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Louisiana Forest Products Laboratory

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Assessment of Site and Stand Disturbance from CTL Harvesting

ABSTRACT

Assessment of stand and ground disturbance resulting from cut-to-length (CTL) winter season harvest demonstrations performed on a 12-year-old pine plantation first thinning, 23-year-old second thinning, and a mixed pine/hardwood natural stand clearcut harvest is reported. The harvests were performed on Martin Timber Company lands in central Louisiana, during February and March, 1997. Machine productivity and harvest costs will be reported separately. Ground disturbance results show that 10.9% of the total harvest area was disturbed to some level, soil compaction in disturbed areas was increased by 21.4% in the most severe cases, rut depth averaged 13.0 inches in the most severely disturbed areas along the corridor trail, logging slash occupied up to 70% of the corridor trail distance, and mean soil density in lightly rutted (one machine pass) traffic areas was 1.44g/cc or 17.4% greater than in undisturbed areas. Mean soil bulk density in traveled areas covered with slash was 0% to 14% higher than the undisturbed areas. In first thinning harvest trials, 2.1% of the residual trees had bole injuries, and in second thinning trials injury to the stand was less than 1%.

Keywords. Logging, cut-to-length, soil compaction, rutting.

INTRODUCTION

Forest managers in the South Central region are becoming increasingly interested in Scandinavian-designed timber harvesting/forwarding systems developed during the early 1970's for thinning and clearcutting Southern pine plantations, principally for environmental reasons. Guimier (1997) reported that about 30% of the timber now harvested in Canada is by use of CTL logging systems which is up from 10% in 1990. Loggers are interested in the equipment because of reduced labor costs, reduced workers' compensation insurance costs, and more operable days per year. The CTL system is generally composed of two machines: a harvester and a forwarder. The harvester consists of a felling/processing head and usually a measuring system which allows the operator to cut stems to lengths and diameters in accordance with mill specifications for logs. The forwarder consists of a carrier with a load-carrying rack and loader which allows it to self-load and self-unload onto logging trucks. Advantages claimed for these systems are economic and environmental and include less damage to the residual stand than harvesting by conventional systems, the ability to merchandise products in the woods, recovery of higher valued products, minimum site damage, may eliminate the need for a loader, large forwarder payload, and operator safety and comfort (Tufts and Brinker 1993 and O'Connor 1991). Disadvantages of CTL systems include high initial cost of individual machines, complexity requiring highly skilled mechanics and operators, single-stem processing by the harvester which makes the system very sensitive to tree size, log size/weight limitation, forwarders not as versatile as skidders, and log length limitation of the forwarder (Tufts and Brinker 1993, O'Connor 1991, and Conway 1982). Because the harvester felling head is boom-mounted, the machine does not have to drive to every tree harvested, as is the case with commonly used wheeled feller-bunchers, which reduces the number and severity of tree injuries and ground area compaction. In a site and stand impact study of a first thinning harvest of an 18-year-old pine plantation stand comparing a CTL operation to a feller-buncher-skidder operation, Lanford and Stokes (1995) reported the CTL system disturbed significantly less area than the skidder system. They also reported that the skidder system injured 25 trees per acre compared to 10 trees per acre for the CTL system in that study. After severing the tree from the stump, the boom is retracted to allow the top to fall within the growing space the tree occupied rather than being forced down or carried through the residual stand. Processing the tree in front of the machine and then driving over the slash is reported to reduce soil compaction from the harvester and the forwarder. Seixas et al. (1995) reported that for a single forwarder pass on wet soil, slash coverage at 20kg/m^2 was effective at controlling soil compaction. However, on dry, loamy sand soils, Seixas reported the presence of slash did not decrease soil compaction for a single forwarder pass but for multiple forwarder passes the presence of slash did reduce soil compaction. The forwarder follows in the same path as the harvester and makes fewer trips than a skidder for the same production. Although the CTL system is not being used extensively in Louisiana, many forest managers are interested in its potential for their lands.

OBJECTIVES OF STUDY

The objectives of this study were to assess ground disturbance of a CTL harvesting system to the harvested area for first thinning, second thinning and clearcut operations, and damage to residual stands in the first and second thinnings.

METHODS

In the first thinning trials of a 12-year genetically improved loblolly pine plantation, which was planted on 8 by 8-feet spacing, every seventh row was removed for an expected corridor center spacing of 56 feet. Desired stand density was 165 trees per acre. The corridor row was clearcut and the three rows to right and left of travel were operator-select thinned. Logging slash consisting of limbs and tops discarded by the harvester was placed in the path in front of the harvester travel way to act as a cushion for the wheeled machines to travel on and to provide ground cover to minimize the disturbances. Stems processed by the harvester-processor were placed on either side of the corridor in "sorted" piles according to the product as pine pulpwood, hardwood pulpwood, or pine logs. Pulpwood was taken to a minimum top diameter of 3-inches and pine logs for plywood manufacture were cut to lengths of either 9 or 17.5 feet with the small end diameter greater than 5-inches. Traffic on each trail consisted of three machine passes--one pass of the harvester as it traveled in operation from roadside into the harvest area (or returning as it operated from the far end of the area to roadside), one pass of the forwarder as it traveled empty from roadside to the far end of the harvest area, and one pass as it loaded itself while traveling to the roadside--all in an effort to minimize loaded travel distance.

In the second thinning study of the 23-year pine plantation with a targeted final stand density of 100 trees/acre, the harvester operator did not align machine travel with planted rows or the corridor cut out from the first thinning but cut new corridors generally perpendicular to the original corridors. Corridor spacings were in accordance within the 32.8-foot "reach" distance of the harvester's boom. The clearcut harvest was in a natural stand and operating width of the harvester was also in accordance with the "reach" of the harvester head.

Site disturbance for the CTL harvest system was assessed by determining the portion of the total harvest area disturbed and the severity of disturbance for the three harvest trials. Percentage of area disturbed was determined from measurements of corridor center-to-center distances and machine trail width along the cut corridor. Severity of disturbance was determined by measuring distance occupied by slash along the corridor trails, depth and width of rutting, and level of soil compaction resulting from the operations of the wheeled machines. Rutting depth and width means were determined from ten measurements each, taken at areas of severe disturbance along the corridor trail--away from slash accumulations or where roots limited rutting depth. Measurements were confined to the most severely disturbed areas and not taken at random along the corridor trail. Soil compaction was determined by comparing values of soil bulk density in undisturbed areas to that of disturbed areas from surface soil core samples taken 0 to 4-inches deep. Soil bulk density values were determined from ten samples each from each of the three harvest trials--first thinning, second thinning, and clearcut operations for undisturbed area values, under slash, and in the deepest of the rutted areas which resulted in a total of ninety samples analyzed. All soil samples for bulk density and moisture content reporting were oven dried to a constant weight at 105° C. Representative values of soil moisture content were determined for background information. Damage to the final stand was determined by visual inspection for tree injuries in one harvest area each for the first thinning and second thinning trials.

STUDY SITES

The CTL harvests were performed on Martin Timber Company lands in the North Central Louisiana Parishes of Bienville and Natchitoches during February and March, 1997. The first thinning operation was in Bienville parish, Section 28 of Township 15 North, Range 8 West. At that site, the soil is described by the Soil Survey of Bienville Parish as being of the Malbis fine sandy loam (MgB) series and Sawyer very fine sandy loam (SnC) series. The MgB and SnC soils have 1 to 5 percent slopes and are described as well drained soils. Moist Bulk density of the MgB soil is 1.30 to 1.60 g/cc and for the SnC soil 1.45 to 1.60 g/cc. Soil texture classification performed on a sample taken from the first thinning study site indicated the soil to be composed of 6% clay, 36% silt, and 58% sand which is classified as a sandy loam soil. The second thinning was located in Section 17 and the clearcut harvest site was in Section 23--both in Township 11 North, Range 8 West of Natchitoches Parish. According to the Soil Survey of Natchitoches Parish the soils are described as belonging to the Gore-Acadia-Wrightsville series which are level to gently sloping, moderately well drained, some poorly drained, and poorly drained soils that have a loamy surface layer and a clayey subsoil. Those soils are formed in old stream deposits. Moist bulk density is from 1.30-1.50 for the Gore series, 1.35-1.70 for the Acadia series, and 1.35-1.65 for the Wrightsville series.

In the second thinning site a bulldozer cleared out the old rows of the first thinning to facilitate timber cruising. Unfortunately, this caused some problems with the logging equipment's flotation, so the CTL operators cut new rows where the ground was particularly soft. The logging occurred during the time of year when the ground conditions are typically the least favorable for equipment flotation because ground conditions are at their wettest from winter rains and because evapotranspiration is at its seasonal lowest. The logging conditions during these trials were even wetter than normal. Originally, it was planned to perform a conventional harvest operation adjacent to the CTL operation using feller-buncher/skidders, but ground conditions were too wet on both thinning sites.

Timber cruise summaries for the first and second thinning trials are provided in Table 1. Cruise data on the clearcut harvest site, which was a mature upland pine-hardwood stand, was not taken.

THE CTL MACHINES

The CTL machines used in this study consisted of a Ponsse HS 15 Ergo harvester and Ponsse S 15 Ergo forwarder (Lumpkin, 1996).[1] Both 114-kw (153- hp) diesel engine powered machines were 6-wheeled all-wheel drive and were equipped with 700/55-34 tires on the single axle and 700/50-26.5 tires on the tandem axles. The tandem axles on both machines were equipped with 34-inch wide "over-the-tire" type metal tracks and tire chains were fitted to the 700/55-34 single axle tires for the tests. According to Ponsse technical data, total weight of the harvester is 13,050 kg (28,770 lb), and for the forwarder total weight is 10,970 kg (24,184 lb) + 12,000 kg (26,455 lb) load capacity. Specified ground clearance for the front axle was 560 mm (22-inches) and 640 mm (25-inches) for the rear axles--for both machines. Wheel tread measured 2.1 m (83-inches) and wheelbase measured about 4.8 m (190-

[1]The use of brand or trade names is for the relative convenience and is not an endorsement by the authors or their respective organizations.

inches) with the tandems spaced 1.4 m (57-inches). The knuckleboom/slideboom- mounted harvester head had an outreach distance of 10-meters (32.8 feet) from the pivot center.

DISCUSSION OF RESULTS

Site disturbance assessment values for the first thinning, second thinning, and clearcut CTL harvest trials conducted in North Central Louisiana during a wet harvest season for sandy loam soils are given in Table 2. For the first thinning trial of the plantation planted on 8 by 8-ft spacing with 7th row removal, corridor trail spacing was 56.0 feet--in exact agreement with the expected value. Mean corridor center spacing for the second thinning harvest was 52.0 feet but the harvester travel was not in alignment with first thinning corridor removal. Trail spacing for the clearcut harvest was not measured because the harvest area was irregular in that mixed pine-hardwood natural stand. Overall width of the corridor opening was about 15 feet, which was controlled by spacing of the planted stand. Mean spacing between rutted centers along the trail was from 84.6 inches for the clearcut harvest to 86.4 inches for the first thinning. Those values are in agreement with the 83-inch wheel tread measurement and indicates that the forwarder traveled in the tracks made by the harvester. Mean rut depth and width were 13.0 and 36.6-inches for each rut in the most severely rutted areas along the corridor trail for the first thinning study. Mean rut depth in the second thin and clearcut harvests were somewhat lower. Considering the rutted width of 36.6-inches and trail center spacing of 56-feet for the 1st thinning, 10.9% of the area was disturbed by travel of the harvester and forwarder but at varying levels of severity. The 10.9% disturbance value does not include disturbance at the end of the harvest area as the harvester travels from the end of a completed corridor to the beginning of the next corridor. Considering the depth of the harvest area in this trial was typically 581 feet and the spacing between corridors was 56 feet which the harvester traversed at the far end of the harvest area every second pass, the area disturbed by wheel traffic was 11.4%. Ground area disturbance for the 2nd thin harvest was somewhat higher at 12.4% since the rutted width was higher and the trail center spacing was less than for the first thinning operation. Again, the 12.4% value did not include ground disturbance at the end of the harvest area as the harvester moved from a completed corridor to the next corridor. Ground area disturbed for the clearcut was not determined because trail centers could not meaningfully be measured but should not be appreciably different than for the thinning trials. Hunt, 1995, in a CTL harvest soil disturbance study reported average trail spacing to be 17.7 m (58 feet) with trail width 3.1 m (10 feet) and resulting area disturbance of 17.9% but with space between ruts not accounted for.

Soil compaction occurred along the wheel traffic areas for the three harvest trials as was evident from the resulting permanently formed wheel ruts. Soil bulk density was as high as 1.53 g/cc in the deepest ruts of the sandy loam soils of moisture contents from 22.4 to 24.1% (dry weight basis) for the first and second thinning harvest trials where mean rutting depth was as high as 13.0-inches. The presence of logging slash deposited along the trail reduced compaction levels resulting from multipass wheel traffic from 1.53 g/cc in the unprotected rutted areas to 1.35 g/cc. Undisturbed soil bulk density determined from samples taken near the vicinity of the trails varied from 1.23 for the clearcut harvest, 1.24 for the second thinning, to 1.35 g/cc for the first thinning harvest. In the first thinning, the bulk densities of the samples from the undisturbed soil were essentially identical to the samples from under the slash. Samples taken from the exposed ruts (1.53 g/cc) had bulk densities that were significantly higher than samples from the undisturbed and slash sites (both 1.35 g/cc).

In both the second thinning and the clearcut corridor trails however, bulk densities of samples from the rutted areas, under slash, and undisturbed areas were all significantly different indicating that compaction occurred in both the rutted areas and the under slash trafficked areas. In the rutted areas soil density was 1.53 g/cc compared to 1.34 g/cc in the under slash trafficked areas. Undisturbed soil bulk density was 1.24 g/cc.

An additional five samples were taken from light ruts where a machine had made only one pass resulting in ruts 2 to 6 inches deep. While the mean of these samples resulted in what is considered a reasonable value of 1.44 g/cc (compared to 1.23 g/cc for the undisturbed site and 1.49 g/cc for the rutted site), the small sample size prevents a statistically sound conclusion.

All bulk density values reported are on a dry weight basis and were determined from cores taken 0 to 4-inches deep. According to Proctor Density tests for sandy loam soils, the optimum moisture content for maximum compaction is about 12% (Oglesby and Hicks, 1982) which indicates that compaction would have been even more severe than resulted from these trials had soil moisture been about 12%.

Although it wasn't an objective of this study to determine soil moisture which would limit operations, it was found that logging operations could not be performed on the sandy loam soil having a moisture content of 41.6%. Operations could not be performed because of wheel rutting to the ground clearance limit of 22 inches. The harvester and forwarder were both equipped with 700 mm wide tires with 34-inch wide "over-the-tire" tracks on the tandem axles. Operations were performed with some level of rutting where the soil moisture was about 25% as discussed earlier.

Slash accumulations were highly variable in depth and spacing. Spacing between slash deposits along the corridor travel paths, which resulted in soil unprotected from wheel compaction, varied from a mean of 10.4 feet for the clearcut harvest to 22.0 feet for the second thinning harvest. Distance occupied by slash varied from an average of 8.7 feet for the first thinning to 18.9 feet for the clearcut trials. In the second thinning, slash occupied 34.6% of the corridor trail distance while in the clearcut slash occupied 69.6% of the trail. Considering the presence of slash significantly reduced soil bulk density in the traveled areas for the three harvest trials and that from 34.6% to 69.9% of the distance is covered with slash, it is important to note that considerably less than 12.4% of the total area is impacted as noted earlier. Mean slash depth varied from 6.2 inches for the second thinning to 8.5 inches for the clearcut harvest after having been compacted by three machine passes.

Damage to the residual stand was found to be 2.1% in the first thinning trial which was determined by inspecting all trees in one of the harvest blocks which was of area 0.75 acres. Three trees out of 137 trees were found to be injured--one injury being 2 by 3 inches at 1.5 ft above ground, 3 by 4 inches 4-ft above ground, and one a continuous strip from 2.5 to 6-ft above ground. This was equivalent to 4 trees per acre being injured. Lanford and Stokes (1995), reported 10 trees per acre to be injured in a similar study. In the second thinning harvest trial damage to the 100 tree/acre final stand was found to be 0.6% in which only one tree was found to be injured out of 163 trees inspected in one of the harvest areas. That injury was 2 by 3 inches at 6-ft above ground and that tree was next to the corridor. The machine operators were highly skilled, which resulted in a minimum of injuries to the final stand.

CONCLUSION

Assessments of ground and stand disturbances from CTL winter harvest demonstrations performed on a first pine plantation thinning, second thinning, and a mixed pine-hardwood clearcut harvest in North Central Louisiana show low adverse impact from operation of the system for extremely wet soil conditions. Ground disturbance results show about 11% of the total harvest area was disturbed to some level. Soil compaction in disturbed areas was increased by 21.4% in the most severe cases. Rut depth averaged 13-inches in the most severe cases and was limited to the corridor trail and only in that portion of the trail not covered with slash. Logging slash from tops and limbs removed from felled trees covered up to 69.9% of the corridor trail distance in the clearcut trials and was shown to limit compaction significantly in that portion of the trail. In first thinning harvest trials with 160 trees per acre left, 2.1% of the residual trees had some bole injury and in the second thin trials injury to the stand was 0.6%. The ability of the harvester to operate with 7th row removal in an 8 by 8-ft spacing stand should allow leaving more quality crop trees in first thinning operations compared to conventional feller-buncher/grapple-skidder operations doing 3rd or 5th row removal in first thinning harvests. The value of that capability needs to be further explored.

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Table 1. Timber cruise summaries of the first-thinning and second-thinning tracts. Confidence intervals are 95%.

	First thinning trial		Second thinning trial	
	Pre-harvest	Post-harvest	Pre-harvest	Post-harvest
Tract number	4-5-320		4-6-814	
Age, years	12		23	
Average DBH, in	6.1±0.1	6.8±0.2	9.9±0.4	10.7±0.4
Quad. mean DBH, in	6.2±0.2	7.0±0.2	10.1±0.6	10.8±0.6
Basal area, ft^2/ac	91.6±7.09	42.6±2.62	90.7±9.98	65.4±6.94
*Merch. ht, ft	26±0.3	28±0.2	48±1.0	49±1.0
Harvested area, ac	15.6		19.5	
# trees/ac	431±40	160±12	163±16	103±11
Vol. (cords/ac)	21.67±1.84	10.36±0.84	32.39±3.75	23.51±2.40
(CCF/ac)	16.02±1.25	7.57±0.49	25.91±3.00	18.81±1.92

*Average merchantable height to a 2 inch top diameter

Table 2. Site Disturbances from first thinning, second thinning, and clearcut CTL harvests.

factor evaluated	--mean values with 95% confidence interval[1]--		
	first thin	second thin	clearcut
Trail Traverse Results			
rut depth, inches	13.0±1.6	9.3±1.3	10.4±1.3
rut width, inches	37.1±2.7	38.7±2.4	41.6±3.9
rut center spacing, inches	86.4±2.0	84.7±1.7	84.6±2.9
corridor trail center spacing, feet	56.0±2.3	52.0±6.5	--
percentage of total area disturbed	10.9	12.4	--
soil mc in undisturbed site, %[2]	25.8±2.8	27.0±4.4	29.4±2.2
soil mc under slash, %	28.9±3.5	29.0±5.0	26.7±1.9
soil mc in trail rut, %	24.1±2.4	22.4±2.8	24.8±3.6
soil mc in shallow ruts (2-6 inches), %	--	--	23.1±2.5
soil bulk density, undisturbed site, g/cc	1.35±0.05	1.24±0.08	1.23±0.09
soil bulk density, under slash, g/cc	1.35±0.06	1.34±0.08	1.39±0.05
soil bulk density, in rutted site, g/cc	1.53±0.03	1.53±0.09	1.49±0.09
bulk density in ruts 2 to 6-inches, g/cc	--	--	1.44±0.11
spacing between slash deposits, feet	18.8±3.7	22.0±11.0	10.4±2.37
distance along slash deposits, feet	8.7±1.7	10.0±4.27	18.9±5.3
space along trail occupied by slash, %	46.5	34.6	69.9
slash depth, inches	6.7±1.2	6.2±1.3	8.5±2.0
soil mc too wet to operate, %	41.6±8.4	--	--
Stand Damage, % residual trees injured	2.1	0.6	--

[1]Confidence interval reported only when applicable.

[2]Soil moisture content reported on dry weight basis.