TIMBER HARVESTING EFFECTS AFTER 16 YEARS IN A TUPELO-CYPRESS SWAMP

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Abstract—A variety of concerns have been expressed regarding harvesting in forested wetlands. These concerns usually revolve around such issues as potential losses in site productivity, altered wetland functional processes, and development of appropriate best management practices. In 1985 a long-term study was established to evaluate harvest disturbance effects on water quality, soil properties, hydrology, and site productivity in a water tupelo (*Nyssa aquatica*) -baldcypress (*Taxodium distichum*) swamp. The study site is a deltaic red river bottomland within the Mobile-Tensaw River Delta in southwestern Alabama. After 1 year of baseline data collection, three disturbance treatments were installed in 1986: Clearcutting with helicopter removal, clearcutting with rubber-tired skidder trafficking, and clearcutting followed by complete vegetation control via glyphosate application. The three disturbance treatments were installed as three 3 X 3 Latin squares. Data were also collected from adjacent non-disturbed reference areas for comparison with disturbance treatments. Measurements of soil, water, and vegetation have been conducted at treatment ages 0-2, 7-8, 10, 12, and 16. The skidder and helicopter treatment plots have recovered since harvest due to frequent flooding, shrink-sell soils, and sediment accumulation on the site. Sediment accumulation on treatment plots increased after harvest and has returned to near pre-harvest levels at age 16. The skidder treatment has shown somewhat better recovery than the helicopter treatment, although the differences between the helicopter and skidder treatments are becoming less pronounced. As the treatment plots mature, the species composition is becoming similar to that of the reference area, and the treatment areas are expected to fully recover from disturbance.

INTRODUCTION

Forested wetlands provide a wide variety of functions and values including flood control, wildlife habitat, carbon storage, sediment removal, recreation, and timber production. Riparian wetlands affect water quality protection and enhancements; therefore, forest harvesting operations within wetlands are often more highly scrutinized than in adjacent upland areas. Wetland harvesting operations may also be within the jurisdiction of the Clean Water Act. It is very important that land managers have long-term data that can quantify the actual effects of timber harvesting in a forested wetland area. The overall purpose of this study is to quantify the long-term effects of timber harvesting on above ground biomass, sediment accumulation, and stand composition in a 16-year-old water-tupelo (*Nyssa aquatica*) - baldcypress (*Taxodium distichum*) wetland that was harvested with aerial and ground based systems.

METHODS

Study Area

The research site is located within the Mobile-Tensaw River Delta below the confluence of the Alabama and Tombigbee rivers in Baldwin County in southwest Alabama. The site consists of a two-aged stand of water-tupelo (85 percent), baldcypress (10 percent), and Carolina ash (*Fraxinus caroliniana*; 5 percent) situated within a "gum-cypress" pond. Harvesting in the delta during the past 3 centuries had resulted in two age classes at the establishment of the study in 1986, with the major component being 70-year-old trees with a few 130+ year-old residual stems remaining throughout the study site (Aust 1989, Mader 1990). Site productivity of the study area is high, with an average basal area of 330 square feet per acre and above ground biomass of 250 tons per acre in 1986. Site index was 85 feet at a base age of 50 years. The elevation of the site is approximately 10 feet above mean sea level. The site floods yearly with the wettest periods occurring during winter and spring due to lower evapotranspiration rates and increased runoff throughout the entire watershed. Floods during the rest of the year are common although less frequent than winter and spring floods. Seasonally, the water table on the site can range from several feet below the soil surface to 10 feet above the surface. Daily water table fluctuations, which can be several feet, are tidally influenced due to the close proximity of the site to the Mobile Bay and Gulf of Mexico (< 30 miles). Soils on the site are of the Levy series, a clayey, mixed, superactive, acid, thermic Hydraquent (USDA NRCS 1997). The soils contain both illite and montmorillinite clays, the latter lending to the shrink-swell properties of the soil.

Treatments

There were three disturbance treatments implemented on the study site as well as an adjacent undisturbed reference area used as an experimental control (fig 1). In 1986, all stems greater than 2.0 inches d.b.h. were felled by chainsaw on all disturbance treatment plots. Following clearcutting, all merchantable stems on all treatments were removed using a Bell 205® helicopter. Helicopter removal was the only method of timber removal on the helicopter (HELI) plots. Skidder harvesting was then simulated on skidder (SKID) treatment plots. Skidding simulation was performed to an average depth of greater than 12 inches using a Franklin 105® loaded cable skidder with 34 inch-wide rubber tires. Approximately 52 percent of the area within the SKID treatment plots was trafficked, commensurate with skidder harvesting in practice in the Mobile-Tensaw Delta at that time according to local procurement foresters (Aust 1989, Aust and Lea 1992). The third treatment involved removal of all vegetation via backpack spraying of the herbicide Rodeo (Glyphosate) for the first two growing seasons following harvest (GLYPH). The

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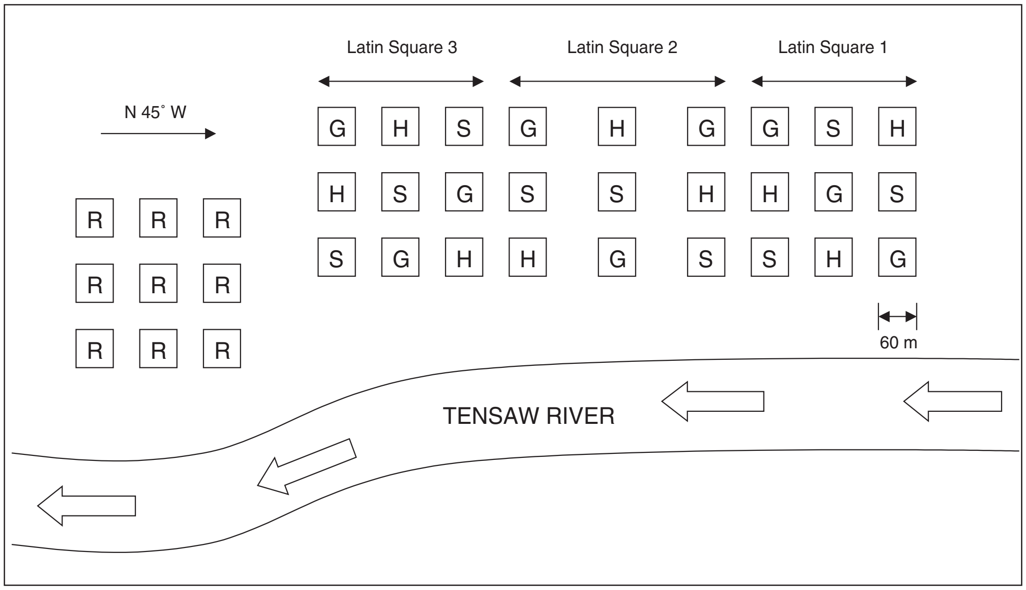

Figure 1—Mobile-Tensaw study site layout. R = Reference area; S = Skidder treatment; H = Helicopter treatment; G = Glyphosate treatment.

purpose of the GLYPH treatments was to compare the effects of vegetation versus other site factors on early site recovery after clearcutting (Aust and Lea 1991). The GLYPH plots are currently a freshwater marsh that is progressing towards a shrub-scrub, palustrine wetland. While this treatment provides an interesting study of wetland succession, it is not the focus of this paper.

Treatments were arranged in a 3 x 3 Latin Square design (Steel and Torrie 1980) to help account for potential gradients both parallel and perpendicular to the Tensaw River (fig. 1). The Latin Square design was repeated three times for a total of nine replications of each treatment. Both treatment and reference plots measured approximately 3 chains by 3 chains for an area of approximately 0.9 acre each. Reference plots were pseudo-replicated in a similar row-column pattern but could not be included in the treatment areas due to helicopter logging safety restrictions. However, the adjacent reference area and treatment area plots were compared before treatment application, and they were not significantly different from one another in terms of vegetation, soils, and hydrology. Therefore, they are suitable for use in comparison to the treatment plots.

Field Measurements and Analysis

Sediment accumulation—Nine sediment rods were installed on a grid spacing of approximately 1 chain in each of the 27 treatment plots and the 9 reference plots for a total of 324 rods in the study. The rods consist of a piece of steel rebar with a washer welded on as a benchmark for sediment accumulation. The rods were installed at the commencement of the study with the washers flush at the soil surface. The depth of sediment that accumulated (or was scoured) on the washer could then be measured periodically.

Overstory vegetation—Fixed 1/30th-acre circular overstory plots were established at all treatment and reference plot centers. All stems greater than 1.49 inches d.b.h. had the following measurements taken: species, d.b.h., total tree height, and crown class. Total biomass for each species was then determined using biomass equations developed for this site by Zaebst (1997) and Mader (1990).

RESULTS AND DISCUSSION

Stand Composition and Aboveground Biomass

There were four species that made up 98 percent of overstory species density in HELI plots and 95 percent in SKID plots at age 16: water tupelo, Carolina ash, black willow (*Salix nigra*), and baldcypress. The remainder of the species found in treatment plots included red maple (*Acer rubrum*), pumpkin ash (*Fraxinus profunda*), and water-elm (*Planara aquatica*). This is a fairly common species makeup in deep-water alluvial swamps containing tupelo-cypress stands (Larsen 1980).

One major development at stand age 16 was that black willow had started to make up a much smaller component of the HELI and SKID treatment plots (table 1). At stand age 10 (1996), HELI and SKID treatments had a black willow biomass of 13.27 and 16.41 tons per acre, respectively. By year 16 (2002), black willow comprised only 6.99 tons per acre on the HELI treatments and 9.28 tons per acre on SKID plots. Similar results can be seen in overstory species density. At age 10, HELI plots contained 436 trees per acre and SKID plots had 506 trees per acre whereas by age 16 these numbers had fallen to 173 and 223 trees per acre, respectively. Black willow is a short-lived, intolerant, pioneer species and grows aggressively from seed on disturbed wet sites (Meadows and Stanturf 1997). It is not uncommon on the research site to see 16-year-old individuals greater than 15 inches d.b.h. and 65 feet tall. However, even at age 16, the black willow component was rapidly disappearing, and the canopy gaps were being filled by the more tolerant water tupelo.

Table 1—Average density (stems per acre) and average aboveground biomass (tons per acre) of overstory trees in HELI, SKID (age 16), and REF (age 86) treatments

Common name	Genus species	HELI	SKID	REF	HELI	SKID	REF
		- - - - - -*stems per acre*- - - - -			- - - - - - -*tons per acre*- - - - - - -		
Baldcypress	*Taxodium distichum*	90	93	36	1.30	1.71	30.04
Black willow	*Salix nigra*	173	223	—	6.99	9.28	—
Carolina ash	*Fraxinus caroliniana*	1,003	740	113	8.17	5.63	4.83
Pumpkin ash	*Fraxinus profunda*	13	13	—	0.17	0.15	—
Red maple	*Acer rubrum*	16	53	—	0.32	0.46	—
Water elm	*Planara aquatica*	6	23	—	0.02	0.09	—
Water tupelo	*Nyssa aquatica*	543	676	136	25.17	31.77	182.56
Total		1,845	1,823	285	42.14	49.09	217.43

Table 2—Average basal area (square feet per acre), average d.b.h. (inches), and average total height (feet) of overstory trees in the HELI and SKID treatments at age 16

Common name	Genus species	HELI	SKID	HELI	SKID	HELI	SKID
		square feet per acre		- - -*inches*- - -		- - - - -*feet*- - - - -	
Baldcypress	*Taxodium distichum*	7.16	7.13	3.4	3.5	24.7	26.2
Black willow	*Salix nigra*	45.40	60.23	6.7	6.8	51.7	52.2
Carolina ash	*Fraxinus caroliniana*	24.40	16.77	2.2	2.1	25.4	24.4
Pumpkin ash	*Fraxinus profunda*	0.47	0.47	2.4	2.5	30.0	29.3
Red maple	*Acer rubrum*	0.85	1.31	2.8	2.2	33.2	27.4
Water elm	*Planara aquatica*	0.18	0.71	2.3	2.9	20.0	27.9
Water tupelo	*Nyssa aquatica*	54.15	70.81	4.0	4.3	35.5	36.1
Total		132.61	157.42				

Full crown closure had occurred by age 16 in both the HELI and SKID treatments, and it appeared that the rate of biomass accumulation had started to slow. After 10 growing seasons, HELI treatments had 29.36 tons per acre and SKID treatments had 38.33 tons per acre of total woody biomass for a growth rate of 2.94 and 3.83 tons per acre per year, respectively. At age 16, HELI biomass was 42.14 tons per acre, and SKID biomass was 49.09 tons per acre for rates of 2.63 and 3.07 tons per acre per year. It is likely that competition for light due to crown closure and the mortality of fast growing black willow can account for the slowdown.

Throughout the 16 years of the study, water tupelo has had greater density, growth, basal area, and biomass in the SKID treatments than in the HELI treatments (tables 1 and 2). HELI plots contained 25.17 tons per acre of water tupelo while SKID plots had 31.77 tons per acre. Water tupelo stems were also slightly larger on average in the SKID treatment, with a mean d.b.h. of 4.3 inches and height of 36.1 feet versus 4.0 inches and 35.5 feet in the HELI treatment (table 2). However, Carolina ash, an intermediate sized and less desirable timber species, comprised a greater density and biomass in the HELI plots. The preference for water tupelo on the SKID treatment was likely due to the alterations in soil properties by skidding, effectively making those plots wetter during the early years. Saturated hydraulic conductivity, soil oxygen percentage, and redox potentials were greatly reduced in both the HELI and SKID treatments compared to the REF plots after harvest (table 3). The changes to soil properties in the HELI plots were likely due to the felling of timber during harvest onto the wet ground creating indentations in the soil surface. The greatest changes in the soil properties, however, were in the SKID plots. Rutting from the skidder and load caused a loss in soil porosity, and particularly macroporosity, thus leading to a drop in saturated hydraulic conductivity and ultimately reduced soil oxygen and redoximorphic potentials (Aust and Lea 1992). The rutting reduced both horizontal and vertical groundwater flow resulting in wetter conditions in the SKID plots. The wetter conditions were most pronounced in the first two years following harvest; however, the SKID treatments were observed to have higher water tables up to 8 years after harvest (Aust and others 1997). The initially wetter conditions following harvest favored water tupelo, the most flood tolerant species found on the site. Over time, ruts have gradually filled with sediment, and the soil has been churned due to its shrink swell properties, making the SKID and HELI plots more similar in terms of soils, hydrology, and species makeup.

Table 3—Effects of HELI and SKID disturbance treatments post-harvest (1988) on saturated hydraulic conductivity, soil oxygen, and redox potential, as compared to the undisturbed REF plots

Soil property	HELI	SKID	REF
Saturated hydraulic conductivity (*inches/hour*)	3.3	1.6	7.0
Soil oxygen (*percent*)	1.8	1.4	5.4
Redox potential (*mV*)	276	182	408

Table 4—Average and total sediment accumulation in the HELI, SKID, and REF treatments after 16 growing seasons

Sediment accumulation period	HELI	SKID	REF
	- - - - -*inches per year*- - - - -		
1987 – 1988	0.9b	0.6ab	0.4ab
1989 – 1993	0.6b	0.5ab	0.3a
1993 – 1996	1.0a	0.9a	0.6a
1996 – 1998	0.3a	0.3a	0.2a
1998 – 2002	0.3a	0.2a	0.2a
Total (over 16 years)	8.3b	6.7ab	4.2a

Different letters indicate significant treatment effects within each group of years at α = 0.05.

Sediment Accumulation

Total sediment accumulation at year 16 was greatest in the HELI treatment (8.3 inches), though not significantly higher than the accumulation in SKID plots (6.7 inches; table 4). Both the HELI and SKID treatments had more accumulated sediment than the REF plots (4.2 inches), though only the HELI treatment was significantly different from the REF. Sediment accumulation was greater on treatment plots due a thick herbaceous layer that flourished following harvest and was present until crown closure when the herbaceous layer thinned out substantially (Zaebst 1997). The thick herbaceous layer essentially increased surface roughness of the treatment plots and thusly slowed down floodwaters on the site, which causes sediment deposition. Over time as the herbaceous layer was reduced, sediment accumulation in treatment plots became similar to that of the reference area.

CONCLUSIONS

Both the HELI and SKID treatments recovered well since harvest in 1986. The rapid recovery on the site was likely due to several factors. First, frequent and sustained periods of flooding brought nutrient rich sediments to the site. The flooding also helped to fill in depressions and ruts from tree felling and log skidding. Shrinking and swelling of the soil also sped site recovery by restoring macroporosity and increasing soil oxygen.

Overall, the more heavily disturbed SKID treatment was more productive than the HELI treatment and resulted in a larger component of water tupelo at age 16. The difference between these two treatments however is becoming less pronounced and may become negligible over a rotation length. The fact that the SKID treatment actually recovered better than the HELI treatment to this point was counter-intuitive. The heavy amount of disturbance that resulted from skidding was mitigated by site factors such as flooding and shrink swell soil. It cannot, however, be assumed that skidder harvesting on all wetland sites would have the same result as it had in this study. As not all wetlands are equal in their functions and recovery potential, the type of harvest method utilized should be chosen on a site-by-site basis. If a site has the potential for rapid recovery, skidder harvest should remain a viable option.

If water quality enhancement is a desired management objective in an alluvial wetland system, harvest by clear-cutting should be considered. As shown in this study, clearcutting increased the amount of sediment removed from open water systems adjacent to the site relative to the reference area. Sediment scouring and accumulation are natural processes in braided river systems such as the Mobile-Tensaw River Delta. However, clearcutting and associated sediment trapping could eventually allow less flood tolerant bottomland hardwoods to become established. Small changes in elevation in bottomlands can greatly effect what species will flourish. A productive deepwater swamp that produces water tupelo and bald-cypress could change to a less wet area with such species as water oak, green ash, and American elm. While this process will occur naturally, it might be accelerated by harvest, which would have implications for land managers and landowners.

Overall, growth rates, aboveground biomass accumulation, stand density and species composition in HELI and SKID treatment plots show that the site is recovering. It is expected that stands in the treatment areas will resemble the reference area in terms of species composition in the next 20 to 30 years.

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