STRIPS, CLEARCUTS, AND DEFERMENT CUTS: HARVEST COSTS AND SITE IMPACTS FOR ALTERNATIVE PRESCRIPTIONS IN UPLAND HARDWOODS

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ABSTRACT

Clearcutting upland hardwood stands is a common management prescription in the South which maximizes harvest efficiency. However, with increasing concerns about esthetics and ecological impacts, a better understanding of alternative treatments is needed. This study compared conventional block clearcutting, strip clearcutting, and deferment cutting in replicated treatments in northem Alabama. Treatment did not have a significant effect on felling productivity or costs, but did affect skiddiig productivity. The primary factor affecting harvesting productivity was average tree size of nmovals. Clearcutting caused significantly greater increases in soil bulk density than deferment or strip cutting. However, clearcut soil disturbance was the same as for deferment cutting.

INTRODUCTION

Management of upland hardwood stands in the southern Appalachian and mid-South areas of the United States has historically relied on high-grade single-tree prescriptions which have created extensive stands of low quality hardwoods (Mills, 1988; Sander, 1980). Single-tree selection has environmental and esthetic advantages primarily due to maintenance of continuous forest cover, but the subsequent stand quality is limited by the presence and regeneration of lower quality trees. The ultimate outcome of this practice is a low quality stand which is often block clearcut to minimize recovery costs and to aid in regeneration of a better quality stand.

While clearcutting has many legitimate silvicultural and economic justifications, the public is increasingly sensitized to this prescription for even-aged forest management. Valid or not, there is a widespread perception that clearcutting is harmful to the environment and represents an ecologically-insensitive approach to forest management. About half of the non-industrial private forest landowners in a recent poll considered clearcutting acceptable (Bliss, 1993), while nearly 40 percent consider it an unacceptable forest practice. These results are particularly striking considering these are *forest* landowners, not the general public, responding to the survey.

Because of **such concerns, resource managers are increasingly looking for alternatives to conventional clearcutting (Houston et al., 1995). Any alternative, however, must he able to meet the three most commonly cited objectives of southern forest landowners (esthetics, income, and wildlife). While each is important, these objectives may have conflicting requirements. Maximizing income, for example, may mean minimizing esthetic benefits and reducing some wildlife provisions. Selection among alternative management practices then, must he based on a thorough understanding of the tradeoffs associated with each treatment in terms of biological, economic, and esthetic factors.**

In the mid-South, most of the upland hardwood stands am in the oak-hickory forest type and are dominated by a variety of oaks associated with a diverse community of other tree and shrub species (Sander, 1980). The most

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valuable timber species within this type (i.e. ***Quercus alba, Liriodendron tulipfera*) are** at best intermediate in shade tolerance (Sims, 1980) and are naturally dominants in the overstory. Regeneration of oaks in these stands presents unique challenges to the forester. Oaks and hickories are heavy seeders which do not disperse well into openings. While shade intolerant, oaks are also slow growers which are easily overtopped by faster growing species such as **sweetgum (*Liquidambar styraciflua*)** or dogwood **(*Cornus sp.*)** if the stand is opened up too much. White oak seedlings, however, have the unique characteristic of persisting in the **understory** for long periods (up to 90 years) through successive sprouting and **dieback** without becoming suppressed. With the benefit of a mature root system these seedlings are prepared to occupy openings that may occur (Rogers, 1990). Stump sprouting is also a significant source of regeneration in this type for many hardwood species. Given these biological factors, **careless** application of stand treatments can have major effects on species composition, stocking, and stem **quality in** the new stand.

While a number of silvicultural treatments have been applied in the oak-hickory forest type, three treatments have been selected in this study to represent a range of possible stand regeneration options-block clearcutting, strip clearcutting, and deferment cutting.

***Block Clearcutting*—**Sander et al. (1981) note that clearcutting can be used to regenerate the oak-hickory forest type when adequate advance regeneration is present. Clearcutting in the oak-hickory type with advance regeneration is actually a "natural" one-pass shelterwood. This method of stand management produces an even-aged stand with low-cost harvesting, efficient administration and planning, rapid growth, and excellent habitat for some wildlife species. Regeneration in clearcuts may come from stump sprouts, the soil seed bank, or inseeding from adjacent areas. Supplemental planting may be required if desired species are not present in sufficient numbers in the pre-harvest stand. Chemical or mechanical control of competing vegetation may also be required to insure survival and growth of crop trees.

Esthetic concerns can be addressed by planning irregularly shaped cutting units that follow natural topographic features. However, as noted previously, the public's attitude about clearcutting indicates that esthetics are not adequately considered in current practice. Water quality should not be detrimentally affected by well-planned and properly executed clearcutting (Lawson, 1980). However, the short-term increase in water yield can raise the risk of soil movement and water quality impacts (Anderson et al., 1976).

***Strip Clearcutting*—Strip** clearcutting has been used successfully to regenerate northern hardwoods (Leak et al., 1969) and southern bottomland hardwoods (Williams, 1995). This regeneration method is essentially a modification of clearcutting (Smith, 1986) which can be used to regenerate either a two-aged stand or a multi-aged stand through a several-entry system. The basic concept is to promote natural regeneration and growth in the cut strips through the adjacency of the uncut area. The uncut strips provide a seed source and protection for the cut areas. As regeneration is established in the cuts, the uncut areas are progressively removed. A study of strip cutting in Michigan (Krefting and Phillips, 1970) found that deer habitat was improved because of the combination of browse development in the cut strips with the nearby protective cover of the uncut areas. Hombeck et al. (1975) found that erosion and stream sedimentation following strip clearcutting was significantly less than that produced from larger block **clearcut** areas. In addition to these potential benefits, strip clearcutting offers most of the ease of access associated with lower harvesting costs. Because individual strips are clearcut, marking and administrative costs are also minimized.

While the uncut strips can provide protection for regeneration, the adjacent stand may also **negatively** affect growth. Williams (1995) noted reduced height growth within 0.5 chain of the edge. Stocking also varied with significantly higher stocking closer to the edges, suggesting an effect of reseeding or alternatively increased damage of advanced regeneration nearer the center of the cut strip. Kockx et al. (1995) observed that patch

clearcutting maintained esthetic values, but required more careful planning than block clearcuts to insure proper location of landings and access roads for multiple-entries.

***Deferment Cutting*—Another** regeneration alternative for upland hardwoods is deferment cutting. This method is also known as an irregular shelterwood or a shelterwood with reserves. Deferment cutting leaves an overstory which provides site protection, regeneration, and esthetic benefits. Unlike a conventional shelterwood however, the residual trees are carried through the entire next rotation. While providing various benefits, retaining the overstory will reduce the growth of the developing regeneration.

Like a clearcut, deferment cutting manages the stand as a single management unit. Additional management costs are incurred, however, to select and mark the residual trees. If the prescription is based on advance regeneration as the primary source,.the residual trees can be selected for esthetics and shading. It is not necessary to select the residual overstory from the "biggest and best."

Clearly the selection of silvicultural system will affect regeneration, growth, esthetics, and wildlife. The prescription selection will also affect the amount and type of site disturbance and the economics of performing the forest operations, Intensive forest management practices have been correlated to increased bulk density and soil strength and reduced porosity and water infiltration (Gent and Ballard, 1984; Greacen and Sands, 1980; McDonald et al., 1995). Site disturbance also affects erosion potential. Annual sediment yield in southern forests increased substantially in response to harvest operations and contributed to decreased water quality and lowered site productivity (Yoho, 1980).

The scale of these disturbances will also vary with prescription. In a block clearcut, the entire area is affected in the initial entry. Subsequently, for the rest of the rotation, site disturbance effects are recovering and will be in a near-undisturbed condition for most of a conventional rotation. In a strip clearcut, some portion of the site will be disturbed in the initial entry. Like conventional clearcuts, the cut portion of the stand will then be left undisturbed for the remaining portion of the rotation. Additional disturbance will occur in the adjacent strips as each harvest entry is effected. While the area managed and volume produced over the rotation are essentially the same in the two types of clearcut systems, the site disturbance patterns are different. Deferment cutting offers yet another pattern of disturbance. The stand is disturbed once during the rotation like a clearcut, but traffic patterns during the harvest are constrained by the presence of the residuals and may present more deeply disturbed areas due to concentrated traffic.

OBJECTIVE

In selecting among alternative silvicultural prescriptions it is important to consider a range of effects (esthetics, soil impacts, regeneration, harvesting productivity) over a time scale that will include an entire rotation. The objective of this study was to compare the effect of three alternative prescriptions (clear-cut, strip clearcut, and deferment cut) on forest operation productivity, site impacts, esthetics, and silvicultural response in an upland hardwood stand. This report describes the installation and initial findings of the productivity and impact assessments. The installation of the silvicultural evaluation is described in a companion paper in this proceedings (Dubois et al. 1997). The esthetic comparisons will be presented in a future work.

METHODOLOGY

Site and Study Description

The project was located on an upland hardwood site in Lawrence County, Alabama. The site is in the southern Cumberland Plateau physiographic province and consists of east-west ridges with slopes of 20 to 25 percent.

The three prescriptions were replicated in nine, 1.6-ha blocks. Six treatment blocks were installed on a northerly aspect and three on a southerly aspect. There were two, 0.8-ha unharvested control blocks located on the north aspect and one on the south aspect. The northerly aspect stands averaged 924 trees per ha with a basal area of 30 m^2 per ha. The southerly aspect had somewhat smaller trees with 940 trees per ha and a basal area of 26 m^2 per ha.

Figure 1 illustrates the treatments that were evaluated. The clearcut treatment was defined as a silvicultural clearcut which required all stems over 3.8 cm to be felled. Similarly, in the strip cut treatment, all stems over 3.8 cm were cut in the marked strips. Approximately 37 m wide, the strips were laid out parallel to the contours with 37 m wide uncut- strips separating the cut strips. Finally, the deferment cut was marked to leave approximately 5.7 m^2 of basal area per ha in healthy, quality trees which could be expected to survive through the rotation.

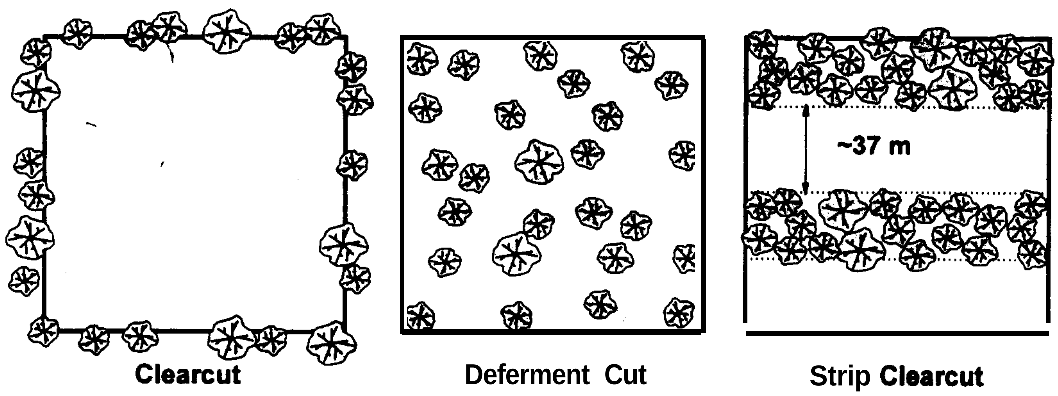

Figure 1. Alternative silvicultural treatments evaluated on an upland hardwood site.

The treatment blocks were located and marked during the spring of 1996. A pre-harvest inventory was conducted and sample plots were installed for the silvicultural measurements. A 48 x 24-m grid point intersection system was superimposed on each treatment block for measurement of soil physical properties and disturbance classes (60 points/block). Preharvest and postharvest soil measurements consisted of bulk density, gravimetric soil moisture content, and soil strength (Klute, 1986). Harvesting started on the six northerly blocks during the summer of 1996 and concluded on the 3 southerly blocks in the early fall.

All of the treatments were installed by a single contractor using a conventional harvesting system that incorporated chainsaw felling and grapple skidding. Limbing and topping were performed in the woods and the tree-length pieces were skidded to the landing for processing into sawlogs and pulpwood. The six northerly blocks were skidded with a 94 kW machine, while the southerly blocks were skidded with a 114 kW machine. Skid trails were located as "logger's choice" with some constraints to maintain buffer areas and to avoid trails in the uncut strips in the strip clearcut treatments. Standard elemental production data were collected for the felling and skidding functions in each block.

After the harvesting was completed, the soil and silvicultural sampling points were relocated and initial post-harvest measurements were taken. Each sample point was visually classified as either: (1) untrafficked, (2) trafficked with litter in place, (3) trafficked with litter removed or mineral soil exposed, (4) soil depression less than 15 cm, or (4) soil depression greater than 15 cm (Kluender and Stokes, 1992). Post-harvest soil sampling was conducted for bulk density and soil strength.

RESULTS

Harvesting Productivity

The felling cycle was divided into the following elements: walk-to-tree, brush, fell, and limb 8z top. Top diameter, dbh, and species were recorded for a randomly selected sample of trees in each block. Distance between felled trees was also measured. Cubic volumes were calculated for each cycle using volume equations appropriate for .the study area (Clark et al., 1986) to determine felling productivity. A summary of means for each felling parameter by treatment is shown in Table 1. Trees felled on the deferment cut blocks were smaller, on average, since dominants were marked as residuals.

Table 1. *Summary* of felling production statistics for the three harvest methods.

	Harvest Method		
Statistic	**Clearcut**	**Strip** cut	Deferment Cut
Number of observations	51	41	**49**
Average dbh (cm)	31.8	33.5	28.4
Average stem volume (m^3)	1.10	1.10	0.67
Inter&e distance (m)	7.7	8.0	7.1
Walk (min)	0.23	0.31	0.17
Brush (min)	0.13	0.19	0.11
Fell (min)	0.89	0.70	0.46
Limb & top (min)	0.89	0.89	0.62
Total-time (min)	1.79	2.06	1.34
Productivity (m^3/PMH[1])	35.43	32.21	31.00

Productive machine hours

An analysis of variance found no significant difference in elemental times or productivity among treatments. Total cycle time, however, was a function of tree size, block slope, and stocking.

$$\text{Total } \textit{fell and top time (min)} = (0.000849 \cdot DBH^2) + (0.06570 \cdot Slope) - (0.000676 \cdot TPH)$$

Corrected R-Square = 0.60

where: ***TPH*** = Initial trees per ha
DBH = Diameter at breast height (cm)
Slope = Average block slope (percent)

The skidding cycle was divided into the following elements: travel empty, position & hook/grapple, winch, intermediate travel, travel loaded winching, travel loaded, and unhooklungrapple. Travel empty and travel loaded skid distances were measured to the nearest 0.5-m for each cycle. At the landing, dbh and top diameter of each tree were recorded, along with the species of each tree. Cubic volumes were calculated for each cycle using volume equations appropriate for the study area (Clark et al., 1986) to determine skidding productivity. Because skid distance varied among blocks, the observed distances were transposed to produce a common average skid distance of 200 m. Adjusted travel times were calculated using a regression of time as a function of skid distance. The adjusted cycle times were then used to calculate a standardized productivity. A summary of means for each skidding parameter by treatment is shown in Table 2.

Table 2. Summary of skidding production statistics for the three harvesting methods.

	Harvest Method		
Statistic	**Clearcut**	**Strip Cut**	Deferment Cut
Travel empty (min)	1.75	2.04	**1.50**
Position & hook (min)	2.53	3.23	4.99
Position & grapple (min)	2.06	2.07	2.59
Winch **(min)**	0.64	0.50	0.62
Travel loaded **(min)**	3.89	3.30	2.71
Unhook **(min)**	0.97	0.80	0.97
Ungrapple (min)	0.02	0.06	0.05
Total cycle time (min)	9.36	8.81	7.87
Stems per cycle	3.6	3.6	4.5
Volume per cycle **(m^3)**	3.92	3.36	2.78
Travel empty distance (m)	246	287	193
Std. total time (min)	8.31	7.98	7.52
Std. productivity **(m^3/PMH[1])**	**27.43a[2]**	**25.92ab**	**22.45b**

[1]**Productive** machine hours

[2]**Means** with the same letter are not significantly different at the 0.05 level.

Analysis of variance indicated a significant treatment effect on skidding productivity. A comparison of the treatment means showed the strip cut treatment was not significantly different from either the **clearcut** or the deferment cut. However, productivity in the **clearcut** treatments was significantly higher than in the deferment cut. This is primarily due to piece size. Skid cycles in the deferment cuts had mom pieces with a lower total volume than in the other two treatments. This affected productivity by increasing hook or grapple time and by reducing payload. A combined productivity and cost for felling and skidding were calculated for the three treatments at the standardized skid distance of 200 m (Table 3).

Site Impacts

The utilization of strip cutting in this study resulted in less site disturbance compared to the deferment cut or **clearcut** treatments (Table 4). Approximately 60 percent of the strip cut treatment was tabulated as untrafficked and less than 24 and 6 percent as slightly disturbed and highly disturbed, respectively. In contrast, deferment and clear cut treatments resulted in less than 20 percent untrafftcked while the percent of slightly and highly disturbed classes increased to approximately 55 and 20 percent, respectively. The higher percentage of the untrafficked disturbance class within the strip cut treatment was expected since about half of the total stand area was in the uncut strips.

Pm-harvest bulk density and soil moisture content across the study site averaged 1.02 g/cc and 28 percent, respectively. Post-harvest bulk density increased in each treatment from preharvest levels and resulted in significant differences among **treatments** (Table 5). Clearcutting had the greatest impact on bulk density which increased to approximately 1.19 g/cc. Analysis of variance indicated mean bulk density of the **clearcut** treatment was **significantly** higherthan deferment and strip cuts; all **treatments** were significantly higher than control plots.

Table 3. System analysis for combined felling and skidding production and cost.

Treatment	Utilization (%)	Production (m^3/SMH[1])	Function Cost ($/SMH)	Production Costs[2] $/m³	$/tonne
Clearcut					
Chainsaw	50	17.72	11.11	0.63	0.55
Skidder	65	17.72	42.91	2.42	2.13
System		17.72	54.02	3.05	2.68
Strip Cut					
Chainsaw	50	16.11	11.11	0.69	0.61
Skidder	62	16.11	42.55	2.64	2.32
System		16.11	53.66	3.33	2.93
Deferment Cut					
Chainsaw	50	15.50	11.11	0.72	0.63
Skidder	69	15.50	43.52	2.81	2.47
System		15.50	54.63	3.53	3.10

‘Scheduled machine hours.

[2]Owning and operating costs only, does not include profit, overhead, or other production costs.

Table 4. Post-harvest soil surface disturbance classes for alternative silvicultural prescriptions.

Disturbance Class	Percent of total stand area[1] Clearcut	Strip cut	Deferment cut
Untrafficked	18	60	20
Slightly disturbed			
litter removed	33	17	30
soil exposed	24	7	25
Highly disturbed			
less than 15 cm depth	16	4	20
more than 15 cm depth	<1	2	0
Non-Soil	8	10	5

*Includes the uncut strips in the strip cut treatment

Table 5. Post-harvest mean bulk density by treatment and disturbance class for alternative prescriptions.

Disturbance Class	Soil bulk density (g/cc) Clearcut	Strip cut	Deferment cut
Overall[1]	**1.19a**	**1.03b**	**1.08b**
Untrafficked	1.13	1.10	1.04
Slightly disturbed			
litter removed	1.04	1.09	1.07
soil exposed	1.20	0.95	1.14
Highly disturbed			
less than 15 cm depth	1.38	1.00	1.10
more than 15 cm depth	1.48	—	—

‘Overall treatment means with similar letters were not significantly different at the **P=0.05** probability level.

Higher overall mean bulk density measurements in clearcut treatments resulted from greater bulk densities in the slightly and highly disturbed categories (Table 5). Mean bulk densities for surface soil exposed, depressions less than 15 cm, and depressions greater than 15 cm were consistently higher in the clearcut treatment compared to similar classes in the deferment or strip cut treatments. This would be expected since the clearcut treatments generally included a single primary skid trail which was used to extract the total stand volume. In the strip cuts, the individual primary skid trails were used to extract one-fourth the total stand volume. The deferment cuts, while removing most of the stand volume, used a system of dispersed traffic which minimized the impact of primary trails.

CONCLUSIONS

The management objectives for a given forest area establish the desired future conditions for a management unit. In many instances, there are alternative silvicultural methods which can be used to attain those conditions. For example, in this study, clearcutting, strip cutting, and deferment cutting all produce a naturally-regenerated even or two-aged stand of hardwoods. However, while the treatments may produce generally similar results, they may have significant differences in economic performance, esthetic values, or long-term sustainability and stand productivity. Resource managers must have a good understanding of these effects to make informed selections of treatments.

The productivity of the conventional harvesting systems examined here was affected by tree size. Given treatments that produce similar removal volumes per hectare (i.e. the strip cut and the clearcut), there should be little difference in harvesting productivity or cost. The deferment cut, on the other hand, significantly reduced harvesting productivity because the leave trees were selected from the largest trees in the stand. Skidding less than optimum load sixes becomes even more significant as skid distance increases beyond the 200 m average distance used in this study. With this in mind, the purpose of the residual trees should be carefully considered. If the trees are solely for shading or esthetics, then size, species, and quality are less important than crown radius. Selecting smaller, poorer quality trees for residuals would reduce the economic difference between clearcutting and deferment cutting. If, on the other hand, the residual stand is also the primary source of post-harvest regeneration, then tree quality is critical and a deferment cut will require a premium in harvesting costs. The observed difference in felling and skidding costs between clearcut and deferment cuts was 15 percent.

Alteration of soil bulk density in response to forest harvest operations is well documented (Greacen and Sands, 1980). The degree of change in bulk density has been attributed to a number of factors and their interaction including type of equipment utilized, the number of passes over a site, total load, and soil physical condition (Lanford and Stokes, 1995; Stokes et al., 1993; Wronski, 1984). Soil bulk density increased in this study as disturbance intensity increased in the clearcut treatment. However, in the deferment and strip cut treatments, factors such as the total area harvested, smaller turn volumes, and differences in trafficking intensity may have resulted in less overall disturbance and less impact in individual disturbance classes. Further evaluation of the silvicultural responses to these harvesting treatments will determine whether differences in disturbance patterns have an impact on stand regeneration and growth.

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