

COMPARISON OF TWO THINNING SYSTEMS. PART 1. STAND AND SITE IMPACTS

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ABSTRACT

During the winter of 1991, a side-by-side comparison was made between two popular thinning systems: a feller-buncher, grapple skidder, loader/slasher system and a harvester, forwarder system. A first commercial thinning was conducted in an 18-year-old loblolly pine stand. Test areas were cruised prior to thinning and remeasured after operations were completed. The target basal area per acre was successfully met by the forwarder system but not by the skidder system. Individual tree damage was recorded during plot remeasurement. The skidder system scarred 25 trees per acre versus 10 trees per acre with the forwarder system. Ground disturbance was recorded by two samples. One focused on skidder and forwarder trails where the area in various levels of disturbance was measured along with soil bulk density. The other sample was a systematic survey covering the entire study area and gave an overall sample of ground disturbance levels. The skidder system had more disturbed area and compacted the soil more than the forwarder system.

Choosing the most effective and efficient thinning method has been the subject of many forestry discussions. In an effort to better understand the dynamic relationships between machines, trees, and land during thinning, a controlled test was installed in a loblolly pine plantation in south Alabama. The goal was to detect differences in environmental impacts and costs between a commonly used thinning system that employs a skidder and a less common system that employs a forwarder. More specifically, the experiment was designed to examine:

1. Differences in tree sizes of the residual stands left by the two thinning systems;
2. Damage to trees left in the residual stands;
3. Disturbance to the ground litter and soils after thinning operations;
4. Compaction of soils during thinning activities;
5. Harvesting productivity and costs for the different thinning systems.

This report will address only the first four objectives and will be followed by Part 2. Harvesting Costs and Productivity, which will cover objective 5.

METHODS

THINNING SYSTEMS

Two popular thinning systems were compared: a skidder system and a forwarder system. The skidder system had been operational for 8 years. Equipment included a Hydro Ax 411 feller-buncher with 23.1x26 tires, a John Deere 640 grapple skidder with 28x26 tires, a delimiting gate, a Dunham knuckleboom loader with a CTR slasher saw, and tractor trailer highway haul vehicles.¹ In addition to a separate operator on each vehicle, a chain saw operator worked on the landing cleaning off any limbs missed by the gate. The foreman operated the loader/slasher and was a part of the four-man woods crew. Tractors with pulpwood trailers were supplied as needed.

Valmet of Gladstone, Mich., sup-

plied forwarder system equipment and a trained crew for a Valmet 546 Woodstar Harvester and a Valmet 546 Woodstar Forwarder. Both the harvester and forwarder had single front wheels with 23.1x26/10 Firestone FS tires and tandem rear wheels with 600/55x26.5/16 Nokia ELS tires. Set-out trailers for shortwood and cut-to-length wood were supplied as needed.

STUDY PERIOD, AREA, AND LAYOUT

A study period was chosen that would make comparisons of the two thinning systems under conditions when soil moisture was the highest. Tests were conducted during February and March of 1991.

The test site was located in Baldwin County, Ala., near Bay Minette on land owned by a large wood products company. The tract consisted of an 18-year-old loblolly pine plantation that was scheduled for thinning.

The prescription was to thin to 75 ft.² of basal area in a manner that thinned from below (commonly called selective thinning). Due to machine size requirements, the landowner would accept row removals for access if target residual basal areas were maintained.

Initially, both systems tried to thin with complete selectivity, that is, taking only the poorest trees. The feller-buncher for the skidder system did not have sufficient room to operate and still leave the target basal area and, therefore, had to go to a row/selective pattern. With row/selective, every fifth row was removed for access and the remaining trees selectively removed from the two side rows to either side of the clearcut

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¹The use of brand or trade names is for the reader's convenience and is not an endorsement by the authors or their respective organizations.

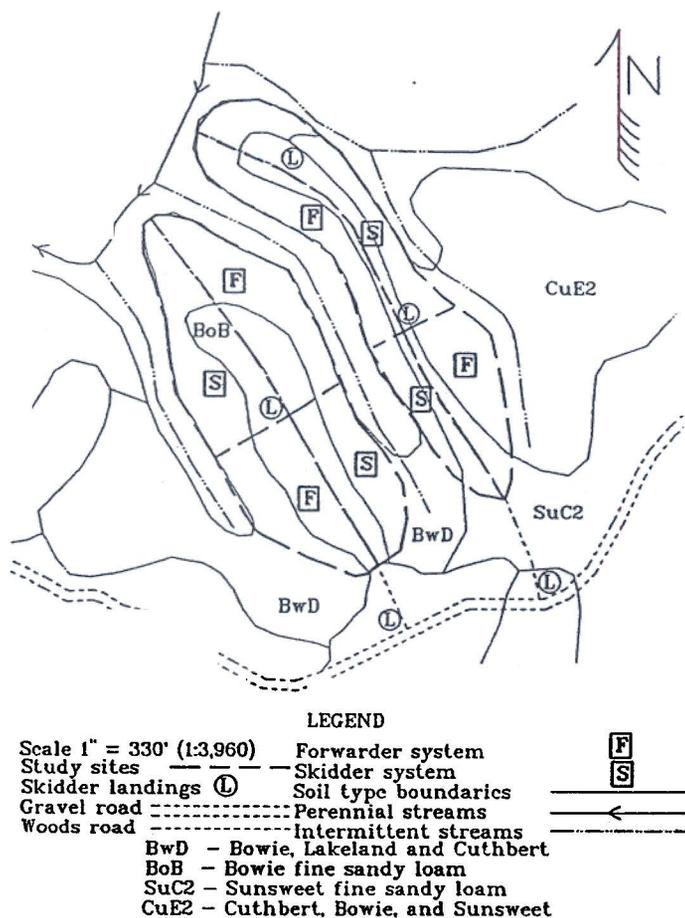


Figure 1 Study area near Bay Minette, Ala.

row. In general, the forwarder system was able to thin selectively for the entire test with only an occasional tree removed for access.

As shown in Figure 1, the test sites consisted of two ridges divided by drains and stream side management zones (SMZs) where logging activities were restricted. The two sites were approximately equal in size and totaled 20 acres. Unimproved trails (woods roads) suitable for pickups extended from a graveled main haul road down the center of each ridge to a SMZ at the end. Each test site was divided into four study blocks, two for the forwarder and two for the skidder system. The systems were assigned areas alternately to reduce bias. All areas appeared similar in terrain, soil, and timber characteristics. Four soil types were encountered. The ridges where the trails were located had a Sunsweet fine sandy loam (SuC2) with 5 to 8 percent slope or a Bowie fine sandy loam (BoB) with 2 to 5 percent

slope. The side slopes had Bowie, Lakeland, and Cuthbert soils (BwD) with 8 to 12 percent slope or Cuthbert, Bowie, and Sunsweet soils with 12 to 17 percent slope.

Since the forwarder system required no road building, its tests were conducted prior to those of the skidder system. The forwarder system started with the southwest portion of the west test site and then the northeast portion. When the west test site was completed by the forwarder system, it moved to the east test site, and the skidder system started on the northwest portion of the west test site.

STAND COMPOSITION

Since effects on residual stands were of particular interest, the stand was inventoried prior to all thinning activities. Thirty-two, 1/40th- (0.025) acre, fixed radius plots were randomly installed within soil type strata throughout the test sites, with equal numbers of plots in each area and strata. Plot locations were documented so they could be relocated after the stand had been thinned.

After all logging was completed, the original 32 plots were remeasured and an additional 32 random plots were added for a total of 64 plots. Plantation trees 2.5 inches diameter at breast height (DBH) and larger were measured to the nearest 1 inch. Plot basal area per acre after harvesting was compared to the target (75 ft.²) using t-tests for significance.

Tree measurements other than DBHs were not measured during the inventory cruise but were taken during the felling operations. Diameters of felled trees were measured with calipers at various lengths along the merchantable bole. Outside bark (o.b.) cubic foot content was calculated from diameters and lengths using Smalian's formula.² Recorded tree heights included total, merchantable to a 3.5-inch (o.b.) top, merchantable to a 2.0-inch (o.b.) top, and actual top. (Actual top height was where the top was severed from the merchantable bole.) Trees felled by the feller-buncher were measured up the entire tree to the various top diameters; those felled and processed by the Valmet Harvester generally were measured to the 3.5-inch top and the actual top.

Stump diameters were also recorded from downed trees. The Hydro Ax feller-buncher with its shear felling head cut stumps at the groundline. The Harvester with a bar and chain cut stumps approximately 6 inches above the groundline. With stump diameters and DBHs from both machines, least squares regression relationships for determining DBHs from stump diameters were calculated.

DAMAGE TO RESIDUAL TREES

Residual stand damage was measured at the cruise plot locations for the original 32 plots after all thinning activity was completed in an area. On scarred trees, measurements of DBH, distance from ground to scar, and scar size (width and height) were recorded along with plot identifications. There was no minimum scar size. Least squares regression with dummy variables for the two harvesting systems was used to compare tree damage.

DISTURBANCE TO FOREST FLOOR

Ground disturbance was measured using two different samples. Trail disturbance focused on the highest impact areas: the skidder and forwarder trails. Stand-wide disturbance surveyed

²Husch, B., C.I. Miller, and T.W. Beers. 1972. Forest Mensuration. Ronald Press Co., New York.

TABLE 2. Harvesting system effects on adjacent test areas.

Stand parameters	West site				East site				All plots	
	SW Fwd ^a	SE Skid ^a	NE Fwd	NW Skid	SE Fwd	SW Skid	NW Fwd	NE Skid	Fwd	Skid
Trees per acre										
Initial	435	420	485	480	320	350	355	425	399	419
Residual	220	230	270	235	190	210	215	185	224	215
Removed	215	190	215	245	130	140	140	240	175	204
Volume per acre (ft. ³ outside bark)										
Initial	2,815	3,016	3,366	2,872	3,834	3,388	3,670	4,130	3,421	3,351
Residual	1,679	1,730	2,145	1,485	2,624	2,534	2,550	2,408	2,250	2,039
Removed	1,136	1,286	1,220	1,387	1,210	854	1,120	1,723	1,171	1,312
Average DBH (quadratic)										
Initial	6.58	6.93	6.73	6.40	8.16	7.42	7.59	7.46	7.27	7.05
Residual	7.08	6.94	7.18	6.52	8.70	8.12	8.12	8.33	7.77	7.51
Removed	6.06	6.85	6.31	6.32	7.73	6.11	6.88	6.62	6.75	6.47
Basal area per acre (ft. ²)										
Initial	101	107	120	106	113	104	111	127	111	111
Residual	59	61	74	53	75	75	75	70	71	65
Removed	43	46	46	53	38	29	36	57	40	46

^a Fwd = forwarder system; Skid = skidder system.

TABLE 1. — Ground disturbance classes.

Code	Description
1	Undisturbed
2a	Slightly disturbed with litter in place
2b	Slightly disturbed with litter removed and mineral soil exposed
2c	Slightly disturbed with litter and mineral soil mixed
2d	Slightly disturbed with mineral soil deposited on top of litter
3	Deeply disturbed with surface soil removed and subsoil exposed
4a	Rutted 0 up to 6 in. by log and/or machine
4b	Rutted 6 up to 12 in. by log and/or machine
4c	Rutted 12 in. or more by log and/or machine
6	Downed wood, stumps, standing trees

ground disturbance for the entire test site in a systematic fashion.

Trail disturbance involved selecting a skidder or forwarder trail as a baseline and establishing transect lines along its length at fixed intervals of 25 feet. The baselines started near the ridge trail and were a maximum of 125 feet long. (Due to the width of the test sites, some baselines were shorter than the maximum.) The 30-foot transect lines were perpendicular and centered on the baseline (15 ft. on either side). Transect lines were subdivided and recorded according to type of disturbance (Table 1). Two skid trails were randomly selected from each study block for a total of 16.

At the first occurrence of a distur-

bance class on any transect line, a soil bulk density core sample was taken. Soil samples were taken from two depths (2 in. and 6 in.) over the range of disturbance classes (Table 1). For each sample, bulk density and soil moisture were measured, and on some samples, soil texture (percentage of sand, silt, and clay) was measured.³ No soil samples were taken where downed wood covered the ground (Class 6).

Compaction was determined by comparing the difference in bulk density of disturbed areas to undisturbed areas. Least squares regression with disturbance classes represented by dummy variables enabled bulk density measures to be compared.

Stand-wide disturbance measurements were taken systematically. Three lines parallel to the long axis of the study blocks were installed: one line along the top of the ridge near the ridge trail, one on the side, and one on the bottom of the ridge. A total of 12 lines were placed in the 2 test sites. Sample points were taken every 40 feet along each line. At these points, the disturbance class (Table 1) and slope were recorded.

Ground disturbance for both trail and stand-wide measures were analyzed using least squares regression with dummy variables for qualitative descriptors.

RESULTS

Weather during the study consisted of short dry periods spread between rainy days. For the week prior to the test,

it rained 3 days. The first study week (February 25 to March 1, 1991) had no rain until Friday. The forwarder crew completed its assigned thinning areas starting on Monday and finishing the last forwarder load on Friday. The skidder crew started on Thursday and continued until Friday when rain curtailed operations. Rain halted operations of the skidder system on the southeast portion of the west test site. Due to rain, the skidder crew was unable to finish the cut until March 19 and 20, 1991.

GENERAL STUDY OBSERVATIONS

Roads and landings requirements were different for the two thinning systems. The forwarder system transported wood to the existing main haul road where set-out trailers were positioned. The existing ridge trails coupled with in-woods travel were sufficient for the forwarder to get wood to the set-out trailers with no additional road preparation. Since the main haul road was wide enough for set-out trailers and passage of other vehicles, prepared landings were not necessary. Average forwarding distance was estimated to be 924 feet based on measured distances and mapped area.

The skidder system required that ridge roads be improved for tractor trailer traffic. The grapple skidder was used to widen ridge roads and build landings. In addition to the trail improvements, tractor trailers needed the assistance of the skidder for pushing or pulling while moving from the landings to the main haul road.

³ Buckman, H.O. and N.C. Brady. 1960. The Nature and Properties of Soils. Macmillan Company, New York.

As shown in Figure 1, five landings were used by the skidder system, three in the east portion and two in the west portion. Each landing was split into an

area for gate delimiting and an area for slashing and loading tractor trailers. It was a policy of the thinning contractor to use two small landings rather than

one large one because it left smaller openings in the plantation. Average skidding distance was estimated at 512 feet.

Weather effects were evident during the tests. While rain was encountered on only 1 day for the forwarder system, rain preceded the tests and the ground was saturated. When rain was encountered by the forwarder system, it was not hampered. In the woods, the forwarder and its payload were given added support by limbs and tops placed in the forwarder trail by the harvester. Both operators were in enclosed, climate-controlled cabs. When the skidder system encountered rain, it had to move operations to a tract where rain caused less of an impact. While operators did not have work stations as comfortable as those with the forwarder system machines, they were generally protected from outside elements, except for the chainsaw operator. Stoppage due to rain was caused by the inability of tractor trailers to get from the landings to the main haul road even with assistance from the skidder.

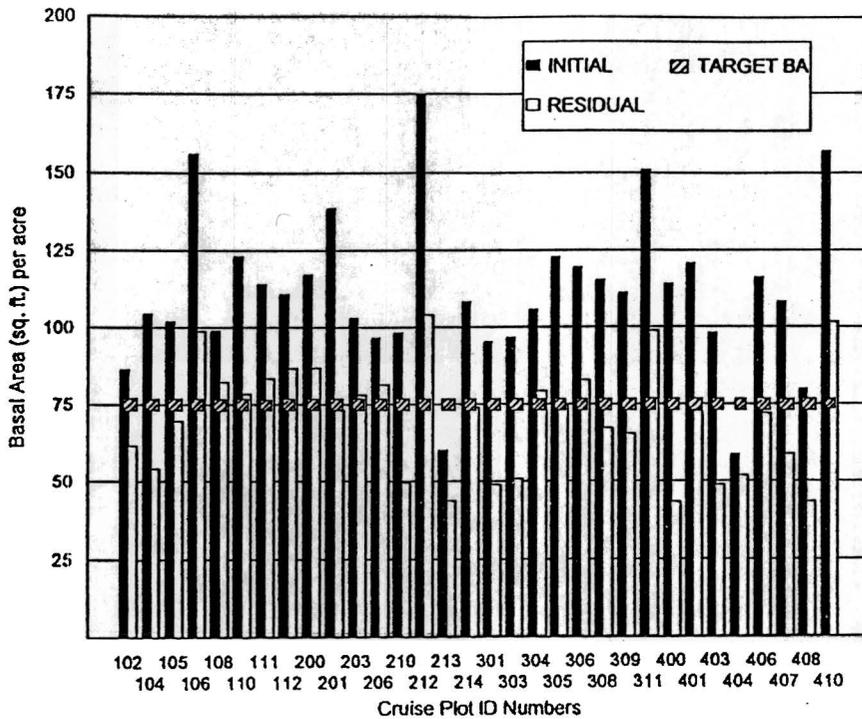


Figure 2. — Comparison of basal area before and after thinning with forwarder system.

RESIDUAL STAND IMPACTS

From remeasured cruise plots, the forwarder system averaged 71 ft.² of basal area per acre (BA), which was not significantly different from the target (75 ft.²) at the 95 percent confidence level (Table 2 and Fig. 2). The target BA met or exceeded 14 out of 32 plots (44%) with a coefficient of variation of 25 percent.

The skidder system averaged 65 square feet of BA, which was significantly under (at the 95% confidence level) the target BA, with only 10 plots or 31 percent meeting or exceeding the target (Fig. 3). The coefficient of variation for the 32 plots was 43 percent.

Table 2 combines plots taken in test areas and compares test area averages for those that were side by side on the ground. For these four comparisons, the forwarder system left more trees per acre for two pairs, more volume per acre for three pairs, larger average DBHs for three pairs, and more basal area for two pairs.

DAMAGE TO RESIDUAL TREES

Residual tree damage was measured by scar size and number of scarred trees per acre. The relationship between scar size and tree size (DBH) was not significant at the 95 percent confidence level.

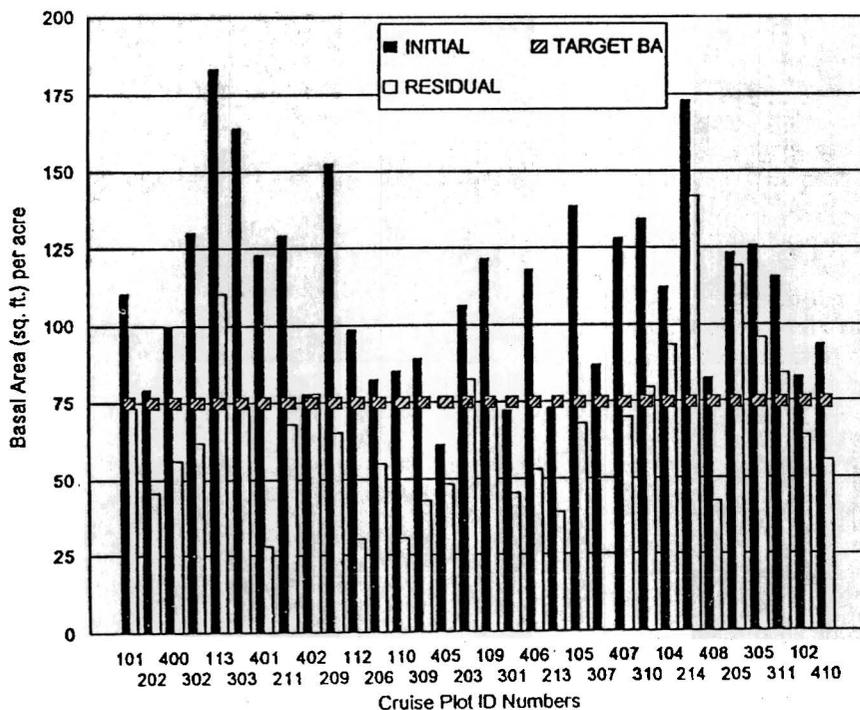


Figure 3. — Comparison of basal area before and after thinning with skidder system.

TABLE 3. — Residual stand damage from 1/40th-acre plots.

Thinning system	Scarred trees per acre (no.)	Scar size per tree ----- (in. ²) -----	Scar area per acre
Forwarder			
Mean (n = 16)	10	7.15	71.50
Standard deviation	17.3	1.81	129.05
Coefficient of variation (%)	58	394	55
Skidder			
Mean (n = 16)	25	68.29	1,707.25
Standard deviation	34.3	47.19	2,628.51
Coefficient of variation (%)	73	145	65
Comparison of systems			
t-test	1.56	5.18	2.49
Level of significance (%)	80	99	95

TABLE 4. — Ground disturbance in percentage of sampled area.

Disturbance classes	Trail sample		Stand-wide sample	
	Skidder	Forwarder	Skidder	Forwarder
	30	57	44	53
	20	11	13	9
	0	0	1	0
	45	23	38	29
	5	9	4	9
	100	100	100	100

The skidder system scarred significantly more trees per acre than the forwarder system (25 trees vs. 10 trees per acre, Table 3). The skidder system had significantly larger scars than did the forwarder system. On individual trees, skidder scars averaged 68 in.² as compared to 7 in.² for the forwarder system. Over the test area, the skidder system averaged 1,707 in.² of scar area per acre versus 72 in.² for the forwarder. Compared to the forwarder system, the skidder system had 10 times larger scars and 24 times more scar area per acre.

**GROUND DISTURBANCE:
TRAIL SAMPLE**

Of the list of ground disturbance classes (Table 1), only code 4c (ruts greater than 12 in.) was not observed. Due to limited observations of some codes, all code 2's (a,b,c, and d) were lumped into a single category, called slightly disturbed. Likewise, code 4a and 4b were summed into a "rutted" category. Table 4 summarizes results of both the trail and stand-wide samples.

Since trail measurements were from the centerline of the test areas near the ridge roads and extended down slope toward the SMZs, it might be expected that more disturbance would occur near the ridge road rather than further down the slope. Analysis of the amount of undisturbed area in relation to the distance from the ridge road did not confirm this hypothesis. While it would be

expected that areas with more traffic would have more disturbance, the trail lengths of 125 feet maximum may not have been long enough to detect this difference.

As shown in Table 4, 30 percent of the transect lines were identified as being undisturbed for the skidder system versus 57 percent for the forwarder. The forwarder system had significantly more undisturbed area than the skidder system. Location within the test sites was examined and found not to significantly affect the amount of undisturbed ground.

The skidder system had significantly more area coded as slightly disturbed, 20 percent versus 11 percent for the forwarder system. No areas were coded as deeply disturbed in this trail sample, which may have been due to the small differences in definitions between deeply disturbed and rutted code 4a.

The skidder also had significantly more rutted area (45% vs. 23%). Over all classes with some type of disturbance, the skidder system showed almost twice as much disturbance (65% vs. 34%).

The forwarder system did have significantly more downed wood to walk over (9% vs. 5%). The forwarder system could have placed more limbs and tops in the trail had soft ground conditions required it, but it would have cost

the system in lost productivity. Limbs and tops that accumulated at the gate were scattered when the gating sites were retired.

**GROUND DISTURBANCE:
STAND-WIDE SAMPLE**

When ground disturbance was sampled across the entire test area, similar results to that of the trail examinations were found (Table 4). The forwarder system had significantly more undisturbed area (53% vs. 44%) and downed wood (9% vs. 4%). The skidder system had significantly more slightly disturbed area (13% vs. 9%), deeply disturbed area (1% vs. 0%), and rutted area (38% vs. 29%). Over all classes of disturbed area, the skidder system disturbed 52 percent of the area and the forwarder system disturbed 38 percent.

As with the trail disturbance measures, location within the test area was tested and found not to have significantly different disturbance levels.

SOIL COMPACTION

Table 5 gives average bulk densities and number of observations for the various disturbance classes at the two sample depths.

Soil moisture content significantly impacted bulk density at both the 2-inch and 6-inch depths. In addition, bulk density was influenced by soil texture in the areas that had ground disturbance; soils with different textures reacted differently to compaction. As expected, there were no differences in bulk density between thinning systems in the undisturbed areas (code 1) after accounting for soil moisture.

Some disturbance classes were found to have similar bulk densities at both the 2- and 6-inch depths. The areas described earlier as slightly disturbed (codes 2a through 2d) either did not have recordings or were not statistically different. Likewise, codes 3 and 4a through 4c had similar bulk densities and were combined into a "highly disturbed" classification (Table 6).

At the 2-inch depth, the skidder system had significant increases in bulk density compared to the undisturbed samples (Table 6); the slightly disturbed areas had 11 percent more compaction and the highly disturbed areas had 20 percent more. Compared to the undisturbed areas, the forwarder system created no additional compaction in the slightly disturbed conditions but had a

TABLE 5. — Average bulk density (observations).

Disturbance classes	2-inch depth			6-inch depth		
	Forwarder	Skidder	Average	Forwarder	Skidder	Average
	----- (g/cm ³) -----					
Undisturbed						
1	1.01 (66) ^a	1.04 (54)	1.03 (120)	1.18 (68)	1.27 (54)	1.22 (122)
Slightly disturbed						
2a (with litter in place)	1.05 (31)	1.14 (47)	1.11 (78)	1.22 (30)	1.33 (48)	1.29 (78)
2b (with litter removed and mineral soil exposed)	1.07 (3)	1.16 (22)	1.15 (25)	1.19 (3)	1.31 (22)	1.30 (25)
2c (with litter and mineral soil mixed)	1.06 (2)	1.13 (7)	1.11 (9)	1.24 (2)	1.27 (7)	1.26 (9)
2d (with mineral soil on top of litter)	0.98 (2)	0.85 (1)	0.93 (3)	1.06 (1)	1.36 (1)	1.21 (2)
Deeply disturbed						
3 (with surface soil removed and subsoil exposed)	1.21 (2)	1.18 (2)	1.20 (4)	1.28 (2)	1.26 (2)	1.27 (4)
Rutted						
4a (0 to 6 in. by log or machine)	1.15 (64)	1.21 (71)	1.18 (135)	1.29 (66)	1.38 (73)	1.34 (139)
4b (6 to 12 in. by log or machine)		1.23 (4)	1.23 (4)		1.34 (4)	1.34 (4)
4c (more than 12 in. by log or machine)						
Downed wood						
6 (stumps, limbs, tops, trees)						
Average	1.08 (170)	1.14 (208)	1.11 (378)	1.23 (172)	1.33 (211)	1.28 (383)

^a Values in parentheses are numbers of observations.

TABLE 6. — Bulk density increase from undisturbed areas.

Disturbance classes	2-inch depth		6-inch depth	
	Forwarder	Skidder	Forwarder	Skidder
	----- (%) -----			
Slightly disturbed (code 2a, 2b, 2c, 2d)	0	11	0	7
Highly disturbed (code 3, 4a, 4b)	12	20	0	10

12 percent increase (highly significant) in the highly disturbed areas. The skidder system caused significantly more compaction than the forwarder system at all levels of disturbance.

At the 6-inch depth, the skidder system showed significant increases in compaction compared to the undisturbed: a 7 percent increase in compaction in the slightly disturbed and a 10 percent increase in the highly disturbed areas. The forwarder system had no significant increase in compaction in either of the disturbed conditions. As in the case of the 2-inch depth, the skidder system also had significantly more compaction than the forwarder system in the 6-inch depth.

SUMMARY AND CONCLUSIONS

This comparison focused on two popular thinning systems. Skidder systems are currently performing most of the thinning work, but forwarder systems are viewed as a desirable option. An 18-year-old loblolly pine plantation was chosen for a side-by-side trial. Care

was taken to assure that each system was given similar conditions in which to work.

Noticeable differences were observed in the layout for each system. The skidder system installed woods roads by widening existing trails and built five in-woods landings. Rain caused these roads and landings to be unusable and required the operation to be moved before tests were completed.

The forwarder system was less hampered by rain because forwarders were able to transport wood on the existing trails without improvement. Set-out trailers were positioned on graveled haul roads where hauling was less impacted by rain. The noticeable lack of roads and landings gave a less disturbed appearance after the stand was thinned.

A target basal area was set by the landowner at 75 ft.² The forwarder system achieved this goal, but the skidder system did not.

Residual tree damage was signifi-

cantly higher for the skidder system with 25 trees versus 10 trees per acre scarred. The individual scars from the skidder system averaged 10 times larger, and there was 24 times more scar area per acre.

The skidder system had significantly more ground disturbance than the forwarder system for all categories of disturbance. The skidder system significantly compacted the soil for all disturbance classes; the forwarder system did not significantly compact the soil except when an area was highly disturbed at the 2-inch depth.

Conclusions drawn from this comparison were that the forwarder system damaged the residual stand and site less than the skidder system and took less land out of timber production by requiring less roads and landings. While not absolutely conclusive from this study, the forwarder system also appears to offer the potential for more consistent wood flow due to less sensitivity to weather conditions.

Future studies should focus on how stand and site damage affect stand productivity. While the skidder system gave overall poorer impact results, it is not known if these impacts will adversely affect tree growth and site productivity.