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CARBON STORAGE RESPONSE TO HARVESTING AND SITE PREPARATION IN A FORESTED MIRE IN NORTHERN MICHIGAN, U.S.A.

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This study considered the effects on carbon pools in a forested mire following whole-tree harvesting and two site preparation treatments; bedding and trenching. Whole-tree harvesting, which resulted in complete removal of the overstory biomass, and bedding exhibited the greatest loss of carbon from the site. Removal of the overstory biomass and increased decomposition of organic matter were the major causes of carbon loss. Measurement of the soil carbon pools in the tree planting zone did not provide an accurate assessment of the treatment effect. Renewal of carbon accumulation will depend on the productivity and composition of the regenerating plant community and on the rate of decomposition of organic matter.

Keywords: Decomposition, organic matter, site preparation, whole-tree harvest

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INTRODUCTION

Mires are carbon (C) accumulating wetlands in which peat and living biomass comprise the two largest C pools. Physical and chemical processes associated with the soil C pool affect important wetland functions, including water quality, hydrologic properties, site productivity, element cycling, and C accumulation. Silvicultural disturbances in forested ecosystems change C pools primarily by altering the composition and productivity of the vegetation and the decomposition of soil organic matter.

An experiment was initiated in 1988 to study the effects of different types of silvicultural disturbance on C pools and wetland processes in a forested mire. This paper considers (1) the effects of whole-tree harvesting and site preparation (bedding and trenching) on C pools in soil and vegetation, and (2) how soil sampling location affects the assessment. The treatments for this experiment were selected because they are representative of common silvicultural practices in the upper Great Lakes region of the U.S.A.

METHODS

Study site

The study site is on a glacial outwash plain and represents a common soils–vegetation condition prevalent on wetlands in northern Michigan, U.S.A. The soil is typified by a 13-cm thick histic epipedon, composed primarily of *Sphagnum* moss, overlaying sandy alluvium. Beneath the epipedon, the mineral soil is sandy to a depth of 2.5 m and is acid (pH <4.2) throughout. Forest vegetation consisted of *Picea mariana, Larix laricina,* and *Pinus banksiana*; the dominant species in the shrub layer were *Vaccinium angustifolium, Chamaedaphne calyculata*, and *Ledum groenlandicum*.

Experimental and treatment design

A Latin square experimental design consisting of three 3 x 3 squares was used. The gradient factors associated with the Latin square corresponded to vectors that were parallel and perpendicular to the river that is adjacent to the site. The treatments consisted of (1) whole-tree harvesting (WTH), (2) WTH followed by disk trenching, and (3) WTH followed by bedding. Following WTH of the site in July, 1988, the site preparation treatments were randomly assigned to 32 m^2 rectangular plots within squares. Nine reference plots were located parallel to the squares in an adjoining uncut stand. Three subplots for soil and vegetation sampling were located along the diagonal of each plot.

Field sampling

Shrub layer biomass was estimated by weighing all stems occurring within a 1 m^2 sample quadrat; 50 quadrats were randomly located within the harvest boundary prior to harvest. Estimates of vegetation biomass were obtained from the actual mill scale of the harvested products. Woody residue was measured on each subplot following harvest according to procedures outlined by Brown (1974). Biomass estimates were converted to carbon using a factor of 0.5 (Vogt 1991).

Because the site preparation treatments modified the soil surface elevation, it was necessary to use an approach that permitted sampling the same unit volume of soil for each treatment. Three soil cores (7.6 cm diameter) were taken to a depth of 25 cm below the normal soil surface. The organic and mineral layers of the three cores were composited for each subplot. Two approaches were used to compare sampling locations for estimating soil response to site preparation. Soils were sampled (1) perpendicular to the tillage direction (whole-soil estimate), and (2) parallel to the tillage direction (tree planting zone). Soil sampling was conducted in May and September, 1989.

Laboratory methods

Biomass samples were dried at 60°C until constant weight was obtained. Soil samples were also dried at 60°C, passed through a 2-mm sieve, and stored at room temperature. Organic C content of the peat layer was estimated by loss-on-ignition (400°C, 16 hrs) using a factor of 0.56 to convert the estimate to organic C (Howard & Howard 1990). Organic C of the mineral soil was measured by the Wakley–Black method. All reported results are on a volumetric basis computed to a 25-cm soil depth.

Statistical analysis

A Latin square model was used initially to test for differences in treatment and gradient effects. The gradient factors were not significant, so a one-way analysis of variance model (ANOVA) was used to test soil C estimates for treatment differences. The ANOVA was conducted using whole-plot means. Comparisons among treatments were made using orthogonal contrasts with the level of significance at $p = 0.05$.

RESULTS AND DISCUSSION

Soil carbon

Bedding, trenching, and WTH caused a significant reduction in whole-soil C pools (Fig. 1). WTH and bedding resulted in the greatest reduction in whole-soil C content as compared to the reference stand. We attributed the reduction in soil C to increased decomposition of organic matter, which is sensitive to changes in substrate availability, soil temperature and moisture, and biomass productivity (Oades 1988). A study of cellulose on these same plots demonstrated that decomposition increased in accordance with the degree of site disturbance, and that decomposition was correlated with changes in soil temperature and aeration regimes (Trettin & Jurgensen 1992). In a recent review of forest management impacts on soil C pools, Johnson (1992) also reported that significant losses of C can occur as a result of intensive harvesting and regeneration practices, but that harvesting alone usually did not significantly reduce soil C.

Bedding and trenching had opposite effects on C content in the tree planting zone (Fig. 1). Bedding was effective at concentrating organic matter in the center of the elevated planting bed. Improvements in nutrient availability and moisture holding capacity have been measured in bedding treatments and attributed to an increase in site productivity on warm, minerotrophic wetlands (Burger & Pritchett 1988). In contrast, trenching produced a planting site that was below the natural surface elevation and had the properties of the acidic mineral soil. Because there was no surface soil mixing on the WTH and control treatments, the planting zone was considered the same as the whole-soil estimate.

A comparison among the whole-soil and planting zone techniques for sampling soil C pools demonstrated that soil C values were dependent on the sampling method. Sampling the planting zone alone can not provide an estimate which represents the entire soil, because the planting zone does not reflect the variation in the soil caused by bedding or trenching.

Soil and vegetation C pools

Biomass removal was the primary cause of C loss in each treatment (Fig. 2). Woody residue did not increase because of whole-tree harvesting. Since post-harvest shrub biomass was not measured, post-harvest measures of understory biomass were considered the same as pre-harvest for the WTH treatment and were reduced by 50% as a result of bedding and trenching. Also note that the estimate of the whole-soil C pool did not include below ground root biomass, which may contribute 1 to 17 t ha^{-1} (Grigal et al. 1985, Håland & Braekke 1989).

The quantity and distribution of C in the mire affects both its form and function. Accordingly, information on the recovery of C, particularly soil C, is important for assessing the long-term consequences of these forest management practices. Factors contributing to the recovery of C pools include site productivity potential, species composition, decomposition processes, and hydrology. The primary factor affecting organic matter accumulation in mires is the response of *Sphagnum* to treatments because it is a major component of net primary productivity in mires (Grigal 1985); *Sphagnum* is also important because it influences the chemical and physical properties of the soil (Clymo 1984). Although shrubs accounted for only 4% of the biomass on this site, the annual biomass increment and nutrient cycling of that stratum may be an important mechanism for C accumulation (Grigal et al. 1985). Clearly tree biomass is an important C pool on the site, and recently Laine and Vasander (1991) and Vompersky et al. (1992) reported that C stores on drained mires may increase as a result of changed site conditions and tree productivity. Whether that is a generalized response that is applicable to undrained sites needs to be established.

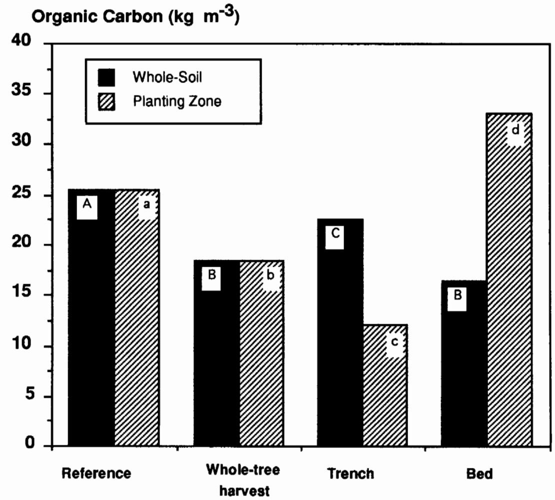

Fig. 1. Estimates of organic carbon (C) in soil based on samples taken perpendicular to the tillage direction (whole-soil estimate) and within the tree planting zone for a reference site and three silvicultural treatments (whole tree harvesting, trenching, and bedding). Soils were sampled to a depth of 25 cm. Whole-soil means with same upper-case letter are not significantly different, planting zone means with same lower-case letter are not significantly different, p = 0.05.

CONCLUSIONS

Whole-tree harvesting caused a 35% reduction in C storage on the site. Change in organic matter decomposition as a result of trenching and

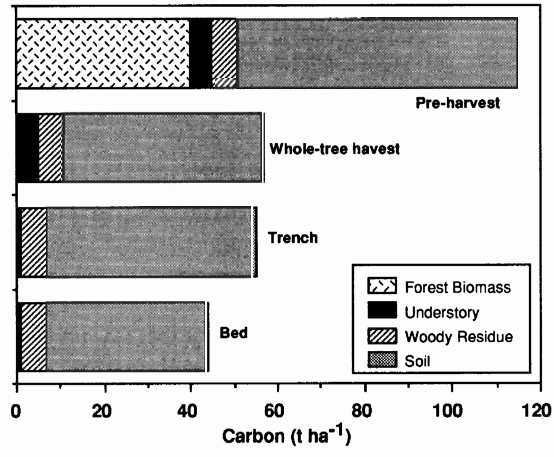

Fig. 2. Estimates of carbon (C) pools for pre-harvest conditions and following whole-tree harvesting, bedding, and trenching of a forested mire.

bedding further reduced C storage 16 to 23%. Although below ground biomass and all post-disturbance biomass pools were not measured, results of this study demonstrate that significant proportions of the C reservoir in this forested mire were depleted as a result of WTH, bedding, and trenching. How the C accumulation function of this site recovers depends on treatment impacts to soil fertility and moisture conditions, species composition, and decomposition rates of organic matter. From a silvicultural perspective, bedding provided the best site conditions for artificial regeneration. Whether anticipated benefits of improved stocking and productivity are realized by bedding, and whether it will compensate for loss of site C is yet to be determined.

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