Forest Ecology and Management 372 (2016) 10–18

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Does clear-cut harvesting accelerate initial wood decomposition? A five-year study with standard wood material

L. Finér [a,*], M. Jurgensen [b], M. Palviainen [c], S. Piirainen [a], D. Page-Dumroese [d]

[a] Natural Resources Institute Finland, Box 68, FI-80101 Joensuu, Finland
[b] Michigan Technological University, School of Forest Resources and Environmental Science, 1400 Townsend Drive, Houghton, MI 49931, USA
[c] University of Helsinki, Department of Forest Sciences, Box 27, 00014 Helsinki, Finland
[d] USDA Forest Service, Rocky Mountain Research Station, Forestry Science Laboratory, 1221 S. Main Street, Moscow, ID 83843, USA

ARTICLE INFO

Article history:
Received 11 January 2016
Received in revised form 30 March 2016
Accepted 31 March 2016
Available online 9 April 2016

Keywords:
Coarse woody debris
Decay
Nitrogen
Pinus sylvestris
Pinus taeda
Populus tremuloides
Soil preparation
Soil temperature

ABSTRACT

Coarse woody debris (CWD) serves a variety of ecological functions in forests, and the understanding of its decomposition is needed for estimating changes in CWD-dependent forest biodiversity, and for the quantification of forest ecosystem carbon and nutrient pools and fluxes. Boreal forests are often intensively managed, so information is needed on the effects of timber harvesting on wood decomposition, and the factors controlling the decomposition process. Therefore, decomposition of standard wood stakes of Scots pine, loblolly pine, and aspen were monitored in an uncut forest and in an adjacent clear-cut in Finland. Stakes of each species were placed horizontally on the top of the surface organic layer, at the organic layer–mineral soil interface, and vertically in the mineral soil to depth of 20 cm in both the uncut forest and in the clear-cut. Five stakes of each tree species were taken every year from each stake location for five years. Mass loss of wood stakes from all three species was greater in the clear-cut than in the uncut forest during the five-year decomposition period, losing an average 59.8% of their mass in the clear-cut, which was greater than mass loss by both pines (19.8 ± 3.0SE%) and aspen (43.3 ± 5.1SE%) in the uncut forest. Aspen wood stakes decomposed faster than both Scots and loblolly pine stakes in the uncut forest during the whole study period, but after two years there were no differences between the three species in the clear-cut. In the uncut forest, mass loss of stakes on the surface of the organic layer was 6–10% faster than those at the mineral soil interface or in the mineral soil. In contrast, mass loss of stakes, placed on the top of organic layer in the clear-cut was 32–35% lower than those deeper in the soil probably due to low moisture conditions at the soil surface. Wood stake mass loss was positively correlated with the sum of soil temperature degree days ($r \geqslant 0.94$). In the uncut forest mass loss was positively correlated with wood stake N accumulation, indicating that N availability was also a factor in decomposition before harvesting. Our study indicates that wood decomposition in this boreal forest is more sensitive to increased soil temperatures and N availability after clear-cut harvesting than found in earlier studies.

1. Introduction

In forest ecosystems coarse woody debris (CWD) forms heterogeneous group of residues consisting of standing dead trees, fallen logs and branches, stumps and coarse roots located either above- or below-ground. CWD serves a variety of ecological functions by providing a habitat for a diverse group of plants, including tree seedlings, animals and microorganisms (Zhou et al., 2007), and so has a key role in maintaining the biodiversity of boreal forests. CWD also plays an important role in forest ecosystem carbon (C) and nutrient cycling and soil formation (e.g., Laiho and Prescott, 2004). Thus the understanding of CWD decomposition is needed for estimating more accurate quantification of forest ecosystem C and nutrient pools and fluxes. National greenhouse gas inventories under international conventions also require estimation of changes in dead wood C stocks (e.g., Moroni et al., 2015). Reliable estimate of CWD decomposition, and its response to changes in temperature and moisture, is of prime importance in developing biogeochemical models, and predicting current and future C sinks and sources of forest ecosystems.

In pristine boreal forests of Europe the amount of above-ground CWD varies from 60 to 110 $m^3\ ha^{-1}$, and is reduced by 70–98% in managed forests due to shorter rotations, intensive harvesting of

* Corresponding author.
E-mail addresses: leena.finer@luke.fi (L. Finér), mfjurgen@mtu.edu (M. Jurgensen), sirpa.piirainen@luke.fi (S. Piirainen), ddumroese@fs.fed.us (D. Page-Dumroese).

http://dx.doi.org/10.1016/j.foreco.2016.03.060
0378-1127/

logging residues for biofuel, and the removal of dying trees to avoid pest insect outbreaks (Fridman and Walheim, 2000; Siitonen et al., 2000). Below-ground CWD consists of stumps and roots, but also above-ground tree fractions, which have been gradually buried in soil due to litterfall deposition and overgrowth of mosses. Below-ground CWD is often neglected in inventories and studies, so there are relatively few estimates of its pool size. However, existing studies indicate that below-ground CWD is usually 20–30% of the above-ground CWD in coniferous forests (Moroni et al., 2015). Clear-cutting is a common practice in European boreal forests, increasing the amount of above-ground CWD by 60–80 m^3 ha^{-1} (Hakkila, 1989), but would also greatly increase the below-ground CWD pool size as well.

In uncut cool, humid boreal forests C and nutrients are released from both above- and below-ground CWD at a slow rate, requiring tens to hundreds of years for full decomposition (Palviainen et al., 2008, 2010, 2015; Russell et al., 2014; Shorohova and Kapitsa, 2014). The decomposition rate of CWD is dependent on climatic regimes, especially temperature and moisture (Chen et al., 2000; Yatskov et al., 2003; Janisch et al., 2005; Moroni et al., 2009; Shorohova et al., 2012), as well as wood quality and the type of microbial communities present (e.g., Laiho and Prescott, 2004; Zhou et al., 2007; Kubartová et al., 2015). Surface CWD in uncut boreal forests is easily buried under litter and growing mosses, which increases its moisture content and decreases temperature (Moroni et al., 2015). Anaerobic soil conditions may develop with increasing soil moisture levels, preventing decomposition by both white-rot and brown-rot fungi (Basidiomycetes), and leading to the dominance of less effective soft-rot fungi (Ascomycetes) and bacteria (Moroni et al., 2015). Clear-cutting and post-harvest soil preparation increase soil temperatures (Kubin and Kemppainen, 1994), which can accelerate CWD decomposition rates. However, increased evaporative water loss from the soil surface after clear-cutting can reduce wood decomposition (Chen et al., 2000; Laiho and Prescott, 2004; Zhou et al., 2007; Crockatt and Bebber, 2015).

The results of clear-cutting studies on decomposition of leaf and other fine litter components are variable, and have shown an increase (Prescott et al., 2000; Lee et al., 2002; Kim et al., 1996; Prescott, 1997), no effect, or decreased decomposition rates (Kim et al., 1996; Prescott, 1997; Lytle and Cronan, 1998; Palviainen et al., 2004). Preliminary results of a chronosequence study by Janisch et al. (2005) in temperate forests indicate that above-ground CWD decomposition is higher in clear-cuts than in intact forests, in contrast to the results of Crockatt and Bebber (2015), who found that wood decomposition rate increases with distance when moving to the forest from the forest opening. These differences are likely due to differences in microclimatic conditions. How decomposition of CWD changes after clear-cutting, and the roles of temperature and moisture conditions are still poorly documented.

The total and available nutrients in CWD and soil, especially nitrogen (N) are also important factors controlling decomposition (e.g., Weedon et al., 2009; Risch et al., 2013; Shorohova and Kapitsa, 2014). CWD has high lignin content and C:N ratios, which limit the activity of fungi and bacteria in wood decomposition (Merrill and Cowling, 1965; Berg and McClaugherty, 2003). The C released as CO_2 during CWD decomposition is quickly lost into the atmosphere, whereas N either moves into the surrounding soil (Krankina et al., 1999; Palviainen et al., 2008), or is retained in the wood and accumulates over several decades (Laiho and Prescott, 2004; Palviainen et al., 2010). In most boreal forests N is of limited supply (Nohrstedt, 2001), but clear-cutting and subsequent site preparation increases soil N mineralization and availability by adding large amounts of easily decomposable organic matter to the forest floor (Smolander et al., 2000; Palviainen et al., 2004; Smolander and Heiskanen, 2007). Laboratory studies have shown that increased soil N availability accelerates decomposition of surface and buried wood (van der Wal et al., 2007). However, it is still unclear whether increased N availability after clear-cutting would have similar impacts on above- and below-ground CWD decomposition rates in forests.

The chemical composition of wood can vary widely among different tree species, which can affect their decomposition rate (e.g., Laiho and Prescott, 1999, 2004; Palviainen et al., 2008, 2010; Strukelj et al., 2013). Compared to conifers, the wood of broadleaf trees usually has higher amounts of N, lower lignin concentrations, and lower C:N ratios. Decomposition rates of above-ground conifer wood are often lower than the wood of broadleaf trees in temperate and boreal forests (Palviainen et al., 2008, 2010; Strukelj et al., 2013; Shorohova and Kapitsa, 2014). However, relatively little is known on species-specific response of below-ground wood to clear-cut harvesting and site preparation.

Therefore, we conducted a five year study in an eastern Finland boreal forest to assess the impacts of clear-cut harvesting and site preparation on the wood decomposition of three tree species. The objectives of our study were to answer three questions: (a) how does clear-cutting and subsequent site preparation affect wood decomposition of these species, (b) how does location in the soil affect wood decomposition, and (c) how does soil micro-climate and N levels in both wood and soil affect decomposition.

Mass loss of wood from Scots pine (*Pinus sylvestris* L.) and two non-native tree species, trembling aspen (*Populus tremuloides* Michx.) and loblolly pine (*Pinus taeda* L.) were used as an index of decomposition. Wood size and chemical properties have variable effects on decomposition rates (van der Wal et al., 2007), which we reduced by using standard wood stakes cut from knot-free, #1 grade boards. Non-native trembling aspen and loblolly pine were used in this study because these two species are standard substrates in a global wood decomposition project (Jurgensen et al., 2006; Risch et al., 2013).

We hypothesized that: (1) wood stake mass loss is greater in the clear-cut than in the uncut forest due to higher soil temperatures and increased soil N availability, (2) wood stake mass loss would be greater in the mineral soil than on the top of the surface organic layer due to less variable temperature and moisture conditions, and (3) aspen stakes will lose more mass than both Scots pine and loblolly pine stakes due to higher wood N contents.

2. Material and methods

2.1. Study site

The study was carried out in the Kangasvaara experimental catchment (56 ha) in eastern Finland (63°51′N, 28°58′E), which has been monitored to determine the effects of clear-cutting and soil preparation on nutrient fluxes and stocks (Finér et al., 1997). The long-term (1981–2010) mean annual air temperature for the area is +2.3 °C and precipitation 527 mm, of which about 200 mm is snowfall (Pirinen et al., 2012). The forest in the catchment is dominated by Norway spruce (*Picea abies* (L.) H. Karst.), but Scots pine, white and silver birch (*Betula pubescens* Ehrh. and *Betula pendula* Roth) and European aspen (*Populus tremula* L.) are also present. The site is classified as a medium rich *Vaccinium-myrtillus*-type (according to the classification by Cajander (1949)), and the soil as a haplic podzol (IUSS Working Group WRB, 2007) developed in sandy till having a clay content of <2% (by mass) and stone content of 28% (by volume). The underlying bedrock (granodiorite) is at a depth of 2 m.

In August 1996, 8.3 ha of the forest in the catchment was clear-cut and the rest remained intact. In September 1998 the clear-cut area was harrowed with a tractor-back mounted disc-plow and