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Dead wood creation to compensate for habitat loss from intensive forestry

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ABSTRACT

Negative consequences of human activities for biodiversity may be mitigated by compensation measures. Although the interest in applying compensation measures is generally increasing, such measures have rarely been applied in forestry. Many boreal forests are managed by clear felling and used for timber and pulp production. There is an increasing interest in intensifying forestry by also harvesting slash and stumps for biofuel at felling. We evaluated the efficiency of combining intensified forestry production with compensation measures, by estimating the net revenue from slash and stump harvest, the cost of high stump creation, and simulating habitat amount for 680 bark- and wood-living species (fungi, beetles, lichens, and bryophytes) in Norway spruce forests in Sweden under different scenarios of biofuel harvest and compensation. We show that the harvest of slash and stumps has a clear negative effect on the habitat amount available for many species, especially for many fungi and beetles. Combining slash harvesting with the creation of high stumps results in an economic surplus and at the same time provides significantly more habitat in comparison with no slash harvesting and no high stump creation. When undertaking stump harvesting it is currently impossible to achieve such positive effects. Thus, our analyses show that compensation can sometimes be a useful tool when both economic and biodiversity goals must be achieved in forestry, but in other cases it is a better alternative to avoid the activity that causes the negative effects.

1. Introduction

Projects related to economic development often have negative consequences for biodiversity (Czech, 2008). In several countries, governmental policy states that such negative consequences should be minimised if possible, and residual effects should be mitigated by compensation measures (McKenny and Kiesecker, 2010). Employing compensation measures may be a way to balance the interests of economic development and biodiversity conservation (Fig. 1). A compensation measure mitigates the negative effects of a human activity on biodiversity by generating ecologically equivalent gains, and the measure is something different from just conducting the activity in a different way or to a lower extent. Compensation measures have rarely been applied in forestry.

Recently, there has been an increasing interest in producing energy from forest biomass, because of the lower carbon dioxide emissions from long-term stored carbon in comparison with many other energy sources (Lattimore et al., 2009). This provides new opportunities for income from forestry. However, harvesting more wood for bioenergy production may have severe environmental consequences, including loss of forest biodiversity (Berger et al., 2013) and function (Schulze et al., 2012). Species confined to dead wood are more directly suffering from forest fuel harvest than any other species (Bouget et al., 2012). It has been estimated that in the boreal zone of Europe, species dependent on dead wood constitute 20–25% of all forest-dwelling species (Siitonen, 2001). In Europe, where many previously forested regions are today strongly affected by habitat loss and degradation, many species dependent on dead wood are threatened (Nieto and Alexander, 2010). However, even in areas with much more intact forest ecosystems (such as Tasmania), there are concerns that fuelwood harvesting may have significant negative effects on threatened saproxylic species (Grove and Meggs, 2003). In managed forest landscapes, dead wood dependent species are threatened mainly due to the much smaller amounts of dead wood in managed forests compared to natural conditions (Siitonen, 2001). It may be possible to mitigate the negative effects of forest fuel harvest on biodiversity by the

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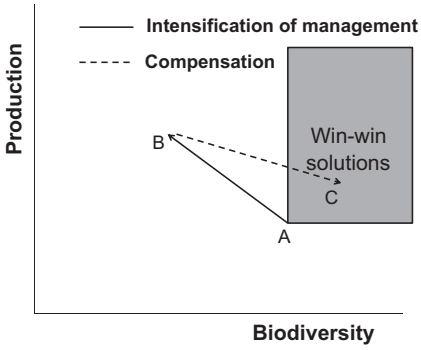

Fig. 1. Intensification of a management practice, for instance biomass harvest for energy production, tends to decrease biodiversity and increase production. This is represented by the arrow from starting point A to B. Compensation measures may be useful if it results in a change like that represented by the arrow from B to C. The overall outcome is represented by point C, which is better than point A with respect to both biodiversity and production.

Table 1
Stand characteristics used in the simulations. All stands were assumed to be 5 ha, even-aged and planted with 100% Norway spruce (from Ranius et al. (2005)).

Stand variable	Northern	Central	Southern
County	Västerbotten (montane part)	Gävleborg	Kronoberg
Vegetation zone[a]	Northern boreal, subalpine	Southern-boreal	Hemiboreal
Site index[b,c]	16	24	32
Age at felling (years)	130	82	70
Number of thinnings	2	4	4
Distance to forest road (m)	500	300	200
Distance to power plant (km)	38	38	38
Pulp wood (m^3 ha^{-1}) [d]	91	200	288
Logs (m^3 ha^{-1})[d]	98	203	191
Stems (ha^{-1})[d]	570	832	953
Stump diameter (cm)[d]	29	35	42

[a] According to Ahti et al. (1968).
[b] Height (m) of the spruce trees at the age of 100 years.
[c] Means ± standard deviations were 16 ± 2, 24 ± 2, 32 ± 3 in northern, central and southern Sweden, respectively.
[d] At felling.

creation of dead wood of high quality for species of conservation concern. Such mitigation measures could include the creation of high stumps (i.e. leaving a 3–5 m high stump of some stems at felling), which is a commonly applied method to increase the amount of dead wood habitat (Jonsson et al., 2006).

Environmental management decisions should be based on information about both the costs (e.g. biodiversity loss) and benefits (e.g. economic surplus) of different management regimes. Many studies consider the effect of forest fuel harvesting; however, so far economics (e.g. Kallio et al., 2011) and biodiversity aspects (e.g. Bouget et al., 2012) have usually been treated separately. However, recently Miettinen et al. (2013) have considered the effect of whole-tree harvesting with stump removal on several ecosystem services including biodiversity conservation, but biodiversity was not included in their numerical analysis. Some analyses consider the cost-efficiency of efforts that could be employed as compensation efforts (e.g. Jonsson et al., 2006), however, they do not include analyses of activities that they may be aimed to compensate for. Thus, the effectiveness of combining intensified forestry production with compensation has to our knowledge never been analysed.

Our objective was to evaluate the effectiveness of combining intensified forestry production with artificial creation of dead wood (high stumps) as a compensation measure to mitigate the negative effects of slash and stump harvest. More specifically, we addressed two questions: (i) Is it possible to mitigate biodiversity loss by using some of the revenues from the forest fuel harvest to pay for compensation? This was analysed by predicting to what extent harvested fuel-wood and dead wood created as compensation host the same species. (ii) How profitable is forest fuel harvesting if combined with compensation that aims at balancing the negative effects of the harvest? This was analysed by predicting economic surplus and amount of habitat given different management scenarios. The analyses included major groups of wood- and bark-inhabiting species in three Swedish regions with varying forest productivity and species pools. We considered harvesting slash and stumps at felling, since these are the two dominant types of biomass harvest for energy production in Fennoscandian forestry.

2. Methods

2.1. Forestry system

By comparing stands in three Swedish regions – northern (Västerbotten county), central (Gävleborg county) and southern (Kronoberg county) Sweden – we examined the outcome given different productivities (mainly due to the warmer climate in the south), and different species pools (Jonsson et al., 2006). The modelled stands were assigned characteristics similar to the average in each study region (Table 1). Forest management was adapted to optimise the economic outcome in terms of present value, as in Ranius et al. (2005). The stands were monocultures of Norway spruce (*Picea abies* (L.) Karst.) in the dominant management system in Sweden, including felling followed by plantation, and with between two and four thinnings during a rotation. Norway spruce is one of two dominant species in Fennoscandian boreal forests.

2.2. Simulation scenarios

We ran the simulation under one scenario without forest fuel harvesting, five scenarios with slash harvesting combined with varying levels of compensation (0%, 25%, 50%, 75%, and 100% of the net revenues from slash harvesting spent on compensation), and five scenarios with both slash and stump harvesting also combined with these levels of compensation (Table 2). Slash harvesting involves tops and branches from cut trees being harvested after felling, but other types of dead wood on the ground are also extracted (Rudolphi and Gustafsson, 2005). Based on interpretation of field data (Rudolphi and Gustafsson, 2005), we assumed that 70% of all dead wood with a diameter <10 cm is harvested at slash

Table 2
Number of high stumps created per hectare, when various percentage of the net gain from forest fuel harvest is used for compensation.

Region	Harvesting of forest fuel at felling	0%	25%	50%	75%	100%
Northern	None	0	na	na	na	na
	Slash	0	50	101	151	202
	Slash + stumps	0	54	123	162	216
Central	None	0	na	na	na	na
	Slash	0	71	142	213	283
	Slash + stumps	0	83	192	250	333
Southern	None	0	na	na	na	na
	Slash	0	54	108	162	216
	Slash + stumps	0	73	168	220	293

na = not analyzed.