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SITE DISTURBANCES ASSOCIATED WITH ALTERNATIVE PRESCRIPTIONS IN AN UPLAND HARDWOOD FOREST OF NORTHERN ALABAMA

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Summary:

A study was installed in an upland hardwood forest to evaluate the site impacts associated with three alternative prescriptions - clearcut, deferment cut, and strip cut. Two methods of site impact assessment were employed: 1) assignment of disturbance classes to selected points within each treatment area and 2) measurement of soil bulk density, gravimetric water content, and soil strength at points previously evaluated for soil disturbance class. Clearcut and deferment cut treatments produced the greatest impacts as evidenced by higher percentage of slightly and highly disturbed areas and increases in bulk density and soil strength. Strip cut treatments had less impact on a stand wide basis but cut strips experienced similar impacts.

Keywords:

Hardwood, clearcut, deferment cut, strip cut, soil strength, bulk density, disturbance class.

Site Disturbances Associated with Alternative Prescriptions in an Upland Hardwood Forest of Northern Alabama

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Introduction

Forest harvest operations usually result in ground disturbances that displace the surface soil and litter layers and alter soil properties in surface and subsurface soil horizons. The type and intensity of disturbance is influenced by a number of factors including soil type, machine parameters, and harvest systems. Several research studies have evaluated the disturbances associated with harvest systems utilizing visual determination of previously defined disturbance categories that describe the surface soil/litter displacement and mixing and its relative intensity over a stand wide area. More intense assessments of disturbance have consisted of the measurement of soil physical variables with the degree of change linked to the intensity of disturbance. An assessment of disturbance from harvest operations is important to accurately gauge the risk of erosion, the potential for lowered site productivity, and loss of aesthetic values.

Critical information is lacking on the impact of forest operations on steeply sloping landscapes which can alter soil physical properties sufficiently to accelerate erosional processes and further lower site productivity. When combined with a limited knowledge of information regarding the use of alternative Silvicultural prescriptions to properly manage upland hardwood stands, it is important to accurately assess disturbance patterns related to harvesting and skidding practices to provide important information on the proper management of upland hardwood stands. The primary focus of this study is an assessment of ground disturbances that result from three Silvicultural prescriptions employed in an upland hardwood stand.

Previous Work

Forest operations have the potential to negatively impact forested sites through displacement of surface soil and litter layers and alteration of soil physical properties. These ground disturbances have been linked to a higher susceptibility of a trafficked site to erosion through removal of forest cover and litter, lowered overall site productivity as a result of compaction and lowered infiltration and aeration, and reductions in the aesthetic qualities of a site. Assessment of soil and litter displacement has been performed utilizing defined disturbance categories that approximately describe the surface soil condition which occur in conjunction with forest operations and/or equipment (Dyrness 1965; Miller and Sirois 1986; Stuart and Carr 1991; Stokes and others 1993; Thompson and others 1995). The disturbance categories employed in previous studies have relied onclasses defined by Dyrness (1965) but modifications have been used to meet the objectives of a study (Rachel and Karr 1988; Aust and others 1993; McNeel and Ballard 1992). The utilization of disturbance classes has allowed comparisons among different components of harvest operations, machines and specific machine parameters, and harvest systems (Miller and Sirois 1986; Stuart and Carr 1991; Seixas and others 1995; Lanford and Stokes 1995). More intensive investigations of soil impacts have consisted of the measurement of the response of soil physical parameters to traffic which is more time consuming but provides critical information on compaction, water infiltration, and rooting potential in disturbed sites (Greacen and Sands 1980; Incerti and others 1987; Rachal and Karr 1988). Recently, investigators have linked soil surface disturbance classes with soil physical properties to permit more rapid estimation of disturbances, their potential to impact site productivity, and proper methods of mitigation (Miller and Sirois 1986; Rachal and Karr 1988; Stuart and Carr 1991; Lanford and Stokes 1995).

Even age management prescriptions (block clear cut) are commonly employed on upland hardwood stands of the southern Appalachian and mid-South areas of the southeastern United States to minimize recovery costs and encourage regeneration of sites that have undergone high grade single tree selection (Sander 1980; Mills 1988). Clearcutting exerts a significant degree of impact on a harvested site as evidenced by the lower percentage of disturbed areas classified as untrafficked and a higher percentage of rutted areas and skid trails (Kluender and Stokes 1993). Negative impacts to soil physical parameters have been consistently reported in previous studies on clearcut sites especially in heavily disturbed, or rutted, locations (Lockaby and Vidrine, 1984; Wronski 1984; Rachal and Karr 1988; Reisinger and others 1988). Less information is available regarding changes in soil physical properties or types and intensity of disturbances associated with alternative Silvicultural prescriptions in southeastern forests. This is essential to provide a body of information on impacts to soils located on sloping landscapes which undergo accelerated erosion upon harvest (Yoho, 1980).

Objective

The objective of the study was an assessment of the impacts associated with three alternative Silvicultural prescriptions - clearcutting, deferment cutting, and strip cutting in an upland hardwood stand utilizing two methods of disturbance assessment: 1) visual determination of disturbance classes in each harvested block, and 2) measurement of specific soil physical properties.

Experimental Methods

Site and Study Description

The project was located in an upland hardwood stand on the southern boundary of the Cumberland Plateau characterized by east-west ridges with slopes of 20 to 25 percent. The study site is located in proximity to Moulton, Alabama in Lawrence County on approximately 25 ha of north and south facing slopes. Treatment areas were established on northerly and southerly aspects of a single ridge line with 15 ha located on the northerly aspect and 6 ha along the southerly aspect. The study site is owned and managed by Champion International. The stand is classified as an oak-hickory association with a stand density of 924 trees per ha and a basal area of 30 m^2 per ha.

The experimental design consisted of a complete randomized block with four treatments: clearcut, deferment cut, strip cut, and an uncut control and replicated three times. Silvicultural treatments were installed in 1.6 ha blocks in six locations along the northern aspect and three along the southern aspect; unharvested control plots, each approximately 0.8 ha in size, were installed in each replicate_ Clearcut treatments were defined as removal of all stems greater then 3.8 cm throughout each harvest block. Strip cut treatments required removal of stems greater than 3.8 cm from strips approximately 37 m wide while maintaining strips of the same dimension in an unharvested condition between cut strips. Deferment cutting was defined as maintenance of approximately 5.7 m^2 per ha of basal area of healthy, quality trees throughout the treatment block and removal of all other stems. Soil types within the study site are members of Typic Hapludults and were derived from parent materials composed of sandstone, shale, or interbedded sandstone and shale. The installation of treatments commenced in July of 1996 and was completed in September of 1996.

<u>Site Measurements</u>

Preharvest

Each treatment block was located and marked in the Spring of 1996 and an assessment of soil characteristics completed prior to establishment of treatments. Soil characterization consisted of collection of soil cores (5.08 x 5.08 cm) for measurement of bulk density and gravimetric water content at 30 sampling points on a 24 x 48 meter grid (6 transect lines and 10 sampling points on each transect) superimposed on each treatment block. In addition, particle size analysis was performed on a select number of samples. Soil physical analyses were performed in accordance with Klute (1986). Soil strength was determined at each sampling point utilizing a Rimik CP 20 cone penetrometer to a depth of 0.20 m in 0.025 m increments (ASAE, 1992).

Postharvest

Upon completion of treatment installation, grid sampling points were relocated and soil disturbance class assessment and soil sampling performed at each grid point; a total of 60 sampling locations within each treatment block and 30 sampling points in unharvested control blocks was evaluated. Soil disturbance classes were defined as the following: (1) untrafficked (U); (2) trafficked with litter in place (2A), trafficked with litter removed (2B), trafficked with mineral soil exposed (2C), and trafficked with mineral soil displaced to top of litter (2D); (3) soil depressions less than 15 cm (4A), depressions between 15 and 30 cm (4B), and soil depressions greater than 30 cm (4C); and (4) non soil (NS). The final tabulation consisted of untrafficked (U), trafficked with litter in place (2A), trafficked with mineral soil exposed (∑ 2B, 2C, 2D) (2), soil depressions less than 15 cm (4A), depression greater than 15 cm (4), and nonsoil (NS). Soil physical characterization consisted of collection of soil cores for bulk density and gravimetric water content determination according to Klute (1986) and soil strength determinations according to ASAE standard S313.2 (ASAE, 1992).

Results and Discussion

Preharvest soil characterization indicated little difference in bulk density, soil moisture content, total porosity, and soil strength among slope positions or treatment blocks (Tables 1 and 2). Bulk density and total porosity values of approximately 1.00 Mg m^{-3} and 65 percent, respectively, are typical of forest soils. Soil strength levels less than 6.0 MPa for coarse textured soils are well below values considered to be limiting for root proliferation (Gerard and others, 1982). Slight increases in bulk density, soil moisture content and soil strength concurrent with decreased total porosity occurred in the bottom slope position in comparison to upper and midslope positions and in the deferment block in the preharvest condition. This may be attributable to differences in soil texture among slope positions, impacts from previous site use, or a combination of the two. Although soil textural classifications were similar among slope positions, the percent of sand was higher in the top slope position than the mid or bottom slope position. Concurrently, the percent silt and clay increased as slope position decreased. Soil strength and bulk density are influenced by a number of factors including texture and/or soil moisture content which may have contributed to the differences detected in this study (Stitt and others 1982; Carter 1990). It is also possible previous site use contributed *to* site variability which exhibited higher soil strength and bulk density in areas designated for deferment cut treatment (Table 2).

Soil response varied by silvicultural treatment with the greatest impacts most closely associated with clearcut treatments

(Table 3). Bulk density and soil moisture content were highest while total porosity was lowest in clearcut treatments in comparison to the remaining treatments. Analysis of variance (ANOVA) procedure detected significant differences among treatments ($P < 0.05$) for bulk density and total porosity and a mean comparison (Duncan's) detected significant differences between clearcut and control ($P = 0.05$). Mean soil strength was significantly different(ANOVA) among treatments with significant differences detected between the deferment cut and the strip cut and control treatments ($P = 0.05$) (Duncan's). No significant difference was detected between clearcut and deferment cut in mean soil strength. Similar results were obtained for soil strength with depth in which the deferment cut exceeded all other treatments at comparable depths (Figure 1). The strip cut treatment had the lowest impact on soil variables in this study and often was similar to the control or unharvested sites: --

Manipulation of each stand had an impact on soil physical properties regardless of treatment. A change in soil physical properties is an anticipated outcome of harvest and wood removal operations and is commonly reported for a diverse number of locations (Incerti and others,1987; Cullen and others,1991; Rachal and Karr,1989). Machine parameters including weight, tire pressure, total load, and number of passes have been implicated in the changes that soil physical properties undergo (Lenhard, 1986; Guo and Karr, 1989; Greene and Stuart, 1985; Meek and others, 1992). The differences in impact among treatments detected in this study may be the result of the total volume of wood extracted and the number of passes made by skidder traffic. Impacts to soil physical properties in the strip cut treatment were less than the other treatments as a lower stand volume was extracted (one quarter of the stand volume) and skidder traffic restricted to one half of the stand. Clearcut and deferment cut treatments induced greater impacts since more traffic was required to remove the total stand volume (clearcut) or a high percentage of the total volume (deferment cut) (Rummer and others, 1997).

The difference in soil response may be related to the degree and intensity of ground disturbances that occurred in conjunction with each treatment (Table 4). Strip cut treatments resulted in lower percentages of each disturbance category throughout the stand compared to the clearcut and deferment cut sites. Clearcut and deferment cut treatments were very similar in the percentages of each disturbance category with approximately 20 percent classified as untrafficked (U), 55 percent as slightly disturbed (2A and 2), and 20 percent as highly disturbed (4A and 4). The impact of harvest operations on the portion of each strip cut treatment which was exposed to felling and skidder traffic was tabulated and the percentages of each disturbance class determined to be similar to those reported for the clearcut and deferment cut treatments (Table 5). Soil bulk density and soil strength values recorded for each disturbance class within treatments showed differences but no clear trend emerged from the data (Table 6 and 7). However, both soil parameters increased progressively when grouped by disturbance class from untrafficked condition to ruts greater than 15 centimeters (Figure 2). Previous investigations have noted an increase in impacts to soil physical properties as soil disturbances progressed in sites where harvesting or thinning had been conducted {Miller and Sirois, 1986; Rachal and Karr, 1989; Lanford and Stokes, 1995). Impacts to both soil parameters were more intense in clearcut and deferment cut treatments compared to the strip cut which would be expected for reasons previously described. However, soil bulk density values indicated clearcut to be the more intensive of the treatments while soil strength data suggested the deferment cut had more impact compared to other treatments. The results for bulk density of clearcut sites supported the expectation that a greater impact to soil properties would be due to increased traffic patterns required to remove stand volume in the treatment area while the elevated soil strength associated with the deferment cut was not expected due to implementation of a system of dispersing traffic throughout the site. However, these differences may not be important as no significant differences were detected between the clearcut or deferment cut treatments. Further explanations for differences in trends for bulk density and soil strength by treatment may be related to the influence of intrinsic soil properties i.e. soil texture and preharvest site variability. Soil texture was the primary reason for fluctuations in soil strength and bulk density in two Canadian soils as the number of passes by a skidder increased (Meek, 1996). Preharvest variability was greater for soil strength than bulk density and may have influenced the postharvest estimates which was not accounted for in the analyses presented here. Grouping of soil physical variables by disturbance class clearly indicated a trend in soil response to disturbance intensity for both parameters. The utility of assessing impacts is still viable and critical information about harvesting impacts could be obtained from disturbance class alone. More careful consideration in the assessment of disturbance classes as a means of comparing Silvicultural treatments may be required to accurately gauge system impacts.

Summary

Harvest and skidder operations have the potential to impact soil surface and subsurface features of an upland hardwood stand. The impacts can be attenuated by utilization of the strip cut treatment as a means of stand wide manipulation but impacts were similar in their intensity in cut strips. No treatment induced changes in soil strength or bulk density that would be considered limiting to site productivity. Further information regarding regeneration and soil movement as a result of each Silvicultural prescription is forthcoming and may have significant bearing on the utility of each prescription in an upland hardwood stand.

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Table 1. Preharvest soil characteristics by slope position in treatment blocks of upland hardwood stand, Alabama.

Slope Position	Bulk Density ($Mg\ m^{-3}$)	Soil Moisture Content (%)	Total Porosity (%)	Texture	Soil Strength (MPa)
Upper	0.97	22.3	63.3	loam	1.07
Middle	1.00	26.4	62.3	loam	1.13
Bottom	1.03	33.9	61.3	loam	1.18

Table 2. Preharvest soil characteristics of future treatment blocks in an upland hardwood stand, Alabama.

Treatment	Bulk Density ($Mg\ m^{-3}$)	Soil Moisture (%)	Total Porosity (%)	Soil Strength (MPa)
Control	0.96	27.2	63.8	0.80
Clearcut	0.94	25.1	64.5	0.99
Deferment cut	1.15	31.1	54.2	1.39
Strip Cut	0.96	27.7	63.8	0.98

Table 3. Postharvest soil characteristics of an upland hardwood stand subjected to three alternative prescription, Alabama.

Treatment	Bulk Density ($Mg\ m^{-3}$)	Soil Moisture (%)	Total Porosity (%)	Soil Strength (MPa)
Control	0.96 b	27.2 a	63.8 a	0.80 c
Clearcut	1.23 a	34.2 a	53.3 b	1.14 ab
Deferment cut	1.06 ab	28.8 a	60.1 ab	1.28 a
Strip Cut	1.02 ab	27.3 a	61.5 ab	0.93 bc

Means in a column followed by the same letter are not significantly different at the 0.05 level.

Table 4. Percentage **of disturbance classes tabulated within each** treatment at the completion of harvest operations **in an upland hardwood stand,** Alabama.

Disturbance Class	Treatment		
	Clearcut	Deferment Cut	Strip Cut
Untrafficked	18	62	20
Slightly Disturbed			
2A	33	18	30
2	24	10	25
Highly Disturbed			
4A	16	6	20
4	<1	<1	0
Non Soil	8	4	5

Table 5. Percentage of disturbance classes in harvested zones of strip cut treatment in an upland hardwood stand, Alabama.

Disturbance Class	Strip Cut
Untrafficked	25
Slightly Disturbed	
2A	35
2	19
Highly Disturbed	
4A	12
4	1
Non Soil	8

Table 6. Bulk density (Mg m^{-3}) of surface soil layer (0 - 10 cm) of disturbance classes within each treatment in an upland hardwood stand, Alabama.

Disturbance Class	Treatment		
	Clearcut	Deferment Cut	Strip Cut
Untrafficked	1.13	1.04	1.10
Slightly Disturbed			
2A	1.04	1.07	1.09
2	1.20	1.14	0.95
Highly Disturbed			
4A	1.38	1.10	1.00
4	1.48	–	--

Table 7. Soil strength (MPa) of upper soil layer (O-20 cm) of disturbance classes within each treatment in an upland hardwood stand, Alabama.

Disturbance Class	Treatment		
	Clearcut	Deferment Cut	Strip Cut
Untrafficked	0.98	1.13	0.87
Slightly Disturbed			
2A	0.94	1.13	0.77
2	1.08	1.35	0.95
Highly Disturbed			
4A	1.31	1.45	1.18
4	1.51	--	1.01

Figure 1. Soil strength (MPa) of harvest treatments by depth

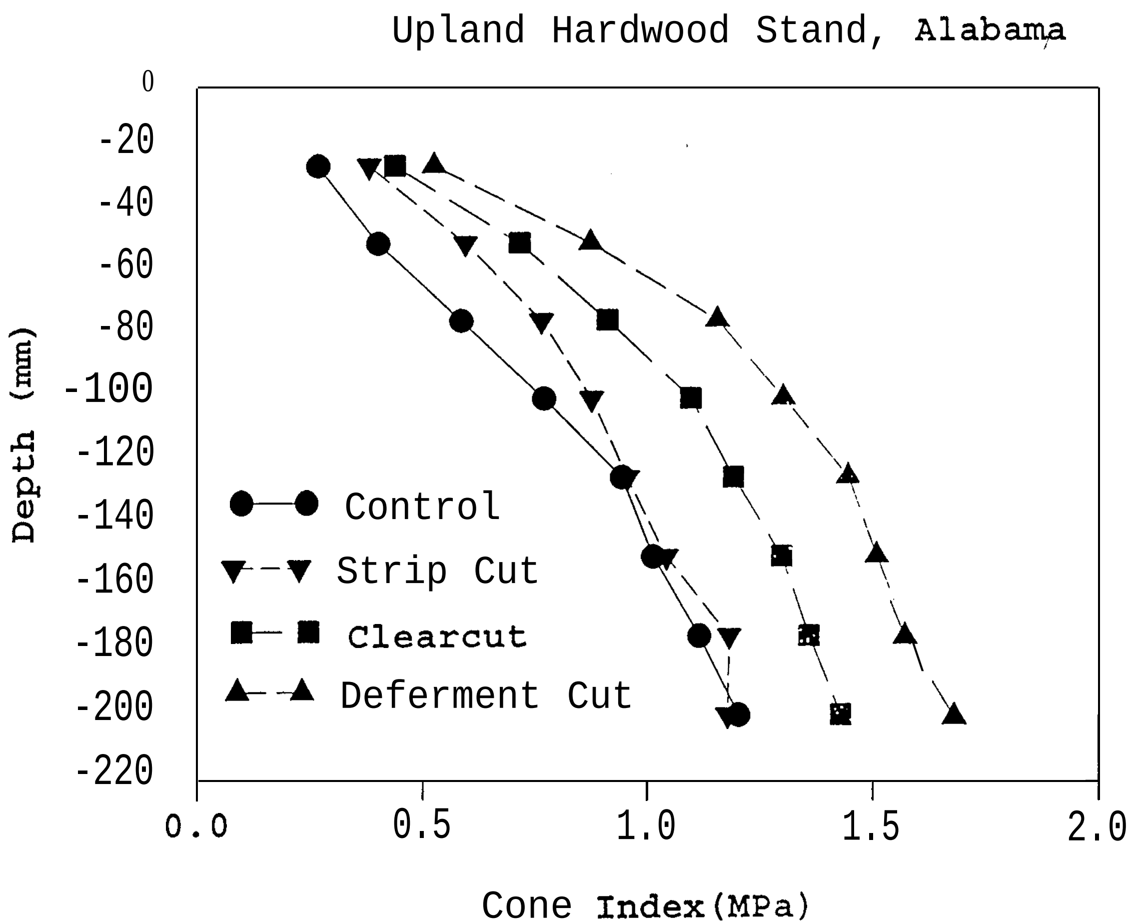

Figure 2. Postharvest mean soil strength and bulk density by disturbance class of an upland hardwood forest subjected to harvest operations, Alabama