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Coarse woody debris dynamics in a post-fire jack pine chronosequence and its relation with site productivity

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Abstract

The long-term relationships between coarse woody debris (CWD) dynamics, soil characteristics and site productivity have, so far, received little attention. The objectives of the study were to describe CWD dynamics along a post-fire chronosequence (43–86 years after fire) in jack pine (*Pinus banksiana* Lamb.) stands, assess the importance of buried CWD in terms of soil available water holding capacity (AWHC), and investigate relationships between CWD, AWHC, nutrient retention and site productivity.

Twelve jack pine stands on sandy, mesic sites of glaciolacustrine origin were surveyed. Buried wood volume within the forest floor varied between 1 and 57 $m^3 ha^{-1}$ (4–92% of total site CWD volume) and showed no relationship with time. Downed log mass accumulation followed a ''U shaped'' successional pattern with time since fire. Buried wood AWHC was negligible compared with that of the 0–20 cm mineral soil layer. The most productive sites were characterised by higher forest floor dry weight, effective CEC and water holding capacity in the mineral soil. Path analyses of relationships between organic matter content, CWD and forest floor CEC showed that CEC was conditioned by forest floor organic matter and buried wood content.
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Keywords: Jack pine; Soil organic matter; Coarse woody debris; Site index; Forest fire

1. Introduction

Coarse woody debris (CWD) made up of snags and downed logs, is part of forest ecosystem structures, or legacies, remaining from disturbances such as fires, windthrow, or insect outbreaks that consume small amounts of wood (Franklin, 1992). As such, CWD affects a disturbed ecosystem's ability to maintain key processes (Perry and Amaranthus, 1997). For example, CWD provides habitat, seedbed and food for numerous organisms (Harmon et al., 1986); stores substantial amounts of carbon (Fleming and Freedman, 1998) and nutrients (Arthur and Fahey, 1990; Means et al., 1992); provides substrate for nitrogen fixation (Hendrickson, 1991; Griffiths et al., 1993; Crawford et al., 1997); and contributes to on-site nitrogen retention through immobilization following severe disturbance (Vitousek and Matson, 1985). Downed logs can also store large quantities of water (Means et al., 1992).

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The amount of CWD in an ecosystem reflects the cumulative balance between inputs through tree mortality and outputs through respiration and export (Harmon et al., 1986). In natural stands originating from fire, causes and rates of tree mortality change with successionnal status from fire-induced mortality to self-thinning, and finally, senescence (Lee et al., 1997). Dynamics of snags and downed wood in post-disturbance stands often follow a ''U shaped'' successional pattern with higher biomass in young and older stands (Harmon et al., 1986; Sturvenant et al., 1997; Clark et al., 1998). Eventually these residues become part of the forest floor as buried wood (McFee and Stone, 1966), and finally, part of soil organic matter (SOM) stable fraction (N'dayegamiye and Angers, 1993). Hyvönen and Ägren (2001) estimated stem wood and coarse-root litter may account for 70% of forest soils' C pool.

A continuous input of organic matter is of particular relevance for coarse-textured soils where stabilisation of organic C by clay is minimal (Oades, 1988) and where most of the soil cation exchange capacity (CEC) depends primarily on its organic fraction (Baldock and Nelson, 1999). Soil organic matter also contributes to soil water retention directly through its own ability to absorb water and indirectly through its effects on soil structure. The effect of SOM on soil available water holding capacity (AWHC) increases as soil sand content increases (Baldock and Nelson, 1999). Available water holding capacity (Pawluk and Arneman, 1961; Béland and Bergeron, 1996) or site characteristics controlling soil moisture (Schmidt and Carmean, 1988) have been shown to explain a high percentage of the productivity of jack pine stands growing on coarse-textured sites. The slow organic matter decomposition rates of species such as jack pine (95% breakdown time of 71 years) (Alban and Pastor, 1993) adapted to coarse-textured sites may contribute to their ability to sustain productive forest ecosystems.

CWD water characteristics have received little attention, but Harmon and Sexton (1995) have shown that CWD ability to store water increases with decay during the first years of decomposition. We hypothesised that as decomposition proceeds and wood density decreases, the capacity of CWD to store water should increase. Buried wood contained in the forest floor of coarse-textured soils should make a significant contribution to overall soil AWHC, and as a source of organic matter, it should also contribute to CEC.

This study (1) assesses the dynamics of CWD – snags, downed logs and buried wood – in jack pine stands in relation to time since fire; (2) measures AWHC of downed logs and buried wood in relation to decomposition status; (3) compares CWD's AWHC to that of the mineral soil; and (4) tests causal relationships between time since fire, amounts of CWD, soil characteristics and site productivity.

2. Material and methods

2.1. Study area

The study area is located in northwestern Quebec, Canada (48°20′–49°20′N; 78°40′–79°15′ W). Climate is continental with mean annual temperature of 0.7 °C and total precipitation of 890 mm, falling mainly as rain (Environment Canada, 2002). The region is part of the Precambrian Shield and the topography is generally gentle. Most of the bedrock is covered with Quaternary surface deposits. Because of their dimensions, eskers are an important feature of the landscape, while a clay plain formed by sedimentation at the bottom of glacial Lake Barlow-Ojibway lies between the eskers (Allard, 1974). The transition zone between the eskers and the clay plain is covered with reworked glaciofluvial material overlaying the bottom of the lake. Soils from the study have evolved from these coarse-textured glaciolacustrine deposits and are classified as humo-ferric podzols (perudic cryorthods) (Soil Classification Working Group, 1998).

2.2. Stands selection

Potential stands where first localised using Quebec Natural Resources Ministry's forest inventory database which provides information such as stand composition, surface deposit, moisture regime and slope. All selected stands were pure jack pine, growing on coarse-textured glaciolacustrine deposits with a fresh soil moisture regime and a slope ranging from 4 to 8%. An initial visit was conducted to confirm this information. The soil moisture regime was validated using Brais and Camiré (1992) field keys. Only natural

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