewable Energy Directive (2009/28/EC) aims to promote renewable energy sources and to reduce greenhouse gas emissions in a sustainable way, ensuring that negative effects on ecosystem services and biodiversity are avoided (EC, 2001, 2010). Thus, it is essential to integrate multiple ecosystem services and biodiversity in assessments of policies and plans for increasing use of forest biomass as a renewable energy source.

Today, forest management in Sweden is to a large extent focused on production of industrial wood (sawlogs and pulpwood). Biomass for bioenergy is extracted as harvest residues, mainly tops and branches, and is consequently a by-product of industrial wood production at present. A large share of forest bioenergy also comes from industrial by-products such as black liquor, wood chips, sawdust and bark. In current forest practice, only a part of the technical potential of harvest residues is harvested in Sweden. For instance comparing actually extracted amounts 2015 (SEA, 2016) with the estimated potential 2010–2019 (SFA, 2015) would imply that around 24% is used, and stumps are only harvested on experimental scale (Melin, 2014). To begin with, an increased demand for bioenergy would probably increase the extraction of harvest residues, possibly also stumps. At higher levels of demand, the bioenergy sector might compete with forest industries for raw material, with the wood board industry as well as with pulp and paper producers (Carlsson, 2012; Jonsson, 2012, 2013; Lauri et al., 2014). The sawn wood industry may also be directly affected by competition from bioenergy demand under higher prices for energy wood, and in a transition to green economy where wood is a renewable material used on large scale to substitute, e.g., fossil-based products (EC, 2012), the overall demand for wood can be foreseen to increase.

Industrial forestry has been identified as a major cause of depletion of forest biodiversity, mainly due to the simplification of forest structure and the loss of old trees and dead wood (Berg et al., 1994; EEA, 2010; Puettmann et al., 2009; Thompson et al., 2011), even if plans and actions are carried out to protect biodiversity (Eriksson et al., 2015). An increasing demand for wood may call for new forest management practices to increase the supply in Sweden (Larsson et al., 2009; Lidskog et al., 2013). Intensified forestry could increase the biomass production through planting of monocultures of native or introduced tree species, forest fertilization and application of shorter rotation times. Intensified forestry resulting from increasing demand for industrial wood and bioenergy feedstock can be expected to have negative impacts on biodiversity by reducing habitat size and connectivity in forest landscapes (Hanski, 2011; Larsson et al., 2009; Ranius and Roberge, 2011). Further impacts may result from increased extraction of forest residues for bioenergy (e.g., de Jong and Dahlberg, 2017; Hedin et al., 2008). Thus, trade-offs between biodiversity and forest biomass production will be a major challenge for energy and climate policies.

Forests provide a multitude of ecosystem services, beside industrial wood, bioenergy and habitat supporting biodiversity, such as cultural ecosystem services including recreation, aesthetics and cultural heritage (Fredman and Tyrväinen, 2010; Milligan and Bingley, 2007; Sonntag-Öström et al., 2014). Forests also play an important role in carbon storage for mitigating climate change (Canadell and Raupach, 2008; Pan et al., 2011). Forests are responsible for almost half of the total terrestrial photosynthesis, and improved carbon-focused forest management has been shown to almost always result in net carbon sequestration (Malhi et al., 2002). The supply of ecosystem services and the balance between them will depend on forest management strategy on both stand and landscape scales. However, there are trade-offs to be made between all these ecosystem services since it may not be possible to increase the supply of one ecosystem service without affecting some other ecosystem service negatively. Even if such trade-offs are seldom analysed in energy assessments (Pang et al., 2014), assessment of ecosystem services is currently a rapidly growing area of research. Depending on the ecosystem service in focus and the geographical scale, different models and techniques have been used. Many assessment initiatives have been large scale, e.g., global (the Millennium Ecosystem Assessment; MEA, 2005) or European (the RUBICODE project; Vandewalle et al., 2009), and may provide important information for policy and decision making on international level, but there is a need for studies that can support decision making on national, regional and local level (Burkhard et al., 2010).

Although the research on forest ecosystem services have kept growing, the trade-offs between services are still poorly understood (Filyushkina et al., 2016). Currently, most trade-off analysis on forest ecosystem services are focused on comparison of two ecosystem services, such as the conflict between bioenergy extraction and carbon storage (Bottalico et al., 2016; Hoel and Sletten, 2016). Many studies provide biophysical mapping of ecosystem services, i.e., descriptions of the present state, but with no projections of possible future trends or with projections based on historical trends or simplified assumptions on future development. In a few studies, development of multiple ecosystem services and trade-offs among them have been projected over time (Forsius et al., 2015; Verkerk et al., 2014). However, some ecosystem services have a spatial component and have to be considered in a landscape context, such as the spatial distribution of habitat for species and of recreation areas for people. Most policy assessments of ecosystem services conducted so far have not included such spatial aspects in long-term projections. A critical issue is thus to develop models that enable projections of the development of different ecosystem services on landscape level as a function of the forest management.

The aim of this study was to develop methods for integrated sustainability assessment of alternative forest management policies, for long-term provisioning of various ecosystem services, considering climate and other environmental and societal goals. Two scenarios based on different land-zoning policies with related forest management strategies were simulated for Kronoberg County, a study area in southern Sweden. This was done using the recently developed LandSim model which is a spatially explicit model for long term projection of forest development (Pang et al., 2017). Building on previous studies, this paper connects existing models for projection of industrial wood production, bioenergy feedstock and carbon storage with spatially explicit methods for recreation area assessment and habitat network assessment. In this way it was possible to analyse trade-offs and synergies among five ecosystem services: provision of industrial wood and bioenergy feedstock, forest carbon storage, recreation areas and habitat networks for selected focal species. We integrated methods and models in a Landscape simulation and Ecological Assessment (LEcA) tool in order to project the corresponding changes of the ecosystem services under alternative forest management scenarios. The LEcA tool thus aims to provide decision support to stakeholders for integrated sustainability assessment of policy and planning alternatives.