LONG-TERM STAND GROWTH AFTER HELICOPTER AND GROUND-BASED SKIDDING IN A TUPELO-CYPRESS WETLAND: 21-YEAR RESULTS

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Abstract—Three disturbance treatments were implemented on a tupelo-cypress forested wetland in southwestern Alabama on the Tensaw River in 1986: (1) clearcutting with helicopter log removal (HELI), (2) HELI followed by rubber-tired skidder traffic simulation (SKID), and (3) HELI followed by removal of all vegetation during the first two growing seasons via glyphosate herbicide application (GLYP). At year 2 the SKID treated areas were wetter and had dramatic negative changes in soil characteristics and hydrology. By year 7 these negative impacts of skidder traffic were ameliorated. Further, the SKID treatment resulted in increased regeneration of *Nyssa aquatica*. Water quality was not adversely impacted by any disturbance treatment and sediment accumulation was actually improved by both HELI and SKID treatments. At year 21 the SKID and HELI treatments are well stocked with over 4,000 stems/ha, but the GLYP plots have little woody plant regeneration. Despite large stand composition differences at year 7, the SKID and HELI plots are becoming more similar. This is largely due to a decreasing *Salix nigra* component. Aboveground tree biomass is also similar for the SKID and HELI treatments with no significant differences for any species.

INTRODUCTION

Forested wetlands, such as bottomland hardwoods, are valued by society because of their unique influence on ecological functions, such as hydrology, water quality, nutrient cycling, and wildlife habitat (Daniels and Gilliam 1996, Klapproth 1996, Sheridan and others 1999, Walbridge 1993, Welsch 1996). Timber harvesting in forested wetlands is viewed with concern because it has the potential to influence these ecological functions. After the passage of the Clean Water Act of 1972 most Southeastern States developed best management practices (BMP) to address these concerns. However, little long-term research has been conducted in forested wetlands that address the effects of harvesting techniques on ecological function or stand development and growth. The purpose of this paper is to summarize the 21-year stand growth results from an on-going study comparing helicopter and ground-based skidding after clearcut logging in a tupelo-cypress (*Nyssa* spp.-*Taxodium* spp.) wetland.

Site Description

The study site is located within the Mobile-Tensaw River Delta along the western bank of the Tensaw River approximately 4.5 km southwest of Stockton, AL. Sporadic baldcypress (*T. distichum*) harvesting occurred on the sites as early as the 1700s with at least two additional harvests in the 1860s and 1915. Evidence of past pullboat logging operations is evident with pullboat channels from 30 to 150 cm in depth every 20 to 50 m. Climate in the area is subtropical with a mean annual temperature of 20 °C, 250 frost-free days, and <3 weeks below freezing. Average annual precipitation is evenly distributed and at 1600 mm/yr (Riccio and others 1973). The Tensaw River is a freshwater river at the study site, but has semidiurnal tidal influence, which occasionally allows the pullboat channels to serve as a direct conduit to the river. During the summer months, when evapotranspiration is maximized, the water table ranges from 25 cm above the surface to 50 cm below the surface. The soils in the area are very poorly drained fluvial sediments classified as Levy silty clay loam. Prior to our harvest the site was a two-age stand with >80 percent of stems at 72 years of age and <20 percent comprised of older residual stems. Water tupelo (*N. aquatica*) comprised 85 percent of the stems, with 10 percent baldcypress and 4 percent Carolina ash (*Fraxinus caroliniana*).

METHODS

Three disturbance treatments were included in the research design with nondisturbed areas retained to serve as a reference (REF). The entire disturbance area was clear-felled with chainsaws down to a 5-cm diameter, 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 rubber tires was used to traffic previously harvested HELI areas in order to simulate typical ground-based harvesting. The skidder treatment (SKID) resulted in 52 percent of the area trafficked to an average depth of 30 cm. In order to separate coppice regeneration from total regeneration an additional disturbance treatment (GLYP) was implemented that included complete suppression of all vegetation regrowth after helicopter harvest using glyphosate for 2 years. Treatments were arranged as three squares of 3 by 3 Latin squares providing nine replications of each treatment with nine pseudoreplications of the REF treatment. We used the Tukey-Kramer multiple comparison procedure to test for treatment differences with an alpha level of 0.05. More detailed site descriptions, preharvest characterizations, and descriptions of past methods used can be obtained from papers developed from research conducted at this site (Aust and Lea 1991, 1992; Aust and others 1989, 1990, 1991, 1997, 1998, 2006; Gellerstedt and Aust 2004; Gellerstedt and others 2002; Jackson and others 2004; Mader and others 1989a, 1989b)

RESULTS AND DISCUSSION

Year 2

Initial results indicated that 2 years after harvesting, both SKID and HELI treatments had substantial effects on site hydrology, soil characteristics, water quality, nutrient cycling,

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and habitat. Soil properties and hydrology were generally negatively affected by the three disturbance treatments. Water table depth during the growing season was raised; mechanical resistance was increased; saturated hydraulic conductivity, soil oxygen levels, and soil reduction-oxidation potential were decreased when compared to the REF treatment (Aust and Lea 1992). The greatest impacts were on the severely disturbed SKID treatment, which became substantially wetter, favoring regeneration of the more flood tolerant *N. aquatica*. Water-quality indices were either not affected or improved with disturbance (Aust and others 1991). Total Kjeldahl nitrogen and total phosphorus were similar for all periods and treatments. Sediment accumulations were greater on the SKID and HELI treatments indicating an improvement in water quality leaving the site. This improvement in sediment trapping was due to increased surface roughness on the SKID and HELI treatments.

During the first 2 years following disturbance, herbaceous and woody vegetation of the HELI and SKID treatments responded vigorously. The HELI and SKID treatments had similar patterns of net primary production aboveground biomass, total height, and numbers of desirable tree species (Mader and others 1989a, 1989b). Stocking in the SKID treatment favored the more flood tolerant *N. aquatica* with more *F. caroliniana* in the HELI treatment (Aust and others 1997). The general conclusion at age 2 was that the HELI and SKID treatments were well stocked, but there would be negative consequences on stand growth in the SKID treatment because of the negative effects on soil and hydrology (Aust and others 1997).

Year 7

Due to the changes in soil physical properties and hydraulic changes we predicted that the SKID treatment would have a negative effect on long-term site productivity. However, by year 7 the opposite of our prediction was evident. Most of the measured soil physical properties and hydraulic conditions had returned to REF levels. The SKID treatment continued to have a greater number of stems of *N. aquatica* and had a greater aboveground overstory biomass than the HELI treatment (Aust and others 1997). This recovery was due to rapid and robust coppice regeneration, canopy closure, return of high transpiration rates, sediment inputs, high site fertility, and soil shrink swell properties. This recovery is unique to this forest type and hydrological setting and should not be expected in other systems.

Sediment

Sediment accumulations were greater than the REF in all three disturbance treatments (table 1). Initially, the GLYP treatment was accumulating less sediment than the REF due to the treatment leaving the ground completely devoid of vegetation. However, once herbaceous vegetation rebounded, the GLYP treatment had the highest levels of sediment accumulation and significant differences with the other treatments until the last sediment measurement at year 16. The SKID and HELI treatments had increased sediment accumulation for approximately 6 years because of increased surface roughness with accumulations returning to REF levels at more recent measurement periods (Aust and others 2006). The increases in sediment accumulation due to site disturbance is an ameliorative mechanism that has helped the disturbed plots to recover and a positive benefit to the water quality that flows from the area.

Year 21 Stand Characteristics

At year 21, stocking levels are high for both the SKID and HELI treatments (table 2) with a mean of more than 4,000 stems/ha. The SKID treatment continues to have significantly more of the commercially desirable *N. aquatica* compared to the HELI treatment with 668 more stems/ha. The higher number of stems/ha of *F. caroliniana* in the HELI treatment compared to the SKID treatment, that were evident during earlier years, have been reduced, and the difference is no longer statistically significant. Black willow (*Salix nigra*) stocking in the HELI and SKID treatments has decreased dramatically since year 7 from 1,153 to 115 stems/ha in the HELI treatment and from 1,153 to 198 stems/ha in the SKID treatment. This indicates that the black willow is being replaced by other species in these treatments. This is expected because of *S. nigra*'s position as an early succession, pioneer tree species. Black willow has increased from 33 to 279 stems/ha since year 7 in the GLYP treatment indicating less

Table 1—Mean annual sediment accumulation by treatment for 1987 to 2002

Treatment	Sediment accumulation					
	1987–1988	1989–1993	1994–1996	1997–1998	1999–2002	Total
	cm/year					*cm*
REF	1.1 ab	0.8 a	1.4 a	0.6 a	0.5 a	13.6 a
HELI	2.2 b	1.6 b	2.6 a	0.8 a	0.7 a	24.6 bc
SKID	1.4 ab	1.3 ab	2.2 a	0.8 a	0.6 a	19.9 ab
GLYP	0.8 a	2.1 b	3.4 c	1.4 b	1.0 b	29.1 c

Values with the same letters are not significantly different (alpha = 0.05).

REF = nondisturbed areas retained to serve as a reference; HELI = helicopter harvest treatment; SKID = skidder treatment; GLYP = disturbance treatment that included complete suppression of all vegetation regrowth after helicopter harvest using glyphosate for 2 years.

Source: Gellerstedt and Aust (2004), Warren (2001).

Table 2—Mean stand characteristics 21 years after disturbance

Biometric/treatment	*Fraxinus caroliniana*	*Fraxinus profunda*	*Nyssa aquatica*	*Salix nigra*	*Taxodium distichum*	Total
Density (stems/ha)						
HELI	1392 a	1178 a	1070 a	115 a	305 ab	4110 a
SKID	1186 a	890 ab	1738 b	198 a	478 a	4695 a
GLYP	222 b	16 b	273 c	279 a	74 b	575 b
Diameter (d.b.h. cm)						
HELI	6.3 a	6.5 a	12.0 a	15.1 a	6.2 a	9.0 a
SKID	5.9 a	6.2 a	12.9 a	20.4 a	7.0 a	10.3 a
GLYP	6.8 a	4.4 a	9.7 a	16.9 a	12.7 a	10.7 a
Total height (m)						
HELI	7.7 a	8.0 a	9.6 a	13.5 a	5.5 a	8.3 a
SKID	8.1 a	7.3 a	9.9 a	12.6 a	6.9 a	9.0 a
GLYP	7.8 a	6.8 a	8.1 a	7.9 a	8.6 a	7.0 a
Overstory biomass (t/ha)						
HELI	11.8 a	10.7 a	90 a	18.7 a	6.4 a	139.4 a
SKID	9.1 a	7 b a	112.1 a	34.6 a	8.5 a	173.2 a
GLYP	3.0 b	0.1 b	15.2 b	40.9 a	5.1 a	70.9 b

Means with the same letter are not significantly different (alpha = 0.05).

HELI = helicopter harvest treatment; SKID = skidder treatment; GLYP = disturbance treatment that included complete suppression of all vegetation regrowth after helicopter harvest using glyphosate for 2 years.

competition from other tree species and their ability to colonize these sites. *T. distichum* has steadily increased in all three disturbance treatments since year 7 with 478 stems/ha in the SKID treatment and 305 stems/ha in the HELI treatment (table 2). Height and diameter of all species are similar with no statistically significant differences between treatments at year 21.

Year 21 Biomass

Aboveground tree biomass continues to be greatest in the SKID treatment at year 21 with 173.2 Mg/ha (table 2). The HELI treatment has 139.4 Mg/ha, but the difference is no longer statistically significant. Much of the difference between the two is still because of greater biomass of *N. aquatica* in the SKID treatment. There continues to be greater aboveground biomass of *F. caroliniana* in the HELI treatment compared to SKID treatment, but again this difference is no longer statistically significant. The lack of significant differences indicates that the two treatments are becoming more similar to each other in terms of aboveground tree biomass.

The GLYP treatment has substantially less biomass at year 21 than the other disturbance treatments. This treatment is still in an early successional stage with herbaceous plants and grasses dominating the plots. Stocking for all species in the GLYP treatment has increased steadily over the course of the study, but it is still understocked with 575 stems/ha and approximately half of the biomass of the SKID and HELI treatments. The GLYP plots are recovering slowly, stressing the importance of coppice regeneration and herbaceous competition for rapid site recovery after extreme disturbance such as agricultural production.

CONCLUSIONS

The negative effects of harvesting and ground-based skidding on the soils and hydrology of the HELI and SKID treatments returned to REF conditions by year 7. This rapid recovery after disturbance can be explained by the prevalence of coppice regeneration, the inherent fertility of the site, frequent sediment inputs, and the shrink swell nature of the soil. Water quality was not adversely impacted and sediment accumulation was actually improved by both HELI and SKID treatments.

The SKID treatment initially made the site wetter which favored the flood tolerant *N. aquatica*. However, differences between the treatments are diminishing. Helicopter and ground-based skidding have resulted in good stocking at year 21 with similar species mixes, stocking levels, and aboveground tree biomass. The stands in these two treatments are becoming more similar, particularly as *S. nigra* decreases. Differences between treatments may also be diminishing due to increases in stand variability. Variability in the stands is increasing because of natural stand disturbances such as storm damage, disease, and flooding. This study has demonstrated the importance of continuing research over longer timelines. If conclusions were based on results from early measurement periods in this study, inappropriate and premature management suggestions would have been accepted.

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