Available online at www.sciencedirect.com
SCIENCE DIRECT
Forest Ecology and Management 226 (2006) 72–79
Forest Ecology and Management
www.elsevier.com/locate/foreco

Long-term effects of helicopter and ground-based skidding on site properties and stand growth in a tupelo–cypress wetland

W.M. Aust [a,*], T.C. Fristoe [b], P.A. Gellerstedt [c], L.A.B. Giese [d], M. Miwa [e]

[a] Department of Forestry, 228 Cheatham Hall, Mail Code 0324, Virginia Tech, Blacksburg, VA 24060, USA
[b] Plum Creek Timber Company, Crossett, AR 71635, USA
[c] North Carolina Division of Forest Resources, Mebane, NC 27302, USA
[d] Wetland Studies and Solutions, Inc., 14088-M Sullyfield Circle, Chantilly, VA 20151, USA
[e] International Paper Company, Bainbridge, GA, USA

Received 24 October 2005; received in revised form 12 December 2005; accepted 12 December 2005

Abstract

Ground-based timber harvesting operations in forested wetlands have the potential to cause soil disturbances. Soil disturbances on upland sites have been linked to reduced site productivity, but the effects of such disturbances on the long-term site productivity of bottomland hardwoods is not well documented. In 1986, a long-term research project was established to compare the effects of helicopter and skidder timber harvesting on the regeneration, growth, and development of naturally regenerated water tupelo (*Nyssa aquatica*)–baldcypress (*Taxodium distichum*) stands. At stand age 16-years, both treatments have well-stocked, vigorously growing stands composed of coppice-regenerated water tupelo, Carolina ash (*Fraxinus caroliniana*), baldcypress, and seed-origin black willow (*Salix nigra*). Although both treatments are well stocked, the skidder treatment favored the establishment and growth of water tupelo, while the helicopter treatment had greater densities and growth rates for Carolina ash. Apparently, the initial effects of the skidder traffic puddled the soils and resulted in more reduced soil conditions, which favored the very flood tolerant water tupelo rather than the less flood tolerant species. Stand growth parameters suggest that both treatments will produce stands that will be similar to the previous stand in terms of species and volumes. Recovery in this area was speeded by annual inputs of nutrient rich sediment, the shrink-swell nature of the soil, and rapid growth of the coppice regeneration.

Keywords: Forested wetlands; Timber harvesting impacts; Sediment; Soil physical properties; Soil chemical properties; Site recovery

1. Introduction

Forested wetlands, such as bottomland hardwoods, are valued by society because they may influence ecosystem functions such as hydrology (e.g., flood duration and depth), water quality (e.g., sediment and nutrient inputs and chemical transformations), nutrient cycling and food chain support (e.g., net primary productivity, biogeochemical cycling, decomposition), habitat (e.g., stand characteristics), and socio-economics (e.g., timber harvesting, recreation) (Walbridge, 1993; Daniels and Gilliam, 1996; Klapproth, 1996; Welsch, 1996; Sheridan et al., 1999) Timber harvesting operations in forested wetlands have been viewed with concern because of the potential effects that such operations may have on ecosystem functions and their societal values (Shepard, 1994). Specifically, environmental agencies and land managers have been concerned about the potential effects that forested wetland timber harvesting might have on water quality and site productivity (Aust and Blinn, 2004). Since passage of the Federal Water Pollution Control Act of 1972 and its amendments, most states have specifically developed forestry best management practices (BMPs) to minimize the potential impact of harvesting operations (Sun et al., 2001). However, there have been very few studies that have monitored the long-term effect of forest harvesting within forested wetlands. The purpose of this paper is to compare the effects of two harvesting systems (helicopter versus ground based skidding) on various indices of wetland functions for 16 years following clearcut harvesting.

2. Methods

2.1. Study site location

The study site is located within the Mobile-Tensaw River Delta (longitude: 87°53′17″W, latitude: 30°58′31″N), which is

* Corresponding author. Tel.: +1 540 231 4523; fax: +1 540 231 3330.
E-mail address: waust@vt.edu (W.M. Aust).

0378-1127/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2005.12.059

the second largest river delta in the United States. The Mobile-Tensaw River Delta is formed below the confluence of the Alabama and Tombigbee Rivers that have a combined watershed size of 11.6 million ha (Smith, 1988). These watersheds extend into four states and five major physiographic provinces. The actual Delta contains approximately 105,000 ha of wetlands and 89,000 ha of forested wetlands. The river systems within the Delta are braided and abandoned river channels are common. The three largest rivers within the 11 km wide Delta are the Mobile, Middle, and Tensaw Rivers (Smith, 1988). Our study site is located on the western bank of the Tensaw River. Climate of the area is subtropical with a mean annual temperature of 20 °C, 250 frost-free days, and less than 3 weeks below freezing. Average annual precipitation is relatively even in distribution and equals 1600 mm (Riccio et al., 1973).

2.2. Site history

Our study site is located on the western bank of the Tensaw River approximately 4.5 km southwest of Stockton, AL. The area was extensively used by Native Americans and the site lies between a large mound and several large shell middens. During the late 1700s the site belonged to Major Robert Farmer who hosted William Bartram during his botanical visit to the region (Mader, 1990). Bartram described the cypress and tupelo in the Delta in his journal.

Sporadic cypress harvesting occurred in the Delta during the 1700s and one of the first sawmills in Alabama was built across the river from the study site. Based on the courthouse records, stand age structure, and on-site evidence, our site has been harvested at least twice prior to our investigation. The site has numerous ancient cypress stumps, greater than 1.8 m in diameter that have axe and saw marks greater than head height. Based on the courthouse records and older residual trees, these stumps were left during a float logging operation that occurred during the 1860s. The site was next harvested in 1915 with a pull-boat operation. This operation used steam powered cable yarders located on the riverbank to drag stems for distances up to 600 m (Mader, 1990). This type of operation was widely used in the delta from around 1890 until the 1930s and abandoned pull boat channels from 30 to 150 cm depth were located approximately every 20–50 m across our study site.

2.3. Preharvest characterization

Prior to treatment installation we collected baseline data. During the spring, summer, and fall of 1986 we found that the site was uniform in terms of hydrology, topography, soils, and vegetation, although the site became slightly wetter, had increased clay, and decreased understory biomass as distance from the natural levee increased.

The Tensaw River is a fresh water river at the study site, but it is tidally influenced. Tides are semidiurnal and river stages commonly range 20–50 cm diurnally. This tidal influence occasionally allows the old pull-boat runs to serve direct conduits to the river. Personnel on the site have observed both inflows and outflows in the same channel during the day. Squirrel Bayou also bounds the western side of the study area. During the winter months when evapotranspiration is minimal and during high rainfall periods, such as hurricanes and tropical depressions, the site floods to depths greater than 1.5 m.

During summer months, when evapotranspiration is maximized, the water table ranges from 25 cm above the surface to 50 cm below the surface. Elevations within the delta range from 0 to 3 m above msl. Our study site was located at approximately 1 m. We deliberately avoided the higher natural levee area adjacent to the river for our study and evaluated the ''pond area''. This area had less than 50 cm of topographic relief across the entire area and sloped slightly downward from the riverside to the distant side.

The soils' series of the study site are very poorly drained fluvial sediments. The soil series is the Levy silty clay loam (Fine, mixed, superactive, acid, thermic, Typic Hydraquents). This site is very productive for flood tolerant species and we found the site $index_{50}$ for water tupelo (*Nyssa aquatica*) to be approximately 26 m. Total basal area averaged 75 m^2/ha and wood volumes averaged 845 steres/ha (Aust, 1989).

The float logging and pull boat operations basically created a two-aged stand for our study whereby >80% of all stems were approximately 72 years of age in 1986 and <20% were comprised of older residual stems. The average diameter of the stems was approximately 45 cm. Water tupelo was the most abundant species comprising approximately 85% of the stems. Baldcypress (*Taxodium distichum*) and Carolina ash (*Fraxinus caroliniana*) comprised 10 and 4%, respectively. Pumpkin ash (*Fraxinus profunda*), red maple (*Acer rubrum*), and water elm (*Planera aquatica*) together formed 1% of the stems.

2.4. Treatments

We included three major disturbance treatments within the major design of the project and we also retained a non-harvested area as a reference (REF). The entire disturbance area was clear-felled with chainsaws down to a 5 cm diameter, thus resulting in a biological clearcut. Then a Bell 205 helicopter was used to fly all merchantable stems from the area. This constitutes the helicopter harvest treatment (HELI).

A Franklin 105 skidder equipped with 86-cm (43 in.) wide tires was used to traffic previously harvested HELI areas in order to simulate typical ground based harvesting. The skidder trafficked the plots so severely that 52% of the area was trafficked to an average depth of 30 cm. This was the SKID treatment. We also wanted to understand the importance of coppice vegetation and herbaceous vegetation in the recovery process. In order to accomplish this theoretical treatment we removed all vegetation in treatment areas that were originally created in a manner identical to HELI with glyphosate herbicide, thereby establishing the GLYP treatment. Additional details regarding the treatments are provided by Aust (1989) and Mader (1990).

2.5. Statistical design

During the pre-harvest measurements we noticed the topographic drop as distance from the river increased. The site also