SOIL PROFILE CHARACTERISTICS OF A 25-YEAR-OLD WINDROWED LOBLOLLY PINE PLANTATION IN LOUISIANA

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Abstract-Windrowing site preparation, the raking and piling of long rows of logging debris, has been reported to displace surface soil, redistribute nutrients, and reduce volume growth of southern pine forests. Many of these studies have reported short-term results, and there are few long-term studies of the effects of windrowing on soil properties and pine growth. A 16.2 hectare tract on Sacul fine sandy loam (clayey, mixed, thermic Aquic Hapludult) in Jackson Parish in northern Louisiana was windrowed in 1975. The objective of this study is to compare soil physical and chemical properties from scraped areas between windrows with that from windrow pile soils, 25 years after windrowing. Surface, subsurface, and subsoil horizons were sampled from 13 soil profiles within inter-row (scraped) and windrow (piled) positions. Thickness of the 0, A, and E horizons, as well as depth to the Bt horizon, were measured in these profiles. Comparisons were made on the following properties for each horizon on each of the two site positions: organic matter, pH, available phosphorus, and exchangeable calcium, magnesium, potassium, and sodium. Bulk density was measured for windrow and inter-row position surface and subsurface soils. Pore space and air-filled volume were calculated using bulk density and water content, Mean bulk density of windrow surface soils was 1 .18 g cm^{-3}, as compared with 1.53 g cm^{-3} for inter-row surface soils. Inter-row subsurface bulk density was also significantly greater than that for windrow positions. Inter-row soils at both depths had significantly less pore space and air-filled volume than that of the windrow positions. In contrast to physical properties on the site, there were no significant differences in surface or subsurface soil chemical properties. Site index (base 50 years) of loblolly pine growing between the windrows was the same (97 feet) as that growing on a non-windrowed part of the tract. Although surface and subsurface soils between windrows were significantly compacted, this compaction does not appear to have limited loblolly pine growth. After 25 years, there was little evidence of nutrient redistribution. The effectiveness of windrowing in reducing woody competition during early stand development may be a more important factor influencing growth.

INTRODUCTION

Piling logging slash into elongated windrows is a common site preparation method in the southeastern US. The moving of slash by rakes or blades usually involves displacement of some surface soil. This displacement of surface soil has been associated with redistribution of nitrogen and phosphorus (Pye and Vitousek 1985, Tew and others 1986, Morris and others 1983) and potassium, calcium, and magnesium (Tew and others 1986, Morris and others 1983) away from the bladed or raked area, into the pile. Loss of some of the organic matter enriched surface can result in higher bulk densities, lower porosity and lower hydraulic conductivity (Tuttle and others 1985). Loblolly pine root growth was decreased with small and large increases in bulk density on sand, loam, and clay (Foil and Ralston 1967). Windrowing has been associated with lower volumes in southern pine plantations. Nineteen years after site preparation, a rootraked and windrowed area contained 187 m^3/a of loblolly pine, but a broadcast burned area had a volume of 346 m^3/ha (Haines and others 1975). Across a wide variety of soils in the deep south, Haywood and Burton (1989) found shearing and windrowing to have the lowest loblolly pine site index and volume after 12 years, as compared with five other mechanical site preparation treatments. The soil physical and chemical research on windrows and site preparation is largely focused on the few years after the treatment, with the exception of few studies. Glass (1976) found that the 2.54 cm of displaced surface soil on a 25-year old raked and piled loblolly pine plantation in the North Carolina Piedmont resulted in a 2.5 meter lower site index (50 years) versus adjacent pines in unwindrowed plantations.

The purpose of this paper is to evaluate effects of windrow site position on soil properties of a loblolly pine (*Pinus taeda* L.) plantation in the upper Coastal Plain in northern Louisiana 25 years after windrowing. The study objectives are to evaluate differences in horizon depths, soil physical properties, and soil chemical properties between windrow pile positions and inter-row (cleared) positions.

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Table 1—Soil horizon characteristics of windrow (piled) and inter-row position soils

Variable	Windrow Mean	SE	Inter-Row Mean	SE	Pr>t
0 horizon thickness, cm	2.96	0.42	3.18	0.39	"0.7867
A horizon thickness, cm	23.50	4.13	13.65	1.77	0.0251
E horizon thickness, cm	23.50	5.04	14.22	2.65	0.1236
Depth to Bt, cm	46.99	1.94	29.15	2.07	0.0010

Table P-Soil physical properties of windrow (piled) and inter-row position soils

Variable	Windrow Mean	SE	Inter-Row Mean	SE	Pr>t
Surface Bulk Density g cm^{-3}	1.18	0.04	1.53	0.02	0.0001
Surface Pore Space, pct	54.56	1.39	41.19	0.67	0.0000
Surface Air Volume, pct	26.67	1.81	12.57	0.75	0.0001
Subsurface Bulk Density g cm^{-3}	1.51	0.04	1.67	0.03	0.0061
Subsurface Pore Space, pct	42.01	1.55	35.96	1.21	0.0072
Subsurface Air Volume, pct	11.47	1.14	7.92	0.92	0.0277

METHODS

The study area, a 16.2 hectare tract, is located in Jackson Parish, LA, within the upper coastal plain. The entire tract is mapped as a moderately well drained Sacul fine sandy loam (clayey, mixed, thermic Aquic Hapludult). The tract was sheared and windrowed after harvesting in 1975. The windrows were burned but not planted to pine, and regenerated to hardwoods. Windrow piles are 3 meters wide, 30.5 meters apart, and comprise 10 percent of the tract.

Vegetation and soils were characterized on plots on windrow piles (windrows) and between windrows (inter-rows). Vegetation was measured in 0.0405 hectare rectangular plots on windrows and in two rectangular plots of the same size between windrows. Heights and diameters of pines and diameters of hardwoods were measured. Dominant and co-dominant trees were classified. Site index for loblolly pine was calculated by inputting the dominant and codominant heights into USDA Natural Resource Conservation Service software version (SCS-690) of the site index curves of Schumacher and Coile (1960).

The impact core method was used to sample bulk density. Cores in aluminum cylinders were taken at the surface (O-10 centimeter) and subsurface (1 O-20 centimeter) depths. Three replicates were sampled at each depth to represent bulk density of a plot. Bulk density was measured for 9 windrow (piled) plots and 9 inter-row plots. All cores were sampled the same day in February, 2000. Cores were weighed in the field-moist state and after oven drying. Pore space and air-filled volume were calculated using these weights.

Soil profiles were described for three windrow locations and ten inter-row locations. Profile locations were located randomly within the tract. Depths, thickness and Munsell colors for the A, E, EB, and BE horizons were measured. Depth to the Bt and thickness of the 0 horizon was also measured. Texture for each horizon, including the upper Bt, was estimated using the hydrometer method. Each horizon sampled was analyzed by the Louisiana State University Soil Testing Laboratory (Brupbacher and others 1970) for pH (1: 1), organic matter (Walkley-Black potassium dichromate oxidation), available phosphorus (Bray 2 ammonium fluoride extraction), and exchangeable (ammonium acetate, pH 7) calcium, magnesium, potassium, and sodium. Phosphorus levels were determined using a spectrometer, and exchangeable cation concentrations were measured using inductively coupled argon plasma emission spectrophotometry (ICP).

Means of windrow position and inter-row soils' horizon thicknesses, physical and chemical properties were compared using the t test procedure in SAS. Equality of variances was tested (F' test), and where the variances were unequal, Satterthwaite's approximate t test was used to test significance (SAS Institute Inc. 1985). Overall significance was determined at the α = 0.05 level.

RESULTS AND DISCUSSION

Soil Profiles

Windrow soils had significantly thicker A horizons and deeper depths to the argillic (Bt) horizon (table 1). Transitional horizons such as EB increased depth to the Bt also.

Table 3-Soil chemical properties of A horizons of the windrow (piled) and inter-row position soils

Variable	Windrow		Inter-Row		Pr>t
	Mean	SE	Mean	SE	
pH	5.50	0.21	5.29	0.08	0.2908
Organic Matter, pct	2.23	0.28	2.37	0.30	0.8231
Phosphorus, mg/kg	7.33	0.88	7.30	0.52	0.9756
Calcium, mg/kg	519.00	179.31	338.10	36.36	0.4218
Magnesium, mg/kg	64.00	12.12	64.20	5.39	0.9867
Potassium, mg/kg	31.33	4.67	41 .00	3.98	0.2425
Sodium, mg/kg	19.33	0.88	19.80	0.65	0.7245

Table 4-Soil chemical properties of E horizons of the windrow (piled) and inter-row position soils

Variable	Windrow		Inter-Row		Pr>t
	Mean	SE	Mean	SE	
pH	5.30	0.20	5.26	0.10	0.8358
Organic Matter, pct	0.45	0.09	0.64	0.05	0.1085
Phosphorus, mg/kg	4.00	0.58	3.89	0.20	0.8164
Calcium, mg/kg	230.67	62.36	211.00	24.14	0.7226
Magnesium, mg/kg	76.33	8.74	57.67	7.26	0.2045
Potassium, mg/kg	25.33	3.18	23.89	1.05	0.5748
Sodium, mg/kg	18.67	1.20	17.44	0.24	0.4186
Sum of Bases, cmol(+)/kg	1.93	0.38	1.69	0.16	0.5038

Table 5—Soil chemical properties of upper Bt horizons of the windrow (piled) and inter-row position soils

Variable	Windrow		Inter-Row		Pr>t
	Mean	SE	Mean	SE	
pH	4.83	0.03	4.77	0.03	0.2456
Organic Matter, pct	0.48	0.06	0.64	0.04	0.0700
Phosphorus, mg/kg	5.00	0.58	4.80	0.25	0.7217
Calcium, mg/kg	344.33	144.35	260.10	43.77	0.4529
Magnesium, mg/kg	473.67	44.18	389.40	50.81	0.4084
Potassium, mg/kg	129.33	12.00	92.90	5.44	0.0103
Sodium, mg/kg	26.00	2.00	27.40	2.02	0.7279
Sum of Bases, cmol(+)/kg	6.03	0.79	4.84	0.51	0.2742

The 0 horizon was primarily leaf litter, and did not differ between windrow and inter-row positions. The A, E, and transitional horizons had a sandy loam texture, whereas the Bt horizon was clay or clay loam for all plots.

Physical Properties

Inter-row site soils were significantly denser, had less pore space, and less volume of air than the windrow position soils, both in the surface (O-10 cm) and in the subsurface (10-20 cm) (table 2). Subsurface inter-row soils had a mean bulk density of 1.67 g cm^{-3}. Surface soil removal (7.62 cm) in Alabama Piedmont and Hilly Coastal Plain sites increased bulk density from 1.47 to 1.64 g cm^{-3}, but bulk density decreased to 1.35 g cm^{-3} after three years (Tuttle and others 1985).

Soil Chemistry

There were no significant differences in any of the measured soil chemical properties between windrow and inter-row position A horizon soils (table 3). Calcium content was very variable, particularly on the windrow sites, where one plot had a concentration of 846 mg/kg. There is no evidence of nutrient redistribution. KG bladed surface soils (including Sacul) in southeast Texas had less K, Ca, and Mg than control, chopped, or burned soils (Stransky and others 1985). In that same study, 7 years after harvest and blading, the surface soils had the same amount of organic matter as the chopping treatment. Bladed soils had significantly less Ca, but not significantly less P, K, Mg than chopped or burned soils. Tuttle and others (1985) found that a 7.62 cm surface removal treatment decreased organic matter by over 50 percent with respect to a control, 3 years after removal. In that study, N, P, Ca, Mg, and K were all reduced from control levels three years after surface removal.

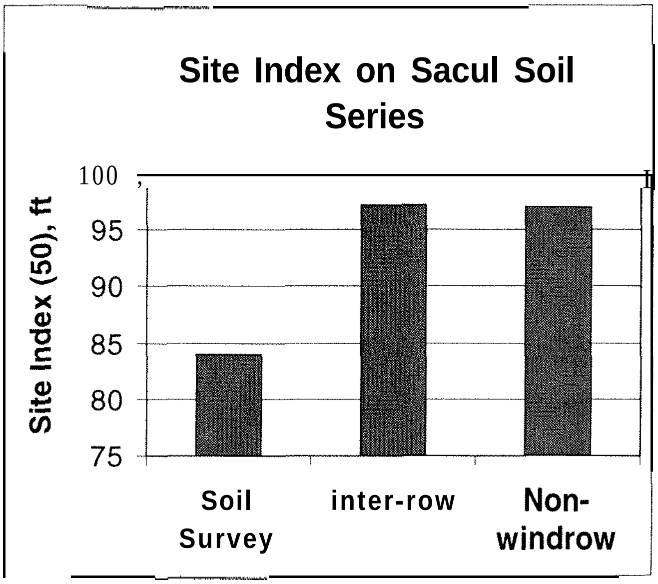

Figure l-Comparison of loblolly pine site index (base age 50 years) on the Sacul series in Jackson Parish, Louisiana, from Stephens (1999) and measured between windrows and on a non-windrowed area on the study area.

The windrow position E horizons had less (not significant) organic matter than the inter-row sites (table 4). There were no significant differences between site positions for any measured soil chemical property.

The windrow position soils had significantly higher exchangeable potassium levels in the upper Bt, as compared with the inter-row Bt's (table 5). This trend may reflect increased potassium leaching from the slash and through the surface (eluviation), due to increased porosity and infiltration rates in the windrow pile. Potassium could be illuviating in the argillic horizon. Surprisingly, the windrow position Bt horizons contained less organic matter than the inter-row positions had. This trend was also apparent in the overlying E horizons. Prolonged, intense fire in the windrow may have consumed some of the organic matter. Tuttle and others (1983) noted C, Mg, and K appeared to be moving through the upper soil profile 3 years after a surface soil removal.

Overall, there is no evidence in this study for nutrient redistribution from the cleared areas to the piles, or nutrient limitations in the inter-row areas.

Growth of Loblolly Pine

Loblolly pine growing between the windrows had a measured site index of 97.2 feet (figure 1), considerably higher than the published (Soil Survey) figure (using same methods and curve) for the Sacul series in Jackson Parish, LA (Stephens 1999). Loblolly pine on a non-windrowed portion of the tract had a site index of 97.0 feet. The displacement of surface soil and subsequent compaction of the surface and subsurface soil have apparently not severely limited growth of loblolly pine on this site. In contrast to this study, in the Lower Coastal Plain of South Carolina, Fox and others (1989) found that 31 year old loblolly pine between windrows had 10.5 feet lower site index (base age 25 years) as compared with that on non-windrowed sites.

Bulk density in the sandy loam subsurface (10-20 cm) of the inter-row position was 1.67 g cm^{-3} (table 2). Growth limiting bulk density for sandy loam texture is >1.65 g/cm^3 (Daddow and Warrington 1983. Coile and Schumacher (1953) found that 5 cm reduction in surface soil thickness could reduce loblolly pine site index (50 years) by 0.3 to 1.5 m. In the few years following shearing and raking debris into windrows, loblolly pine growth may increase over that of non-windrowed areas. Windrowing, by removing part of the woody competition seed bank and roots, can have a beneficial effect on early pine productivity (Allen and others 1991, Powers and others 1998).

CONCLUSIONS

Twenty-five years after windrowing site preparation, surface and subsurface soils between windrows were significantly compacted, as compared to windrow pile soils. This compaction does not appear to have reduced loblolly pine growth, as compared with growth on an adjacent non-windrowed area . After 25 years, there was little evidence of nutrient redistribution into the windrows. The effectiveness of windrowing in reducing woody competition during early stand development may be a more important factor influencing growth.

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