

IMPACT OF INTENSIVE UTILIZATION ON REGENERATION OPERATIONS

by

J. R. Ragan  
Temple-Eastex  
Thompson, GA

W. F. Watson  
Associate Professor  
Department of Forestry  
Mississippi State University  
Mississippi State, MS

B. J. Stokes  
Research Engineer  
U. S. Forest Service  
Auburn University, AL

Written for presentation at the 1987 International  
Winter Meeting of the AMERICAN SOCIETY OF  
AGRICULTURAL ENGINEERS

Hyatt Regency Chicago  
U in Illinois Center  
December 15-18, 1987

**SUMMARY:**

The reduction in regeneration costs attributable to intensive utilization is quantified. The effect on the soils of the various harvesting-site preparation strategies is also reported.

**KEYWORDS:**

Papers presented before ASAE meetings are considered to be the property of the Society. In general, the Society reserves the right of first publication of such papers, in complete form. However, it has no objection to publication, in condensed form, with credit to the Society and the author. Permission to publish a paper in full may be requested from ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659.

The Society is not responsible for statements or opinions advanced in papers or discussions at its meetings. Papers have not been subjected to the review process by ASAE editorial committees; therefore, are not to be considered as refereed.



**American  
Society  
of Agricultural  
Engineers**

St. Joseph, MI 49085-9659

## Impact of Intensive Utilization on Regeneration Operations

J. R. Ragan, W. F. Watson, and B. J. Stokes

The level of utilization in a timber harvesting operation is a function of the value of the products that can be harvested. In the past, hardwood pulpwood was a low-valued product in Mississippi. The income derived for a cord of hardwood pulpwood at a delivery point often would not pay the harvesting and transportation costs. Thus, the hardwood pulpwood was often left on the site to be dealt with during reforestation activities. Now, much of the residual material that is left following logging is usable only as a fuel stock. With the current fossil fuel prices, this wood energy stock (energywood) that can be produced from logging residues is of very low value even when delivered to a user. However, the net benefit of removing this material might be greater when the cost of dealing with the material during site preparation is considered.

Removal of additional increments of biomass from the site requires more traffic across the site during harvest. Additional movement by the feller-bunchers are required to fell the energywood and extra trips by the skidders are required to transport the energywood material to a deck area. A major concern following these intensive utilization operations should deal with the condition of the site following these operations, and the suitability of the site for subsequent establishment and growth of trees.

### LITERATURE REVIEW

Energywood harvesting is not always profitable. Costs as high as \$23 per green ton delivered to the user facility have been reported using modified conventional systems (profitable operations generally produce energywood for about \$10-\$12 per green ton). Harvesting costs alone (from

stump to van) account for at least half the total cost. Transportation is also a significant factor; costs ranging from 11 to 28 cents per ton per mile limit the maximum economical trucking radius (DOE 1984). The farther the harvesting site is from the consumer's delivery point, the more expensive and less competitive the energywood is as a fuel source.

Energywood harvesting operations are, however, in some cases economically feasible as is evidenced by the number of operations currently producing energywood. Generally, the successful operations operate in "near ideal" situations. Four factors which contribute to form these conditions are: (1) high biomass levels (up to 60 green tons per acre), (2) relatively flat topography, (3) close proximity to a user facility, and (4) high gate value for the energywood (Miller et al. 1986).

In situations where the harvest of wood for fuel may be unprofitable, forest products firms have explored the additional benefits of increased utilization. The removal during harvest of the undesirable material reduces the need for costly intensive site preparation. The removal of this undesirable material can reduce site preparation costs by as much as 60 to 80 percent (Watson and Stokes 1984). Site preparation costs were \$55 less per acre following intensive harvest than site preparation treatments following conventional harvests. This savings translated into a site preparation credit (savings) of at least \$3.50 per green ton for every ton of chips removed as fuel stock.

In addition to site preparation savings a reduction in the cost of regeneration can be attributed to the more favorable planting conditions created by the cleaner site. In a study of the influence of site characteristics and preparation practices in the South, Guldin (1982) found that as site preparation intensity increased, planting costs decreased. The

intensity of site preparation treatments was measured in machine passes across a site. Guldin's study found that the use of two or more site preparation treatments reduced machine planting costs by \$7.35 per acre.

Intensive forestry practices have the potential for long-term effects on the site. The success or failure of any regeneration effort is strongly influenced by past harvesting history and subsequent site preparation treatments. The degree of success varies by the methods used, amount of residual vegetation and debris present, and soil characteristics. Therefore, subsequent survival and growth rates of planted southern pines can vary significantly depending on the degree that limiting site conditions are impaired (DeWit 1983).

Damaged soil physical properties are recognized as factors that potentially could contribute to forest site productivity decline. Reductions of 30 to 70 percent in early height growth of loblolly pine have been reported by Switzer et al. (1978) on traffic compacted sites. According to Steinbrenner and Gessel (1955), the major effect of compaction in the Pacific Northwest is the reduction of macro pore space which generally reduces tree growth. Mitchell et al. (1981) reported root and shoot growth of loblolly pine seedlings in a fine sandy loam decreased with increasing soil bulk densities ranging from 1.2 to 1.8 gm/c<sup>3</sup>. The trends from their study indicate that bulk densities as low as 1.3 gm/c<sup>3</sup> can impair root growth.

#### METHODS

This study conducted in the steeper terrain of the upper coastal plains evaluates the opportunities for reducing site preparation and machine planting costs by more intensive utilization during harvest using conven-

tional harvest methods. Also the study evaluated the relative impact on the site of the various harvesting-site preparation combinations. Similar studies have been conducted in the lower coastal plains of Alabama and Mississippi (Watson and Stokes 1986). Cost differentials should occur due to differences in terrain. The study was conducted in three phases. Phase one was quantifying the volume removed by the various harvesting intensity levels. Phase two dealt with assessing costs with various site preparation methods and levels of harvesting residue. Phase three dealt with machine planting the sites to measure the possible effects of the previous treatments on planting costs. Finally, soil physical properties were determined before and after each operation to determine if particular strategies deteriorate the site more than other strategies studied.

This investigation was conducted in Tishomingo County in extreme Northeast Mississippi. The study area is located on the Fall Line Hills physiographic division of the Upper Coastal Plains geographic region. The soils consist chiefly of sands and clays that are moderately permeable. Slopes range from 5 to 40 percent. Consequently, runoff is rapid, and the erosion hazard is high on exposed soils.

Fourteen five-acre blocks (5 chains by 10 chains) were established. Ten blocks were placed in natural stands consisting mainly of shortleaf pine and various hardwood species. The remaining four blocks were placed in loblolly pine plantations. Since prescribed burning had not been carried out prior to our study, a large understory component was present in these stands. Block perimeters were well marked with flagging tape. A loading deck to be used during harvest operations was marked near the center of a 10 chain side of each block near a haul road. The standard location made average skid distances similar on the various blocks.

### Preharvest Inventory

A preharvest inventory was conducted on each block to determine the standing volume (green tons per acre) available. Ten 1/10-acre plots were established on each block to inventory trees greater than 3 inches dbh. Within these plots, 1/200-acre subplots were established to determine the standing biomass in the 1-3 inch dbh categories. These trees were individually destructively sampled to obtain the total green weight and total height for each tree. Trees were classified by species group. A commercially available software package was used to compute the total standing inventory available on each block (Clark et al. 1984). Standing volumes were reported in green tons per acre.

The estimates obtained from the preharvest inventory are presented in Table 1. The total biomass was separated into two use categories. All pine 5 inches dbh and larger was specified as pulpwood. All pines less than 5 inches dbh and all hardwoods 1 inch dbh or larger were specified as energywood.

### Harvest Treatments

Three harvest treatments, differentiated by the intensity of volume utilization, were administered on the study area in July and August. The harvest treatments were:

- (1) A conventional harvest in which all pines 5 inches dbh and larger were harvested. This pulpwood material was felled with conventional high-speed feller-bunchers, transported by grapple skidders to a delimiting gate, delimited, loaded onto trailers, and removed from the site in longwood form.
- (2) A moderate intensity harvest where the energywood (all pines less than 5 inches dbh and all hardwoods greater than 1 inch dbh) were

felled and bunched in the same manner as the pulp material in the conventional harvest, then skidded to a portable inwoods chipper for chipping and loaded into a chip van for transport. All pines 5 inches dbh and larger were harvested in the conventional manner.

- (3) An intensive utilization harvest in which the energywood component was processed as in the moderate intensity harvest. The pine pulpwood component was delimbed, chipped and screened to enhance the quality of the chips, then loaded into transport vans.

The harvesting operations were performed by an independent logger contracted by the Tennessee River Pulp and Paper Company. The logger used a Hydro-Ax 611 for the felling phase of the operation. Skidding was carried out with three Caterpillar 518 grapple skidders. Mississippi State University supplemented the conventional logging crew with an energywood crew. The equipment including operators consisted of two feller bunchers (a Melroe Bobcat and a Caterpillar 910), a Morbark 23 inch chipper, and a Mortran portable screen used to enhance chip quality. The purpose of this crew was to prevent potential underutilization of the chipper due to the inability of a single feller buncher to provide a sufficient supply of the energywood. The under- and over-sized chips detected by the screen were utilized as a fuel stock also. Costs of the harvesting operations have been reported by Broussard et al. (1987).

#### Post Harvest Data Collection

A post harvest inventory to determine the residual volume left on the site was performed in a manner similar to the preharvest cruise. In addition to the standing trees, all logging debris within the 1/200-acre subplot was weighed. As a check measure each truckload delivered to the user facility was weighed to obtain an accurate measure of the amount

harvested on each block. The results obtained from these estimates are presented in Table 2.

The pine pulp material was the major component on most blocks. The component classified as rejects are the under- and over-size pine pulp chips which were removed in the screening process. Harvested volume information was not available for block one due to incomplete records. A utilization percentage greater than 100 percent is indicated on block 14. The error can be attributed to randomness in sample plot selection. The preharvest inventory obviously understated the actual volume on the block.

#### Site Preparation Treatments

The site preparation treatments administered were representative of the usual methods following these harvest treatments. The operation was carried out in the fall following harvest by a Tennessee River Pulp and Paper Company site preparation crew. The treatments were:

- (1) A control non-treatment in which no site preparation treatments were done. Two moderate and one intensively harvested blocks were assigned to receive no treatment.
- (2) A single-pass disking operation carried out with a Caterpillar D8 track-type dozer pulling a Rome 16' disk. Three moderately and one intensively harvested block received this treatment.
- (3) A shear-rake-pile-burn operation carried out by a Caterpillar D8 track-type dozer. This two-pass operation involved an initial pass with a KGB shear blade, followed by a rake-and-pile pass. Windrows were burned with handset fires. Four conventionally

harvested and three intensively harvested blocks received this treatment.

Planting costs were also monitored to allow for the detection of the possible influence of harvesting practices and site preparation treatments on machine planting costs. A Tennessee River Pulp and Paper Company planting crew machine-planted the study area in the spring following site preparation. All blocks were planted at the same spacing (7' x 10'), with 10 feet between rows and 7 feet between trees within a row. Planting was performed using a Case 1150 crawler tractor pulling a Reynolds F900 planter.

#### Production Study

Servis recorders were mounted on the tractors during site preparation to determine the total productive time for the machines to accomplish specific treatments. The removable paper disks were replaced after each phase of the shear-rake-pile operation in order to break out the cost of performing each phase. The machines worked within the study block boundaries until the treatment was completed. Productive time for the planting operation was recorded by a monitor with a stopwatch. Times were recorded as the machine moved off of and on to the study block. This allowed the planting to be carried out in a normal manner.

#### Cost Determination

Machine and labor assumptions costs are presented in Table 3 for each machine observed. The machine rates were developed for each specific machine using new replacement costs and a 12 percent interest rate for financing. A useful life of 5 years was specified for all equipment. Realistic standardized labor rates (including fringe benefits) were used. The number of crew hours per year was assumed to be 2000. Various assump-

tions on the machine rates were based on studies performed by Cabbage (1981) and Miyata (1980). The hourly cost estimates used in the calculations was a rental rate which was multiplied by the productive time for each phase on each block. This figure was then divided by the number of acres per block to arrive at a cost per acre for each treatment (see Table 4).

## RESULTS

The conventional harvesting method removed an average of 55 percent of the estimated volume on the sites as opposed to 82 percent on the moderately harvested sites, and 86 percent on the intensively harvested sites (see Table 2). The residual biomass to be removed during site preparation amounted to 24.9 tons per acre on conventionally harvested blocks, 5.9 tons per acre on moderately harvested sites, and 6.8 tons per acre on intensively harvested sites. The discrepancy in residue levels can be attributed to the fact that three moderate harvest blocks were placed in plantations which had low biomass levels and only one intensive harvest block was placed in a plantation. The understory component made up a greater percentage of the aboveground biomass in the natural stands than in the plantations; thus, even with increased utilization a higher residual volume was produced.

A greater site preparation effort was required following the conventional method of harvest. Site preparation costs decreased as the intensity of harvest increased (see Table 4). Single degree of freedom analysis of variance indicated a significant cost differential between shear-rake-pile-burn treatments following conventional harvests and intensive harvests. Thus, a savings due to increased utilization in site preparation costs can be realized even if shear-rake-pile-burn is the only site preparation treatment being considered. Analysis of variances tests showed no

significant difference in disking costs between moderate and intensively harvested sites. Planting costs did not vary significantly with any harvest/site preparation combination.

Assuming that the mechanical site preparation treatments studied were equally effective in controlling competing vegetation, a site preparation credit was calculated for the reduction in site preparation cost due to the incremental volume removed during harvest by the more intensive utilization methods. (Visual inspections 10 months after site preparation indicate that this assumption is not unfounded. On the moderately and intensively harvested sites there was no difference in vegetation following disking and shear-rake-pile-burn treatments.) The credits were calculated by taking the reduction in site preparation costs from that obtained following a conventional harvest and dividing by the tons of chips generated (see Table 5).

Note the per acre credits are approximately equal for disking treatments on moderate and intensively harvested sites. The difference in credit per green ton is attributed to the amount of energywood available on the site. There was more chippable material on the intensively harvested blocks. Thus, the credit per ton was reduced. Similar credits may be assumed for these treatments where similar energywood tonnages are available.

#### SOIL PHYSICAL PROPERTIES

Given that soil compaction reduces growth, it would be desirable to minimize the impact by choosing the least damaging harvesting-site preparation strategies. Thus, this portion of the study was carried out to ascertain that particular strategies did not significantly deteriorate the site more than other strategies studied.

Ten sets of bulk density core samples at 2-inch and 4-inch depths were taken on each block at the following times: pre-harvest, post-harvest, post-site preparation, and post-planting. The average bulk densities for each sample occasion is presented by treatment in Table 6. The percent change in bulk density following each operation and overall can be seen in Table 7.

Blocks which received conventional harvest treatments were compacted more at the 2 inch depth than were the moderately and intensively harvested blocks. At the four inch sampling depth the blocks which were more intensively harvested exhibited greater soil compaction (see Table 6). Initially, most soil compaction was limited to the 2 inch sampling depth, but as activity within a stand increased there was a tendency for greater soil compaction at the 4 inch sampling depth. Compaction was greater on intensively harvested blocks than on moderately harvested blocks (see Table 7). Compaction was the result of increased traffic on the site. On the intensively harvested blocks two skidders moved the trees to one of several central locations to stockpile both energywood and merchantable material to be chipped, because the chipper was unable to keep up with the additional demands brought about by the pine pulp material. The third skidder moved the material from the stockpile to the chipper. The extra handling of the material increased traffic and consequently soil compaction. One-way analysis of variance tests indicated as was expected a highly significant difference between preharvest and post harvest observations at both sampling depths. This test found no significant differences in bulk density across the harvest intensities at the 2 inch sampling depth, but did indicate significant differences at the 4 inch depth (Table 8).

One goal of site preparation is to improve the microsite for each seedling (Crutchfield and Martin 1984). In this study this goal was accomplished on blocks that were disked. Soil bulk density was decreased significantly at both the 2 and 4 inch level after site preparation when disking was used (see Table 6). The bulk density of the soil was returned to preharvest conditions or was lessened when disking was used. This was also true at the 2 inch level on blocks that received shear-rake-pile and burn treatments. The rake-and-pile phase of this operation scarified the soil and thus reduced compaction. However, the rake did not penetrate the soil deeply enough to be beneficial at the 4 inch level. This intensive site preparation treatment compacted the site further at the 4 inch level.

Soil compaction as a result of machine planting was generally slight. Bulk density was actually decreased at the 4 inch level on the blocks receiving the intensive harvest/control site preparation treatments and intensive harvest/shear-rake-pile-burn treatments. This finding may be partially attributed to healing or recovery of the site due to alternating freezing and thawing of the site. No treatment combinations exhibited significant differences in bulk density after planting.

#### CONCLUSIONS

The harvest of understory biomass for energywood provides significant economic and silvicultural benefits which reach far beyond the original primary goal of reducing dependency on costly fossil fuels. These benefits have the potential to make marginal and submarginal energywood operations more attractive to forest products firms.

Removal of the understory component eliminated the need for intensive and costly site preparation. The moderately and intensively harvested blocks looked as though they had been site prepared following harvest. The reduction in harvesting residue on these blocks allowed the substitution of disking treatments for shear-rake-pile-burn treatments and a subsequent savings in site preparation costs of approximately \$75.00 per acre. When compared to conventionally harvested/sheared-raked-piled-burned blocks there was a reduction of approximately \$100.00 per acre on these blocks. The important finding is that even if shear-rake-pile-burn treatments are planned following intensive harvest a significant reduction (\$26/acre) was attained. The site preparation credits that could be allotted to the chips harvested can make the marginal harvest operations more economically feasible.

Site preparation costs trends were similar but comparatively higher in this study than those of the previously mentioned study conducted in the lower coastal plains. These higher costs were due in whole to the steeper terrain.

Planting costs were not significantly different on any of the harvest/site preparation treatment combination. Intensive harvesting did not reduce machine planting costs, and intensive site preparation was proven not justifiable for reducing planting costs.

Chemical site preparation can be used in the South as an alternative to mechanical site preparation. Due to time constraints this alternative was not explored in this study. Chemical applications cost about \$77.00 per acre for aerial application and about \$110.00 per acre for mobile ground sprayers in the South (Watson et al. 1986). This would be higher than the cost of disking in this study, so chemical site preparation would not be

competitive with disking treatments. Herbicides should provide vegetation control equal to or better than mechanical treatments but would not provide tillage to reduce soil compaction resulting from intensive harvesting methods.

Intensive harvesting and site preparation did not significantly affect the site more than conventional methods studied. Soil compaction increased as the level of activity within a stand increased during harvesting. Disking was found to be the best site preparation method for reducing harvesting compaction. Though the utilization of understory biomass left the site clean enough to plant, soil physical properties and competing vegetation control benefitted from the additional passes across the site when compared to sites which received no site preparation.

## LITERATURE CITED

- Broussard, M. L. 1987. Intensive utilization in rolling topography. Unpublished M.S. Thesis, Mississippi State Univ. 55 pp.
- Clark, A., R. C. Field, and T. M. Burgan. 1984. Total tree multi-product cruise program. S. E. Forest Expt. Station Research Paper, Asheville, NC.
- Crutchfield, D. M., and J. P. Martin. 1984. Site preparation-purpose. In: B. L. Karr (ed.). Proceedings Symposium on the Loblolly Pine Ecosystem (West Region). p. 87-89.
- Cubbage, F. W. 1981. Machine rate calculations and productivity rate tables for harvesting southern pine. Staff Paper Series 24. Dept. of For. Res., College of For. and the Agric. Expt. Station, University of Minnesota.
- DeWit, J. N. 1983. Site preparation effects on early loblolly pine (*Pinus taeda* L.) growth, hardwood competition, and soil physical properties: Interior Flatwoods, Kemper County, Mississippi. M.S. Thesis, Mississippi State Univ. 61 pp.
- DOE. 1984. Energywood harvesting technology. Department of Energy Publication No. DOE/CE/30784-1.
- Guldin, R. W. 1982. Machine planting costs are influenced by site characteristics and preparation practices. USDA Forest Service Southern Forest Expt. Station Research Note SO-287.
- Guldin, R. W. 1984. Site characteristics and preparation practices influence costs of ?????.
- Kluender, R. A. 1980. The pulpwood industry and the energy situation. American Pulpwood Association Paper 80-A-11. 9 p.
- Miller, D. E., T. J. Straka, B. J. Stokes, and W. F. Watson. 1986. Productivity and cost of conventional understory biomass harvesting systems. For. Prod. J. 37:5. pp. 39-43.
- Miyata, E. S. 1980. Determining fixed and operating costs of logging equipment. USDA For. Ser. Gen. Tech. Report N.C.-55. St. Paul, MN. 16 p.
- Steinbrenner, E. C., and S. P. Gessel. 1955. The effect of tractor logging on physical properties of some forest soil sin southwestern Washington. Soil Sci. Soc. Am. Proc. 19:372-376.
- Switzer, G. L., D. M. Moehring, and T. A. Terry. 1978. Clearcutting vs. alternative timber harvesting-stand regeneration systems: Effects on soils and environment of the South. p. 447-515. In: C. T. Youngberg (ed.). Proceedings Forest Soils and Land Use, Fifth N. Am. For. Soils Conf., Colorado State University.

Watson, W. F., and B. J. Stokes. 1984. Evaluating the opportunity for reducing site preparation costs by increasing the utilization of final harvest. Final Report for USDA Forest Service Southern Station Project 4720, FS-SO-3701-832-2. 26 p.

Watson, W. F., T. J. Straka, and S. H. Bullard. 1987. Costs and trends for forestry practices in the South. Forest Farmer Manual Edition 46(5):28-34.

Table 1. Preharvest inventory summary.

| Block | Stand Type | Pine 5"+          | Hardwood<br>and Pine | 1"<br>5" | Total |
|-------|------------|-------------------|----------------------|----------|-------|
|       |            | (green tons/acre) |                      |          |       |
| 1     | P          | 88.7              | 10.3                 |          | 100.0 |
| 2     | P          | 121.8             | 18.8                 |          | 140.6 |
| 4     | P          | 104.1             | 10.0                 |          | 114.1 |
| 5     | P          | 98.0              | 18.6                 |          | 116.6 |
| 11    | N          | 94.8              | 19.4                 |          | 114.2 |
| 12    | N          | 64.5              | 32.5                 |          | 97.0  |
| 13    | N          | 84.8              | 17.8                 |          | 102.6 |
| 14    | N          | 49.1              | 38.1                 |          | 87.2  |
| 15    | N          | 88.5              | 36.0                 |          | 124.5 |
| 16    | N          | 42.8              | 34.3                 |          | 77.1  |
| 17    | N          | 60.6              | 31.1                 |          | 91.7  |
| 18    | N          | 57.2              | 27.5                 |          | 84.7  |
| 19    | N          | 68.1              | 33.3                 |          | 101.4 |
| 20    | N          | 43.6              | 21.2                 |          | 74.8  |

N = Natural  
P = Plantation

Table 2. Residual and harvested green tons per acre.

| Harvest Intensity | Block | Standing Residue | Debris Onground | Total Residue | Pine Pulp Harvested | Hdwd & <sup>a</sup> Pine 5" | Total | Percent <sup>b</sup> |
|-------------------|-------|------------------|-----------------|---------------|---------------------|-----------------------------|-------|----------------------|
| Conventional      |       |                  |                 |               |                     |                             |       |                      |
|                   | 17    | 14.9             | 8.2             | 23.1          | 45.7                | --                          | 45.7  | 49.8                 |
|                   | 18    | 22.9             | 9.5             | 32.4          | 52.0                | --                          | 52.0  | 61.4                 |
|                   | 19    | 17.9             | 8.0             | 25.9          | 55.1                | --                          | 55.1  | 54.3                 |
|                   | 20    | 8.8              | 9.4             | 18.2          | 39.7                | --                          | 39.7  | 53.1                 |
| Moderate          |       |                  |                 |               |                     |                             |       |                      |
|                   | 1     | 0.0              | 6.5             | 6.5           | NA                  | NA                          | NA    | NA                   |
|                   | 2     | 0.1              | 6.5             | 6.6           | 89.2                | 17.4                        | 106.6 | 75.8                 |
|                   | 4     | 0.0              | 6.8             | 6.8           | 84.0                | 16.6                        | 100.6 | 88.2                 |
|                   | 11    | 0.0              | 6.3             | 6.3           | 72.3                | 23.4                        | 95.7  | 83.8                 |
|                   | 12    | 0.0              | 3.3             | 3.3           | 51.7                | 27.3                        | 79.0  | 81.4                 |
| Intensive         |       |                  |                 |               |                     |                             |       |                      |
|                   | 5     | 0.0              | 6.2             | 6.2           | 69.6                | 40.3                        | 109.9 | 94.3                 |
|                   | 13    | 0.0              | 7.6             | 7.6           | 54.8                | 28.9                        | 83.7  | 81.6                 |
|                   | 14    | 0.0              | 6.4             | 6.4           | 41.1                | 52.3                        | 93.4  | 107.1                |
|                   | 15    | 2.7              | 6.6             | 9.3           | 64.5                | 28.4                        | 92.9  | 74.6                 |
|                   | 16    | 0.0              | 4.3             | 4.3           | 43.5                | 29.7                        | 73.2  | 94.9                 |

<sup>a</sup>Includes pine pulp rejects

<sup>b</sup>Percent of cruised total standing volume

NA = Not available

Table 3. Machine and rental labor rates.

| Function    | Machine                         | Machine Rate Per Operating Hour | Labor Rate <sup>a</sup> Per Scheduled Hour | Rental Rate <sup>c</sup> Per Operating Hour |
|-------------|---------------------------------|---------------------------------|--|---|
| Disking     | CAT D8/Rome 16 Disk             | 109.79                          | 10.50                                      | 127.29                                      |
| Shearing    | CAT D8/Rome KGB Blade           | 109.69                          | 10.50                                      | 127.19                                      |
| Rake & Pile | CAT D8/Rome Rake                | 109.58                          | 10.50                                      | 127.09                                      |
| Planting    | CASE 1150/Reynolds F900 Planter | 38.39                           | 10.50/8.50 <sup>b</sup>                    | 70.07                                       |

<sup>a</sup>Includes fringe benefits

<sup>b</sup>Operator rate/laborer rate

<sup>c</sup>Machine rate plus labor per operating hour

Table 4. Average costs by component, treatment, and total regeneration effort.

| Harvest Treatment<br>Site Preparation<br>Treatment | Site Prep<br>Cost \$/AC | Planting<br>Cost \$/AC | Total Regeneration<br>Cost (\$/AC) |
|--|-------------------------|------------------------|------------------------------------|
| Conventional Harvest                               |                         |                        |                                    |
| Shear  | 65.57                   |                        |                                    |
| Rake-Pile  | 81.12                   |                        |                                    |
| Burn   | 1.34                    |                        |                                    |
| Total  | <u>148.03</u>           | 42.47                  | 190.30                             |
| Moderate Harvest                                   |                         |                        |                                    |
| Disk   | 49.56                   | 43.69                  | 93.25                              |
| Intensive Harvest                                  |                         |                        |                                    |
| Disk   | 46.59                   | 46.59                  | 93.18                              |
| Intensive Harvest                                  |                         |                        |                                    |
| Shear  | 55.88                   |                        |                                    |
| Rake-Pile  | 64.90                   |                        |                                    |
| Burn   | 1.34                    |                        |                                    |
| Total  | <u>122.12</u>           | 42.35                  | 164.47                             |

Table 5. Site preparation costs and credits by treatment.

| Harvest Method | Site Preparation Method | Cost \$/ac | Incremental Volume Removed (tons/ac) | Cost Savings Per Acre \$/ac | Site Prep Credit to Incremental Volume <sup>a</sup> (\$/green ton) |
|----------------|-------------------------|------------|--------------------------------------|-----------------------------|--|
| Conventional   | SRPB                    | 148.03     | --                                   | --                          | --   |
| Moderate       | Disk                    | 49.56      | 19.13                                | 98.47                       | 5.15   |
| Intensive      | Disk                    | 46.59      | 48.3                                 | 101.44                      | 2.10   |
| Intensive      | SRPB                    | 122.12     | 28.9                                 | 25.91                       | 0.90   |

<sup>a</sup>Assuming site preparation treatments were equally effective.

Table 6. Average soil bulk density by treatment.

| AVERAGE BULK DENSITY |            |                  |              |                |           |               |      |      |
|----------------------|------------|------------------|--------------|----------------|-----------|---------------|------|------|
| Harvest Intensity    | Soil Depth | Time of Sampling |              |                |           |               |      |      |
|                      |            | Pre-Harvest      | Post-Harvest | Post-Site Disk | Prep SRPB | Post-Planting |      |      |
|                      |            |                  |              |                |           | Control       | Disk | SRPB |
| Conventional         | 2"         | 1.26             | 1.43         | --             | 1.36      | --            | --   | 1.41 |
|                      | 4"         | 1.49             | 1.51         | --             | 1.54      | --            | --   | 1.55 |
| Moderate             | 2"         | 1.31             | 1.38         | 1.31           | --        | 1.44          | 1.34 | --   |
|                      | 4"         | 1.51             | 1.58         | 1.39           | --        | 1.60          | 1.43 | --   |
| Intensive            | 2"         | 1.25             | 1.38         | 1.34           | 1.29      | 1.48          | 1.36 | 1.30 |
|                      | 4"         | 1.41             | 1.59         | 1.44           | 1.86      | 1.49          | 1.47 | 1.56 |

-- = Not tested

Table 7. Percent change in soil bulk density.

| Harvest Intensity | Preharvest to Post-Harvest | Post-Harvest to Post-Site Prep |       | Post-Site Prep to Post-Planting |       | Preharvest to Post-Planting |      | Control |
|-------------------|----------------------------|--------------------------------|-------|---------------------------------|-------|-----------------------------|------|---------|
|                   |                            | Disk                           | SRPB  | Disk                            | SRPB  | Disk                        | SRPB |         |
| Conventional      |                            |                                |       |                                 |       |                             |      |         |
| 2"                | 13.5                       | --                             | -4.9  | --                              | 3.7   | --                          | 11.9 | --      |
| 4"                | 1.3                        | --                             | 9.2   | --                              | 0.7   | --                          | 4.0  | --      |
| Moderate          |                            |                                |       |                                 |       |                             |      |         |
| 2"                | 5.3                        | -5.1                           | --    | 2.3                             | --    | 2.3                         | --   | 9.9     |
| 4"                | 4.6                        | -12.0                          | --    | 2.9                             | --    | -5.3                        | --   | 6.0     |
| Intensive         |                            |                                |       |                                 |       |                             |      |         |
| 2"                | 10.4                       | -2.9                           | -6.5  | 1.5                             | 0.8   | 8.8                         | 4.0  | 18.4    |
| 4"                | 12.8                       | -9.4                           | -14.5 | 2.1                             | -16.1 | 4.3                         | 10.6 | 5.7     |

-- = Not tested