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Projecting effects of intensified biomass extraction with alternative modelling approaches

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Abstract

The effect of intensified biomass extraction on forest ecosystems is a timely question since harvest residues are increasingly utilised to produce energy and the impacts of the changed management practises are not always well understood. We compared two different modelling approaches, the MOTTI-YASSO and the EFIMOD-ROMUL model combinations, with respect to the simulated impacts of the biomass extraction in final felling on subsequent biomass and soil carbon stocks. Simulations following the latest silvicultural recommendations over a rotation were made for six Finnish forest sites varying in fertility, tree species and latitude. Model-projected effect of the intensified biomass extraction was larger with EFIMOD-ROMUL than with MOTTI-YASSO. The soil model ROMUL projected slower decomposition of organic matter than YASSO at all studied sites, which made the effect of biomass extraction on soil larger with EFIMOD. The process-based model EFIMOD-ROMUL includes feedback from soil nutrient status to productivity. With EFIMOD-ROMUL, the intensified biomass extraction decreased slightly the simulated growth of the forests and thereby the biomass carbon stock and litter input to the soil. With the empirical MOTTI model, the intensity of the simulated biomass extraction did not affect forest growth. Our results underline the importance of the selection of the modelling approach when projecting the potential effects of forest management practises on forest carbon balance.

Keywords: Biomass extraction; Carbon balance; Forest management; Harvest residues; Model comparison; Slash removal

1. Introduction

Possibilities to alleviate the human induced increase of greenhouse gases in the atmosphere have introduced carbon management as one of the multiple objectives of forest management (Brown et al., 1996). Carbon in forests is bound to vegetation and soil, which are stocks of different dynamic properties. Globally, forest soil is a remarkable carbon stock (Jobbágy and Jackson, 2000), and its share of the total forest carbon stock in the boreal zone is particularly significant (e.g. Liski et al., 2002).

The effects of different forest management regimes on forest carbon stocks are often studied with simulation models (Rolff and Ågren, 1999; Karjalainen et al., 2002; Peng et al., 2002; Masera et al., 2003; Mikhailov et al., 2004; Thürig et al., 2005). Models are seen especially valuable for the estimation of soil carbon stock changes, since the direct measurements of that stock are hindered by the large spatial variability commensurate with the relatively slow changes in stock (Conen et al., 2004). Differences in selected time and spatial scales where models operate, as well as differences in model assumptions, naturally affect model results and thereby how models respond to different forest management actions. Model validation, including different forest management actions, is difficult since relevant long-term data, especially soil data, are rare. Model comparisons, both qualitative reviews (e.g. Mäkelä et al., 2000; Landsberg, 2003; Peltoniemi et al., 2007) and

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quantitative comparisons of the model performance (e.g. Smith et al., 1997), bring useful information of the model properties by relating varying model results to differences in model assumptions. There are, however, only few model performance comparisons including the aspect of forest management (Matala et al., 2003; Schmid et al., 2006).

The effect of the intensified extraction of harvest residues on forest ecosystems is a timely question, since forest residues as well as stumps are seen as a potentially large renewable energy source (EEA (European Environment Agency), 2007). Intensive extraction of biomass in loggings has been noticed to affect, directly and indirectly, following development of both the carbon stocks of biomass (Jacobson et al., 2000; Nord-Larsen, 2002) and soil (Johnson and Curtis, 2001; Jandl et al., 2007). As a topic of model comparison this suits well, since the management itself can be implemented straightforward by varying the extracted amount of biomass by compartments. It can be expected that process level differences in the models may considerably affect simulated impacts on the carbon balance.

When determining greenhouse impact of forest residue energy from the life cycle perspective (e.g. Savolainen et al., 1994), the decomposition of harvest residues at a forest site is seen as an alternative emission source to the burning of the residues for energy. The estimate of the alternative release of carbon from the forest into the atmosphere is affected by the decomposition model in use. Following the decomposition dynamics of the residues is also one of the most straightforward ways to compare the decomposition models.

The intensity of forest residue utilisation in harvests and decomposition of harvest residues were selected to compare two modelling approaches on forest carbon balance and especially the soil carbon balance. The modelling approaches were: (1) the empirical stand simulator MOTTI (Hynynen et al., 2005) linked with the soil carbon model YASSO (Liski et al., 2005), a combination that has previously been tested in southern Finland stands (Peltoniemi et al., 2004), and (2) the individual-based process model EFIMOD (Komarov et al., 2003) with the sub-model of soil organic matter dynamics called ROMUL (Chertov et al., 2001). EFIMOD-ROMUL has been tested and applied in Finland (Chertov et al., 2003), Russia (Mikhailov et al., 2004), the Netherlands (Nadporozhskaya et al., 2006) and Canada (Shaw et al., 2006). The most relevant difference between the models, with regard to this study, is that EFIMOD-ROMUL includes the nitrogen dynamics omitted in MOTTI-YASSO.

The aim of this study was to assess the effects of intensified extraction of biomass in final felling on carbon stocks of stand biomass and soil by using two alternative modelling approaches. We were particularly interested in the importance of the effect of nitrogen feedback from soil to vegetation and the differences in decomposition dynamics between the soil models. The comparison was made with stand information from six Finnish upland forest sites and by following the latest silvicultural recommendations of the Finnish Forestry Development Centre Tapio (Anonymous, 2006).

2. Material and methods

2.1. Study sites

Six typical Finnish forest sites with mineral soils, two in southern, two in central and two in northern Finland were selected for the comparison. Table 1 shows the geographical information and the stand composition of the studied forest sites. Three were dominated by Scots pine (*Pinus sylvestris* L.) and three by Norway spruce (*Picea abies* (L.) *Karst.*). According to the Finnish classification of forest sites (Cajander, 1926), the pine sites were subxeric *Vaccinium* type (VT) and mesic *Myrtillus* type (MT) and the spruce sites were moist and highly productive *Oxalis-Myrtillus* type (OMT) and mesic *Myrtillus* type.

The study sites were established by the Finnish National Forest Inventory (NFI) for permanent monitoring. Stand data were measured in 1985, and soil data from the same sites were measured between 1986 and 1989 (Tamminen, 2003). The climatic variables for the sites were taken from a model that calculates monthly temperature and rainfall surface for Finland using long-term monthly weather station data (Ojansuu and Henttonen, 1983).

2.2. Stand models

Input information and runtime assumptions of the studied models are given in Table 2.

Table 1
Site information

Study site	Site type	Dominant tree species	Geographical co-ordinates [N–E]		Climate information	
			Latitude	Longitude	DD5 (°C days)[a]	Prec[b] (mm)
VT Pine south	Subxeric	*Scots pine*	60°40′	27°54′	1363	628
MT Pine central	Mesic	*Scots pine*	63°07′	28°17′	1168	600
VT Pine north	Subxeric	*Scots pine*	66°50′	28°11′	780	531
OMT Spruce south	Most productive	*Norway spruce*	61°38′	23°06′	1210	593
MT Spruce central	Mesic	*Norway spruce*	62°41′	26°05′	1147	624
MT Spruce north	Mesic	*Norway spruce*	64°23′	29°21′	960	591

[a] Effective temperature sum with 5 °C threshold calculated from mean monthly temperatures.
[b] Annual precipitation.