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Ash recycling — A method to improve forest production or to restore acidified surface waters?

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ABSTRACT

This cost–benefit analysis compared different strategies for ash recycling in southern Swedish forests, with a special emphasis on the potential to use ash recycling as a measure to ameliorate acidification of soils and surface waters caused by acid deposition. Benefit transfer was used to estimate use values for sport fishing and non-use values in terms of existence values. The results show that the optimal share of acidified forest land that should be treated with ash depends on how optimistic one is about the effect of using ash to restore lakes and streams from acidification. More optimistic assumptions imply that the ash to larger extent should be used to ameliorate acidification. Using the most realistic assumption, given the experiences of forest liming, shows that acidified forest land should not be treated with ash with the aim of restoring lakes and streams from acidification. From a socioeconomic point of view, ash simply does more good as fertilizer on forested organic soils.

1. Introduction

The increased demand for bioenergy has created a market for use of all part of the tree, where logging residues (tops and branches) are sold as biofuels. The supply of biofuels used for district heating has quadrupled in Sweden since the 1990s of which wood fuels accounted for 32 TWh (46%) in 2010 (Swedish Energy Agency, 2011). Logging residues (henceforth we will denote logging residues by the common Swedish acronym GROT) contributed with 7.3 TWh in 2007 (Swedish Forest Agency, 2008a). The large biomass removal causes an increased export of base cations (calcium, magnesium, potassium and sodium) and other nutrients bound to the plant tissues. The base cations originate to a large extent from weathering of soils and if this process cannot balance the base cation removal by harvest, the soils are acidified (Iwald et al., 2012). To ameliorate this effect, ash generated at combustion of biofuels can be returned to the forest to complete the cycle. Besides base cations, ash recycling returns other important nutrients such as phosphorus, boron and copper, while nitrogen – limiting forest growth in most parts of Sweden (Egnell, 2011) – is lost during the combustion process. Based on 89 lime and ash application field experiments in Sweden, Finland and Norway, there are indications on that ash recycling may cause reduced forest production on less fertile soils and increased forest production on more productive soils. However, the variation is large and the relations are not statistically significant (Sikström et al., 2009). This is in agreement with earlier Swedish results (Jacobsson, 2003). In organic soils, nitrogen is rarely a limiting nutrient, while the availability of potassium and phosphorus may be restricted, reducing forest growth. Therefore, ash recycling can result in increased forest production, since the ash contains these elements (Silfverberg and Huikari, 1985).

Currently, forest growth is estimated to contribute 30–70% of the acidification of Swedish forest soils (Swedish Environmental Protection Agency, 2007). At stand level and comparing whole-tree harvesting with maximum levels of current acid deposition the acidifying effect of harvesting Scots pine is 57–108%, Norway spruce 114–263% and birch 60–171%. The percentages are estimated from the ratio between net base cation uptake by the trees, which produces soil acidity, and the amounts of acid deposition (Iwald et al., 2012). Besides soil acidification, there is a growing concern in Sweden that the depletion in soil base cation pools would also lead to surface water acidification associated with lower base cation concentrations in runoff (Swedish Environmental Protection Agency, 2007). For this reason the Swedish Forest Agency (2008b) recommends that for catchment areas of 300–2000 ha, the removal of logging residues from clear cuts and ash recycling should balance each other over a 20 year period. The need for compensatory measures is also mentioned in the Swedish Forest Agency water policy (Swedish Forest Agency, 2010). It is assumed that ash recycling is extra motivated in southern Sweden due to the historically high acid deposition, while nitrogen compensation may be more appropriate in northern Sweden.

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The aim of this study is to make a cost–benefit analysis of ash generated from forest biofuel production most profitably for the society which should be recycled and divided between mineral and organic forest soils in southwest Sweden. The economic net value of ash recycling on forest production as well as on surface water acidification is evaluated.

2. Background

2.1. The production and use of ash — market situation

There are several options on how ash deriving from combustion of logging residues can be utilized. Part of the ash is contaminated due to mixing with other types of fuel and must be deposited at waste disposal sites. However, the most common fields of application for the remaining ash is as cover material for landfills, as improved frost resistance material in gravel roads or for forest recycling (Olsson et al., 2008). A competition between these types of use can easily arise, but in this study we focus only on the ash recycling part. This can be split into two main objectives of recycling (i) to increase the forest production at organic soils and (ii) to restore forest soils and surface waters from acidification. The question then becomes — which of these two objectives should guide where in the forest the ash is recycled? Fig. 1 shows a schematic model of the logging residues and biofuel ash cycle in Sweden.

The analysis distinguishes between mineral soils and organic soils. Furthermore, the economic analysis optimizes the land use over the following five categories: M1: mineral soils which neither produce logging residues, nor receive ash, M2: mineral soils that produce logging residues, but do not receive ash, M3: mineral soils which both produce logging residues and receive ash, O1: organic soils that receive ash, and finally O2: organic soils that do not receive ash. Logging residues are not assumed removed from organic soils, since this may affect the timber production negatively (Proe et al., 1996, Egnell et al., 1998).

The total area of productive forest land in southern Sweden (Götaland) is 4,979,000 ha (Swedish Forest Agency, 2011). Of this area 4,364,200 ha is mineral soils while 582,200 ha is organic soils. The area of acidified forest land in southern Sweden is estimated to approximately 310,000 ha, and the area of acidified lakes and streams adjacent to acidified forest land is estimated to 53,000 ha (Bostedt et al., 2010). The average annual removal of logging residues in southern Sweden between 2007 and 2009 was about 989,600 m^3. Besides combustion of logging residues in district heating plants, ash is also generated by the forest industry through combustion of spill from saw mills and as a by-product of pulp factories. The volume of recycled ash in southern Sweden in 2010 was approximately 27,000 tonnes (Swedish Forest Agency, 2011).

As mentioned the ash has several alternative uses, but no explicit market for forest ash exists in Sweden. A private forest owner usually contracts a forest company to conduct the extraction of forest fuels. The forest company then sells the forest fuel to a forest fuel supplier, who has contracts with a number of energy companies or individual district heating plants, where the ash is produced. The ash is then sold to an ash entrepreneur for further refinement and distribution. District heating plants pays the entrepreneur to get rid of the ash, and private forest owners pay to distribute the ash on their land. In some areas the district heating plants themselves initiate ash recycling while in other areas it is the forest fuel suppliers who initiate ash recycling. Since no single market price for ash exists we have in the following assumed that the price of ash is equal to the district heating plants' cost for transport and distribution of ash in the forest.

In the simulations only the ash that is produced after combustion of logging residues is considered. This means that we implicitly assume that ash that comes from the forest industries – see Fig. 1 – is used for road construction or in landfills. The reason is that the ash from the forest industries usually has a lower nutrient content and a higher level of environmentally hazardous substances, which make them unsuitable for recycling on forest land (Swedish Forest Agency, 2008b).

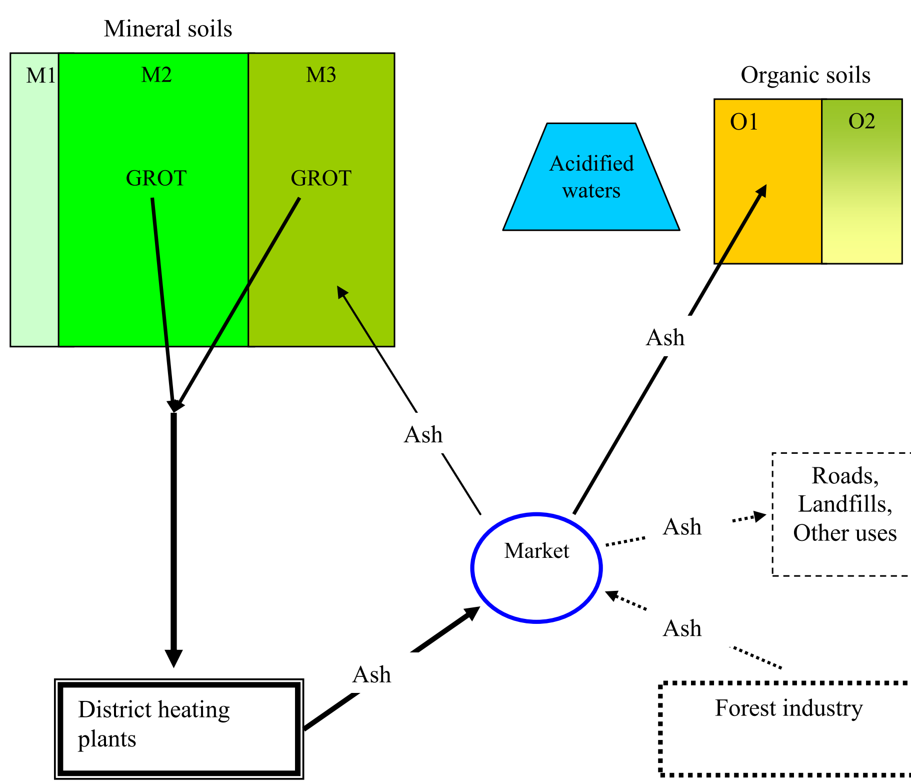

Fig. 1. Schematic model of logging residue (GROT) production and biofuel ash utilization in Sweden. This model represents the base scenario.