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Feedstock specific environmental risk levels related to biomass extraction for energy from boreal and temperate forests

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ABSTRACT

Past research on identifying potentially negative impacts of forest management activities has primarily focused on traditional forest operations. The increased use of forest biomass for energy in recent years, spurred predominantly by policy incentives for the reduction of fossil fuel use and greenhouse gas emissions, and by efforts from the forestry sector to diversify products and increase value from the forests, has again brought much attention to this issue. The implications of such practices continue to be controversially debated; predominantly the adverse impacts on soil productivity and biodiversity, and the climate change mitigation potential of forest bioenergy. Current decision making processes require comprehensive, differentiated assessments of the known and unknown factors and risk levels of potentially adverse environmental effects. This paper provides such an analysis and differentiates between the feedstock of harvesting residues, roundwood, and salvage wood. It concludes that the risks related to biomass for energy outtake are feedstock specific and vary in terms of scientific certainty. Short-term soil productivity risks are higher for residue removal. There is however little field evidence of negative long-term impacts of biomass removal on productivity in the scale predicted by modeling. Risks regarding an alteration of biodiversity are relatively equally distributed across the feedstocks. The risk of limited or absent short-term carbon benefits is highest for roundwood, but negligible for residues and salvage wood. Salvage operation impacts on soil productivity and biodiversity are a key knowledge gap. Future research should also focus on deriving regionally specific, quantitative thresholds for sustainable biomass removal.

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1. Introduction

Much has been written on sustainable forestry practices. Research on identifying potentially adverse consequences of intensive removal of material from forests can be traced back

to the 19th century, with the work of Ebermayer [1] on the impacts of litter raking on forest growth. Past research has primarily focused on forest operations linked to traditional timber and pulp and paper wood production. However, increased use of forest biomass for energy purposes in recent

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years, predominantly spurred by policy incentives for reduction of fossil fuel use and greenhouse gas emissions as well as by efforts from the forestry sector to diversify products and increase value from the forests, has again brought much attention to this issue. Moreover, forest biomass feedstocks traded for and/or combusted under renewable energy support schemes have so far largely been comprised of forest industry by-products, i.e. processing residues such as sawdust and wood chips, and (end-of-life) waste wood such as pallets and construction wood [2]. However, new bioenergy installations, e.g. wood pellet plants, are focusing on an increasing range of feedstocks [2], namely harvesting residues and whole trees.

Both trends, volume increase and feedstock diversification, have fuelled a controversial debate on the sustainability of biomass use for energy generation [3–6]. Assessments of its benefits in terms of climate change mitigation and the environmental impacts of biomass extraction on ecosystems vary. For current decision-making processes, such as European endeavors to implement sustainability criteria for solid biofuels (e.g. in the United Kingdom [7]), it is crucial to portray the issues regarding woody biomass harvesting for energy in a comprehensive, differentiated manner, to highlight the known and unknown factors, the likelihood and magnitude of potentially adverse environmental consequences, and what could be done to circumvent them.

Earlier studies already focused on the environmental issues of forestry practices, but were either limited to single issues, e.g. site productivity [8] or biodiversity [9], or were not feedstock specific [10]. However, current decisions on future policy frameworks are giving much more attention to characteristics of specific feedstocks, such as their carbon impacts/benefits. While several temporal carbon studies of forest biomass use for energy exist, which also distinguish between feedstocks [11–20], they have not yet been included in a wider environmental assessment. Also, literature on salvage operations has so far been largely excluded from the aforementioned reviews and carbon studies. However, climate change induced forest stress and natural disturbances are expected to increase [21–24], and the logging of naturally disturbed stands (although not necessarily exclusively for bioenergy) is already common practice in many parts of the world. Moreover, in countries like Canada, the future potential of salvage wood for bioenergy production is estimated to be larger than that from harvest residues [21].

The overall objective of this paper is to provide a balanced, differentiated evaluation of the environmental factors related to woody biomass harvesting for energy by feedstock. To meet this objective, the study aims to identify the known and unknown environmental aspects related to biomass extraction for energy, before concluding upon feedstock specific risk levels and potential countermeasures to mitigate such risks. Our analysis deals with the use of forest biomass from commercial forests for energy production in the temperate and boreal climates of North America and Europe (as defined by the Food and Agriculture Organization of the United Nations global climate classification [25]). It is feedstock specific and looks at the incremental impacts of the removal of harvest residues and dead trees from salvage logging relative to conventional forest harvesting practices of using stemwood only.

After providing details on our assessment method, the paper gives a synopsis of current research literature for each environmental issue. We then derive the underlying potential risks connected to each feedstock and summarize key findings in table format. The paper closes with a discussion of our results in relation to other work, and a summary of the main conclusions.

2. Material and methods

Lattimore et al. [10] provided one of the most encompassing reviews of environmental aspects of woody biomass for energy production to date. We used the authors' work as a basis and framework for our assessment, making possible the expansion of current knowledge in a coherent manner. Our focus is on three specific aspects, reflected in the following hypotheses on the potential risks of additional forest biomass outtake for energy as compared with regular timber harvest only:

- Forest biomass harvesting reduces soil productivity (i.e. the capacity of a forest soil to sustain a growing forest);
- Forest biomass harvesting alters biodiversity;
- Forest biomass use for energy does not generate net greenhouse gas (GHG) emission savings, or only does so with significant delay, thus reducing the relevance of woody bioenergy for climate change mitigation.

The selection of these issues is based on previous scientific discussions (see e.g. Titus et al. [26] and related references), and additional aspects raised in the current debate. The latter has largely been influenced by European efforts to define sustainability criteria for solid biofuels, which in turn are fundamentally linked to existing criteria for liquid biofuels (as per Directive 2009/28/EC), requiring:

- Minimum GHG emission savings across the life-cycle (Art. 17(2));
- No use of land with high biodiversity value including primary forests, protection areas, and highly biodiverse grassland (Art. 17(3));
- No use of land with high carbon stocks (Art. 17(4)), including e.g. wetlands, continuously forested areas.

Since environmental impacts will vary between extraction volume and type of woody biomass, we apply a distinction between feedstocks, namely harvesting residues and salvage wood, plus stemwood-only as a reference case. We define harvesting residues as tops and branches from commercial timber tree species. In contrast, salvage wood is obtained from areas that are affected by natural disturbances (e.g. wind-throw, fire, insect infestation, drought) and generally available in large quantities but only over a specific time frame.

New and additional studies (to [10]) dealing with the aforementioned hypotheses and specific feedstock or harvesting practices have been derived via keyword searches in scientific journal databases and through discussions with experts in the field including policy makers, industry, research, and non-governmental organizations, e.g. at a topical workshop on sustainability of forest bioenergy at the Forêt Montmorency Research Station, Québec, Canada, in

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