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Evaluation of coarse woody debris and forest litter based on harvest treatment in a tupelo-cypress wetland

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ABSTRACT

Nutrient cycling in forested wetlands can be temporarily disrupted following timber harvesting, primarily through the removal of woody biomass. Impacts to the carbon (C) cycle are especially pronounced. An important component of the C cycle in wetland systems is detrital biomass deposited onto the wetland floor. The objective of this study was to evaluate impacts of harvest treatments to detrital biomass, which consists of coarse woody debris (CWD) and forest litter. In 1986, a tupelo-cypress wetland was logged to primarily investigate long-term impacts of two timber harvest treatments. The two harvest treatments were helicopter harvest (HELI) and helicopter harvest followed by simulated skidder removal (SKID). Adjacent to the treatment plots was an undisturbed reference area (REF). Volumes of CWD and CWD C mass for each treatment were determined along with mass of C from the forest litter. Combining C masses of CWD and litter revealed SKID treatments contained the most detrital C on the forest floor with 6.53 megagrams of C per hectare (Mg-C/ha) followed by HELI (5.94 Mg-C/ha). REF plots contained 4.15 Mg-C/ha. Results show that initial impacts to detrital production following harvest in SKID and HELI treatments were only temporary and the two harvest treatments are currently depositing more C onto the wetland floor than REF treatments, largely due to increased CWD deposits. Percentage of detrital C to aboveground C in the two treatments was shown to be higher than REF treatments. The exchange of aboveground living biomass for CWD would initially reduce C storage within the study plots; however this increase in debris would lead to accelerated nutrient cycling which would promote the future growth of aboveground biomass within the plots. This would indicate that harvest treatments are on an acceptable trajectory for recovery 24 years after harvest.

1. Introduction

1.1. Harvesting in forested wetlands

Forested wetlands in the southeastern United States with long hydroperiods, dominated by water tupelo (*Nyssa aquatica* L.) and bald cypress (*Taxodium distichum* (L.) Rich.), are often referred to as tupelo-cypress wetlands, deepwater swamps, or muck swamp (Hodges, 1997; Kellison and Young, 1997). These forested wetlands have long been valued by society as sources of timber and have been managed for centuries employing a wide range of logging techniques (Loehle et al., 2009; Willingham, 1990). Today, ground-based harvesting systems using wide-tired skidders are the most common and cost-effective means of wood extraction for wet sites (Stokes and Schilling, 1997). Timber removal by helicopter is also used under wet conditions but to a much lesser extent than skidder removal (Stokes and Schilling, 1997).

Relatively little information exists regarding impacts of timber harvesting in deepwater swamps. It is only in recent decades that studies have investigated effects of silvicultural practices in these systems, and even then most studies are limited to short-term results (Conner and Buford, 1998). These previous studies report the main impacts of harvesting timber in deepwater swamps are soil disturbance, changes in water quality, and changes in biogeochemical cycling.

One important biogeochemical process that is greatly affected by timber removal is forest C cycling. Timber harvesting removes a significant amount of biomass from the forest C pool (Turner et al., 1995). On average, half of the total US forest C is present in aboveground biomass, which includes trees, woody debris, forest litter, and understory (Turner et al., 1995). Harvesting operations initially will result in an increase in woody debris, but the amounts are small compared to large reductions in the other three components. Harvesting also can lead to changes in below ground C pools as well. Loss of soil organic C results from decreased litter inputs, changes in root systems, increased soil temperature, and decrease in net primary productivity (Lal, 2005).

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1.2. Forest detrital C

A critical part of the C cycle is the transfer of detrital biomass from the plant to the forest floor. Forest debris, in the form of woody debris and forest litter, only makes up a small percentage (16%) of the total C pool in US forests (Turner et al., 1995). This is partially the reason why forest debris historically has been overlooked in forest management. It was not until recent decades that scientists and forest managers came to realize the role that forest debris plays as a source and sink of C, nutrient regulator, wildlife habitat, fire fuel, and indicator of forest ecosystem health.

Woody debris includes all the forms of aboveground dead woody material and is generally divided into two broad categories: downed coarse woody debris (CWD) and snags (Harmon and Sexton, 1996). The USDA Forest Service (2007) defines CWD as downed, dead tree or shrub boles, large limbs, and other woody pieces that are severed from their original source of growth. This would include naturally occurring debris, as well as debris produced during timber harvesting. Coarse woody debris can influence hydrology and increase sedimentation by increasing surface roughness, thereby slowing flow velocity (Hagan and Grove, 1999; Swanson and Lienkaemper, 1978). Coarse woody debris also plays an important role in biogeochemical cycling of C and soil organic matter formation (Bradford et al., 2009). Furthermore, CWD has been shown to be a useful indicator of site productivity and management effects (Huston, 1996; Jones et al., 2008). Changes in the volume of CWD could indicate a shift in species composition or biomass production.

Forest litter is defined as loose plant material found atop mineral soils (USDA Forest Service, 2007). Forest litter is a significant part of biogeochemical cycling within a forested wetland (Baker et al., 2001). An estimated 43% of the total aboveground net primary productivity is represented by leaf material that returns to the forest floor annually (Conner, 1994). Therefore, forest litter can be a large source of C and nutrients within a forested wetland.

1.3. Long-term harvesting study

To address past concerns that logging in forested wetlands could lead to lasting effects on site productivity a long-term study was initiated to investigate the impact of various harvesting techniques (Aust and Blinn, 2004; Aust et al., 1997). Within the 25 ha study area, three major treatments were arranged in three 60 m $\times$ 60 m plots in a 3 $\times$ 3 Latin Squares design with an adjacent 3 $\times$ 3 reference area (Fig. 1). In the fall of 1986, the entire treatment area was clearcut with chainsaws and timber was removed using a Bell 205 helicopter (Bell Helicopter, Hurst, TX). This represents the treatment for plots designated as helicopter harvest (HELI). A Franklin 105 skidder (Franklin Treefarmer, Franklin, VA) with 86 cm wide tires was used to simulate ground-based harvesting in plots designated as skidder harvest (SKID). Skidder treatments resulted in tire ruts covering approximately 50% of the plot with an average depth of 30 cm. The third treatment (GLYP) consisted of glyphosate herbicide (The Monsanto Company, Creve Coeur, MO) being applied during the first two growing seasons to remove coppice and seed regeneration. The GLYP treatment was not meant to represent typical harvest techniques, but rather to investigate coppice and seed regeneration and to represent a severe site disturbance. This treatment resulted in plots converting to herbaceous-dominated marshes, which is not an effect of typical clearcutting practices. The adjacent reference area (REF) remained undisturbed without harvesting or glyphosate treatment. The majority of the stand was age 70-years in 1986, 94-years in 2010. REF plots could not be integrated within the treatment Latin Square design due to helicopter safety concerns during harvesting. Pre-harvest measurements showed no statistical difference between reference and treatment areas. Detailed information about the study site can be found in Aust et al. (2006) and McKee et al. (2012).

Aust et al. (1997) evaluated site properties and stand growth 7 years after harvest. The authors found that HELI and SKID treatments contained equivalent amounts of biomass and species present, but the distribution was not the same. HELI plots contained more Carolina ash (*Fraxinus caroliniana* Mill.) while SKID plots contained almost twice as many water tupelo stems. The authors suggest that soil disturbance in SKID plots produced a wetter site that was more favorable to the water-tolerant water tupelo, while suppressing the growth of competing species such as Carolina ash. Both treatments contained large amounts of black willow (*Salix nigra* Marsh.), which were not present in the REF plots. The GLYP plots were converted into an herbaceous-dominated marsh with approximately 20 times less stems/ha than the other two harvest treatments. Sixteen years after harvest, HELI and SKID plots contained approximately 20% of REF plot biomass, which was deemed satisfactory (Aust et al., 2006).

One aspect that was not evaluated as a part of this long-term study was the impact harvesting has on the detrital portion of

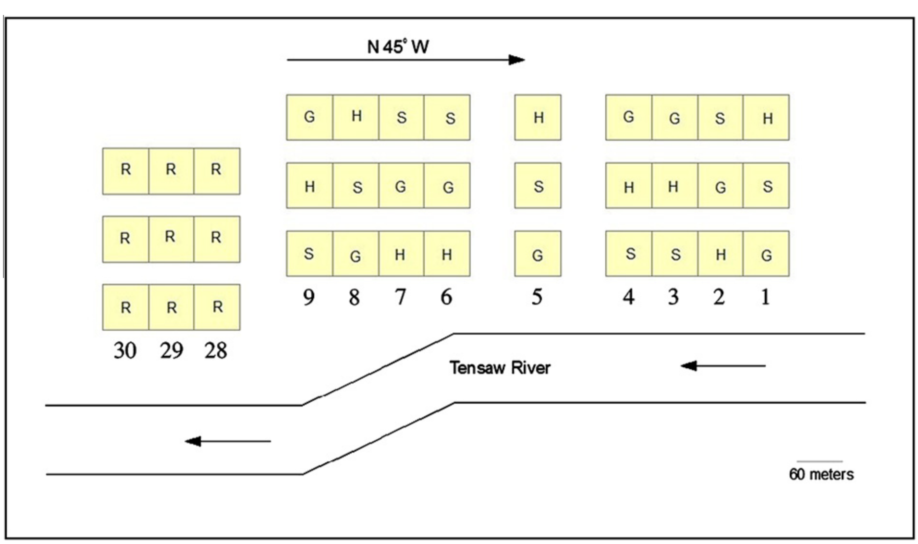

Fig. 1. Study site treatment arrangement. R = undisturbed reference area (REF); H = helicopter harvested (HELI); S = skidder simulated harvest (SKID); G = glyphosate treatment (GLYP). Plots are 60 $\times$ 60 m. Adapted from Aust and Lea (1991).