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Review

The effects of logging residue extraction for energy on ecosystem services and biodiversity: A synthesis

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ABSTRACT

We review the consequences for biodiversity and ecosystem services from the industrial-scale extraction of logging residues (tops, branches and stumps from harvested trees and small-diameter trees from thinnings) in managed forests. Logging residue extraction can replace fossil fuels, and thus contribute to climate change mitigation. The additional biomass and nutrients removed, and soils and other structures disturbed, have several potential environmental impacts. To evaluate potential impacts on ecosystem services and biodiversity we reviewed 279 scientific papers that compared logging residue extraction with non-extraction, the majority of which were conducted in Northern Europe and North America. The weight of available evidence indicates that logging residue extraction can have significant negative effects on biodiversity, especially for species naturally adapted to sun-exposed conditions and the large amounts of dead wood that are created by large-scaled forest disturbances. Slash extraction may also pose risks for future biomass production itself, due to the associated loss of nutrients. For water quality, reindeer herding, mammalian game species, berries, and natural heritage the results were complicated by primarily negative but some positive effects, while for recreation and pest control positive effects were more consistent. Further, there are initial negative effects on carbon storage, but these effects are transient and carbon stocks are mostly restored over decadal time perspectives. We summarize ways of decreasing some of the negative effects of logging residue extraction on specific ecosystem services, by changing the categories of residue extracted, and site or forest type targeted for extraction. However, we found that suggested pathways for minimizing adverse outcomes were often in conflict among the ecosystem services assessed. Compensatory measures for logging residue extraction may also be used (e.g. ash recycling, liming, fertilization), though these may also be associated with adverse environmental impacts.

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1. Introduction

Increasing the contribution of bioenergy to total energy production is one means by which societies can reduce their reliance on finite fossil fuel resources and help mitigate anthropogenic climate change. The increased use of bioenergy is however changing land-management regimes over large areas, with a range of potential implications for biodiversity and ecosystem services. As both biodiversity (Cardinale et al., 2012; Hooper et al., 2012) and the direct and indirect material and energy contributions provided by ecosystems (i.e. ecosystem services) are vital to societal well-being (Millennium Ecosystem Assessment, 2005), concerns are being raised regarding the potential implications of extracting biomass for bioenergy in different production land-uses. To increase the production of bioenergy from agriculture crops may involve changes of land use (Lapola et al., 2010; Joly et al., 2015), while the outtake of bioenergy from already managed forests generally involves more subtle modification of the current management. The consequences of logging residue extraction for biodiversity and the ecosystem services provided by production forest lands are therefore less clear.

Forest-based bioenergy can be sourced by extracting additional biomass from production forest lands, or involve the use of industrial by-product residues from timber production (black liquor, sawdust, bark, etc.). In cases where biomass extraction is increased, specific concerns may be raised regarding the socio-ecological implications of these practices, which may limit the extent to which this resource is exploited (Verkerk et al., 2011). These concerns arise because bioenergy wood extraction involves both increased disturbance and outtake of biomass and nutrients from forests, which may exacerbate biodiversity loss and reduce the provision of ecosystem services. Consequently, while increased extraction of biomass for bioenergy can be consistent with renewable energy targets (e.g. in EU: Directive 2009/28/EC), it may conflict with environmental policy targets. There is thus a need to synthesize the scientific knowledge regarding the consequences of bioenergy wood extraction, and the extent to which bioenergy wood extraction can be modified to ensure the maintenance of biodiversity and ecosystem services.

Here we review the consequences for biodiversity and ecosystem services from the industrial-scale extraction of logging residues in managed forests. This extraction includes tree tops and branches (hereafter “slash”), stumps from harvested trees, and small-diameter trees provided from stand thinnings. This biomass is often referred to as logging residues, due to their lack of use as saw timber or for pulp and paper, and is otherwise left in the forest to degrade. The extraction of logging residues does not itself motivate production forestry, but value-adds to standard industrial wood harvesting. For this review we systematically surveyed the scientific literature that evaluated consequences of slash, stump and small-