UNDERSTORY GROWTH AND COMPOSITION RESULTING FROM SOIL DISTURBANCES ON THE LONG-TERM SOIL PRODUCTIVITY STUDY SITES IN MISSISSIPPI

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Abstract—The response of understory plant communities to forest management can have important impacts on crop tree production, biodiversity, wildlife habitat, and water and nutrient cycling. Soil disturbance caused by harvesting and site preparation can alter soil fertility and porosity and may change understory species composition. At the Long-Term Soil Productivity study in Mississippi, we measured woody biomass by species on plots that had been subjected to three levels of experimental soil compaction. Although soil compaction at harvest reduced understory biomass at ages 5 and 10 years, planted pine biomass was unaffected. The relative dominance of individual species was altered by stand establishment and by soil compaction treatments; soil compaction favored early successional species while reducing the biomass and dominance of hardwood trees.

INTRODUCTION

Within the forest management community, many legal and ecological concerns have come to light over the past two decades about the specific effects of soil disturbances on long-term site productivity. Powers and others (1990) identified organic matter removal/displacement and soil compaction as key factors affected by forest management activities and which alter site productivity. In 1989, officials with the U.S. Department of Agriculture Forest Service National Forest System Deputy area and the agency's Research and Development branch began investigating these factors. Their efforts were directly in response to policies resulting from the Forest Management Act of 1976, as well as other statutes and directives. In 1990, the first Long-Term Soil Productivity Study (LTSP) sites were installed. This nationwide study focused on the impacts of organic matter removal associated with harvesting, site preparation for regeneration, and other activities, as well as soil compaction associated with equipment traffic during timber harvest and site preparation. The removal of organic matter potentially reduces site productivity by altering nutrient cycles, biological functions, and other soil processes. Soil compaction potentially reduces soil productivity by increasing soil strength and reducing soil porosity, which together reduce water and air interchange, thereby diminishing root growth (Greacen and Sands 1980).

Site productivity commonly is indexed by measuring total aboveground biomass. Early in a rotation, noncrop vegetation may constitute most of the standing biomass, and understory species may have different responses to soil compaction than crop trees. Therefore, it is important to study not only the overstory but also to investigate the effect of soil disturbances on the woody understory vegetation. Additionally, understory vegetation plays an important and valuable role in crop tree survival and growth, wildlife habitat and abundance, fuel loads, and nutrient cycling, all of which can be considered part of site productivity. This paper explores how soil compaction affects the growth and composition of crop tree and woody understory vegetation.

MATERIALS AND METHODS

Study Sites

The study site is the Mississippi installation of the LTSP, which was established in 1993. It is located in the DeSoto National Forest, Chickasawhay Ranger District, in Jones County, MS. The soil is a Freest series, which is in the fine-loamy, siliceous, thermic family of Aquic Paleudalfs. This series is somewhat poorly drained and formed in loamy clay sediments in uplands. The preharvest stand was a well-stocked slash pine plantation established in 1935. The site had received prescribed burns at 3- to 5-year intervals during the previous rotation, although the site had not been burned for 10 years prior to establishment of the LTSP study.

Twenty-seven 0.2-ha study plots were established in a split-plot, randomized complete block design. The general plot layout is a three by three factorial arrangement of organic matter removal and soil compaction. Each plot was split in half. One half was maintained as monoculture pine only; herbicides (glyphosate and triclopyr) were applied as necessary to control woody and herbaceous plants. The other half was treated as a natural plantation; no herbicides were applied after plantation establishment. This paper only considers the effect of compaction treatments on the woody understory and pine-stand productivity within the natural plantation plots.

Treatments

Compaction treatments were no compaction (control), moderate compaction, and severe compaction. No equipment traffic was allowed during harvest on the control treatment. Trees were removed by chain-saw felling, and logs were lifted off each plot with a log loader or crane. Only foot traffic was allowed on the control plots. The moderate and severe compaction plots were logged using a chassis-mounted shear and grapple skidders. Prior to harvesting, treatments were applied by towing a pneumatic-tire roadbed compactor with a crawler tractor over the designated plots. The roadbed compactor had a rolling width of 1.52 m. The ballast in the roadbed compactor was adjusted to meet the requirements of the

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Citation for proceedings: Connor, Kristina F., ed. 2006. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–92. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 640 p.

treatment. Field trial tests determined that a load of 3.0 Mg was required to initiate soil compaction in the Freest soil series. The severe load was set at 6.4 Mg and the moderate load at a logarithmic average between these two points, or 3.6 Mg. To ensure complete coverage and uniform compaction, each plot received three passes in one direction and then three more passes in a perpendicular direction for a total of six passes.

One herbicide application on each plot comprised the planting preparation. Technicians applied a mix of Garlon 4 (Triclopyr) and Cidekick (surfactant) at a rate of 8.867 l ha^{-1} and 1.446 l ha^{-1}, respectively. Following treatments, study plots were hand planted with 1-0 containerized loblolly pine (see Appendix for scientific plant names) seedlings from 10 known families on 2.5- by 2.5-m spacing.

Measurements

Tree heights and diameters of planted pine trees were measured every year up to age 5 and then again at age 10. At preharvest, understory biomass was destructively sampled within five randomly located 1-m^2 sampling areas. The understory was collected, oven dried, weighed, and saved for nutrient analysis. All understory species < 7.6 cm diameter at breast height were collected, but the biomass was not separated by species. Percent cover by species was measured on six 30.5-m transects on each of the plots.

At age 5 years, understory vegetation biomass was collected from four randomly placed 1.56-m^2 sample areas on the nonherbicide subplots. No species coverage data was collected at sampling.

A more intense understory vegetation biomass measurement was made at age 10 years. All woody understory species < 1.37 m tall were clipped, bagged, and tallied by species and number of stems in each of three 6.25-m^2 sampling areas on each subplot. All woody understory species > 1.37 m tall were tallied by species, height, and diameter within three 56-m^2 sampling areas randomly placed within each study plot. Plot-level biomass was determined from these measurements using biometric equations developed from the sites.

Data Analysis

The impact of soil compaction was determined on pine biomass, understory vegetation biomass, and species relative dominance by analysis of variance using $\alpha = 0.1$ and Duncan's Multiple Range test to separate the means when differences were found (SAS Institute 2000).

RESULTS AND DISCUSSION

The compaction treatments had no effect on the growth of the pine overstory at 5 and 10 years, respectively. At 5 and 10 years, the loblolly pine overstory averaged 6.7 and 26.9 Mg ha^{-1}, respectively (table 1).

The preharvest total understory vegetation biomass was equal across all treatment plots and averaged 2.67 Mg ha^{-1}. By age 5 years, the total understory vegetation biomass averaged 3.11 Mg ha^{-1} across all plots, but the moderate and severe compaction treatments reduced the total woody understory biomass by 65 and 67 percent, respectively, compared to the uncompacted control plots. At age 10 years, the understory biomass had grown to 6.5 Mg ha^{-1} on the control plots. Understory biomass was still significantly less on the severely compacted plots (3.9 Mg ha^{-1}) and intermediate on the moderately compacted plots (4.7 Mg ha^{-1}) (table 1).

Table 1—Aboveground biomass (Mg/ha) response to three levels of experimental soil compaction through 10 years of stand development

		Soil compaction		
Age	Strata	None	Moderate	Severe
		- - - - - - - - - - - *Mg/ha* - - - - - - - - - -		
Preharvest	Overstory[a]	149.6	138.5	146.5
	Understory[b]	2.7	2.7	2.6
	Total	152.3	141.2	149.1
5 years	Overstory	5.9a[c]	7.2a	7.1a
	Understory	5.6a	2.0b	1.8b
	Total	11.5a	9.2a	8.9a
10 years	Overstory	23.6a	28.7a	28.4a
	Understory	6.5a	4.7ab	3.9b
	Total	30.1a	33.4a	32.3a

[a] Overstory was defined as the planted pine trees on each plot, regardless of size.
[b] Understory was defined as all other woody vegetation.
[c] Means within a row followed by the same letter are not significantly different at α = 0.10 based on Duncan's Multiple Range tests.

At 5 years, the planted pine biomass averaged > 80 percent of the total woody biomass on the compacted plots but only 50 percent on the control plots (table 1). By 10 years, the loblolly pine biomass averaged about 87 percent of the total biomass across the compacted plots but only 78 percent of the total vegetation biomass on the control plots (table 1). Total biomass was not significantly affected by the compaction treatments at any age, indicating that the understory vegetation was much more susceptible to soil compaction than the planted pine trees.

Not only was the understory vegetation more susceptible to compaction than the planted pines, but individual species were quite different in their susceptibility. Soil compaction reduced flowering dogwood, winged sumac, red oak, and red maple biomass by 95, 95, 92, and 65 percent, respectively, although only the red oak biomass showed a statistical difference, due to the high variability of individual species biomass across the plots (table 2). Conversely, eastern baccharis, black gum, and yaupon were positively affected by soil compaction. They had 616, 477, and 111 percent more biomass on the compacted plots than on the uncompacted plots, although only eastern baccharis showed a significant difference (table 2). This species-specific tolerance to soil compaction had important effects on the understory's overall species composition.

At preharvest, 25 woody understory species were identified. At 10 years, only 19 species were found on the moderately compacted plot and 17 species on both the control and severely compacted treatment plots. Also, six species were present at preharvest but were no longer present at 10 years. These species were common privet, hickory, sassafras, arrowwood, winged elm, and ironwood. One species, eastern redcedar, was not present at establishment but was found at 10 years.

At establishment of the LTSP study, gallberry dominated the woody understory species with nearly 60 percent relative dominance before harvest (fig. 1). All other recorded species represented < 10 percent relative dominance. After compaction treatments and 10 years of growth, gallberry still dominated the woody understory composition, although its relative dominance had decreased to 35 percent on the control and 37 percent on the compacted treatments. Compaction treatments did not affect the relative dominance of gallberry in the understory, but there was a significant statistical difference in other understory species. Soil compaction decreased the relative dominance of flowering dogwood and red oaks but increased the relative dominance of black gum, eastern baccharis, and American beautyberry.

These changes in understory composition due to soil compaction may affect wildlife habitat, timber production, and have implications for successional dynamics, all of which are especially important for nonindustrial private landowners. The increase in eastern baccharis, American beautyberry, and yaupon would benefit bird habitat, although the loss of red oak would be detrimental to many species that need hard mast, such as white-tailed deer (*Odocoileus virginianus*) and eastern wild turkey (*Meleagris gallopavo silvestris*). Similarly, the reduction in red oak and red maple could have implications for timber value, although the planted pines would still likely be the preferred timber species. Ecologically, soil compaction appeared to retard succession; early successional,

Table 2—Understory vegetation biomass by species at age 10 years as affected by three soil compaction levels

Species	Soil compaction None	Moderate	Severe
	- - - - - - - - - - - - *kg/ha*	- - - - - - - - - - - -	
American beautyberry	49.4a[a]	116.1a	51.9a
American holly	36.1a	52.5a	20.4a
Black cherry	3.3a	0.0a	0.8a
Blackgum	23.5a	72.4a	135.7a
Eastern baccharis	17.2b	86.1ab	122.9a
Eastern redcedar	0.0a	2.5a	0.0a
Flowering dogwood	494.5a	32.8a	23.8a
Gallberry	1937.8a	1329.0a	1416.5a
Hawthorn	11.5a	13.9a	31.6a
Loblolly pine	54.0a	42.7a	61.6a
Persimmon	16.6a	97.8a	23.3a
Red maple	1467.7a	1036.1a	519.9a
Red oak	747.2a	213.0b	63.1b
Sweetbay	0.0a	0.6a	0.0a
Sweetgum	306.8a	171.1a	60.8a
Vaccinium	291.6a	114.1a	207.3a
Wax myrtle	574.2a	576.8a	547.9a
White oak	0.0a	22.2a	0.0a
Winged sumac	190.0a	6.4a	8.8a
Yaupon	305.5a	704.6a	644.7a

[a] Means within a row followed by the same letter are not significantly different at $\alpha = 0.10$ based on Duncan's Multiple Range tests.

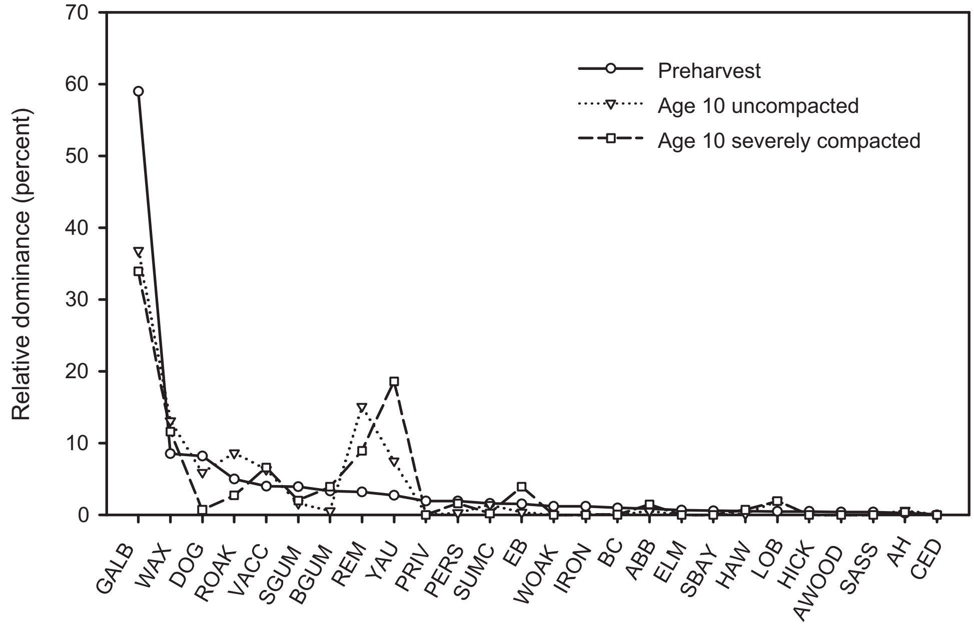

Figure 1—Relative dominance of understory species before harvesting and after 10 years of stand development and two soil compaction levels.

increasing species—-such as American beautyberry, eastern baccharis, and yaupon—were more dominant on the compacted sites, while later successional species such as red maple, flowering dogwood, and red oak were less dominant (fig. 1).

CONCLUSIONS

Soil compaction significantly reduced woody understory biomass while having little impact on planted pine biomass growth. However, compaction affected individual understory species quite differently, causing understory composition to change. Generally, early successional species with good qualities for bird habitat were more dominant on the compacted plots, while later-successional, mast-producing species were reduced. These changes could be quite important, especially for nonindustrial private landowners who are interested in managing their land for both timber and wildlife habitat.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Morris Smith, Paul Jackson, Michael Elliott-Smith, Jerry Wayne Brewer, Allan Springer, James Curtis, and others for installation, maintenance, and data collection on the Long-Term Soil Productivity study sites.

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Appendix—Codes, common names, and scientific names of woody understory plant species found on the Mississippi Long-Term Soil Productivity Study site

Code	Common name	Scientific name
ABB	American beautyberry	*Callicarpa americana* L.
AH	American holly	*Ilex opaca* Ait.
AWOOD	Arrowwood	*Viburnum dentatum* L.
BC	Black cherry	*Prunus serotina* Ehrh.
BGUM	Black gum	*Nyssa sylvatica* Marsh.
CED	Eastern redcedar	*Juniperus virginiana* L.
DOG	Flowering dogwood	*Cornus florida* L.
EB	Eastern baccharis	*Baccharis halimifolia* L.
ELM	Winged elm	*Ulmus alata* Michx.
GALB	Gallberry or inkberry	*Ilex glabra* L.
HAW	Hawthorn[1]	*Craetagus* spp.
HICK	Hickory[2]	*Carya* spp.
IRON	Ironwood or American hornbeam	*Carpinus caroliniana* Walt.
LOB	Loblolly pine	*Pinus taeda* L.
PERS	Persimmon	*Diospyros virginiana* L.
PRIV	Common privet	*Ligustrum vulgare* L.
REM	Red maple	*Acer rubrum* L.
ROAK	Red oak[3]	*Quercus* spp.
SASS	Sassafras	*Sassafras albidum* (Nutt.) Nees
SBAY	Sweetbay	*Magnolia virginiana* L.
SGUM	Sweetgum	*Liquidambar styraciflua* L.
SUMC	Winged sumac	*Rhus copallinum* L.
VACC	Deerberry[4]	*Vaccinium* spp.
WAX	Wax myrtle	*Morella cerifera* (L.) Small
WOAK	White oak	*Quercus alba* L.
YAU	Yaupon	*Ilex vomitoria* Ait.

[1]Hawthorn plants were not separated by species.
[2]Hickories were not separated by species but were dominated by mockernut hickory [*Carya alba* (L.) Nutt. ex Ell.].
[3]Red oaks were not separated by species but included southern red oak (*Quercus falcata* Michx.) and water oak (*Quercus nigra* L.).
[4]Vaccinium species were not separated by species but were dominated by deerberry (*Vaccinium stamineum* L.) and highbush blueberry (*Vaccinium corymbosum* L.).