Effects of Shovel Logging and Rubber-tired Skidding on Surface Soil Attributes in a Selectively Harvested Central Hardwood Stand

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ABSTRACT

Shovel logging, a ground-based, non-tractive yarding method that uses an excavator fixed with a grapple instead of a bucket, offers the potential to yard felled wood with less impact to forest soils than conventional rubber-tired skidding methods. The results of this study, carried out in Apalachian hardwoods, indicated that, although neither conventional nor shovel logging methods can be recommended over the other based solely on short-term impacts to soil bulk density, shovel logging resulted in significantly less surface soil disturbance. In addition, shovel logging eliminated the need for primary skid trail construction, identified as a potential source of particulate matter that may contribute to nonpoint source pollution.

Keywords: *shovel logging, soil bulk density, soil disturbance, deferment harvest, USA, West Virginia, hardwood, deciduous, grapple skidder, feller buncher, excavator.*

As in much of the central hardwood region, West Virginia's steep and uneven topography contributes to some of the most difficult logging conditions in the eastern US. Although cable logging systems have been used in the region, their efficacy has met with mixed results and little enthusiasm by the logging community, and conventional ground based yarding systems using rubber-tired skidders and/or dozers continue to predominate. Unfortunately, conventional tractive yarding methods often require expensive bulldozed skid roads [18] that may consume over ten percent of the timber sale area [15, 21]. In addition, construction of these roads often causes shallow subsurface water to be converted to surface flow over exposed soil, increasing the potential for erosion and sedimentation of surface waters [10]. Although West Virginia's Best Management Practices (BMPs) have been shown to be effective in controlling nonpoint source pollution from logging [16], and compliance with BMPs in the state appears to have increased over the past fifteen years [9], concerns within the forestry community about the adverse effects and costs associated with forest road and trail construction persist [8].

Non-industrial private forest (NIPF) owners hold most of the commercial timberland in West Virginia [2]. Although income drives most of these NIPF owners' decisions to harvest [7], silvicultural clearcutting is only rarely practiced in the region, since most NIPF owners place a high value on the amenities, particularly recreation and aesthetics, associated with maintaining a continuous canopy [3, 14]. Diameter-limit harvesting appears to be the harvest designation method of choice applied by loggers to the region's NIPFs [25], despite persistent questions about the method's long-term effect on forest quality and sustainablility among many in the professional forestry community [6].

Given these circumstances, research on alternative ground-based logging methods that may limit forest trail construction and are effective in partial harvests is timely. Shovel logging (also known as hoe-chucking), a ground-based method that uses an excavator fixed with a grapple to lift trees, has been investigated by several researchers [5, 12, 13, 17]. With few exceptions [e.g., 11, 26], this research has been conducted in clearcuts in the western US and Canada. Research on the efficacy of the method in partial harvests appears to be limited to a study on the effects of shovel logging on residual stands in the central Appalachian region [11], in which the author found no significant differences between shovel and skidder yarding in the occurrence of "severe" tree wounding. Yet the system's ability to reach, lift, and forward felled trees to either a landing or a bunching location for subsequent ground skidding or pre-hauling suggests a potential for partial harvest applications.

In addition, shovel logging studies in clearcuts that have employed a time and motion component [5], as well as anecdotal information about the system's performance in Douglas-fir thinnings in the Pacific Northwest [1], have suggested that the method was economical under the conditions of those shovel operations.

The objectives of this research were to compare both soil bulk density and surface soil disturbance effects after yarding using shovel logging and conventional rubber-tired skidding in central hardwood conditions. The silvicultural method applied was a deferment harvest,

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developed as an even-aged, aesthetic alternative to clearcutting. This method, more commonly applied in forests of Europe than those of the US, leaves a basal area of approximately 4.6 m^2 per hectare [20 ft^2 per acre] in high quality dominants and co-dominants. Leave trees are then recovered when the regenerated stand is at the end of its rotation. Therefore, deferment trees are generally selected based on seed production, phenotype, and anticipated longevity.

METHODS

Three two hectare [five acre] replicates each of shovel logging and conventional rubber-tired skidding were randomly assigned in a partial harvest of an Appalachian hardwood stand in northern West Virginia. The study area was dominated by DeKalb soils (loamy-skeleted, mixed, mesic Typic Dystrochrepts) described as moderately to very steep, well drained, upland soils [28]. The slope of the treatment area ranged from 2-18 percent, with an average slope of over 8 percent. Boundaries of each of the six treatment areas were surveyed to approximate two hectare treatment areas, and 40.2 meter (two chains) wide uncut buffers were maintained between each contiguous treatment block. Each treatment block was cruised before harvest using nine 0.04 hectare [0.1-acre] sample plots per area. Results of the cruise indicated that, although treatment area number 1 had the highest and area number 4 the lowest stocking levels of any blocks, stocking on the other four blocks was comparable (Table 1).

Timber within each treatment area was marked for a deferment harvest. The post-harvest goal was a residual stand of approximately 4.6 m^2 per hectare [20 ft^2 per acre] of basal area, mimicking the range of stocking that may also be left after a seed tree harvest, latter stages of a shelterwood system, or a deferment harvest [27]. The following timber marking guidelines were developed:

(1) only vigorous, long-lived trees with future timber potential should comprise the residual stand;
(2) residual trees should be 30.5 cm to 43.2 cm [12 to 17-inches] dbh; trees either smaller or larger than this range may be left to obtain adequate spacing; and
(3) average spacing between crop trees should be 15.2 meters [50 feet] to 18.3 meters [60 feet].

Table 1. Random treatment assignments, treatment areas, and pre-harvest trees per hectare, basal area per hectare, and volume per hectare, with associated standard errors and coefficients of variation.

Treatment Area	Treatment	Area (hectares)	Trees/ hectare	Basal Area/ hectare (m^2/hectare)	Volume/ hectare (m^3/hectare)
1	skidder	1.98	266.68	32.75	120.78
standard error			21.25	3.44	17.87
cv (%)			23.90	31.53	44.48
2	skidder	1.95	194.45	23.27	81.45
standard error			15.48	2.33	11.52
cv (%)			23.86	30.08	42.37
3	skidder	1.94	183.32	23.86	90.25
standard error			16.68	2.00	11.97
cv (%)			27.27	25.11	41.38
4	shovel	2.02	168.75	17.77	55.05
standard error			22.52	1.92	6.98
cv (%)			37.77	30.62	35.78
5	shovel	1.94	175.00	21.24	79.45
standard error			32.05	2.92	16.05
cv (%)			51.79	38.85	56.99
6	shovel	1.91	200.00	21.83	78.09
standard error			18.90	2.14	12.15
cv (%)			26.73	27.78	44.05

In the summer of 1996 trees to be left were marked and all unmarked trees were to be either felled and removed, or felled and left on site if they were unmerchantable. The timber on all six blocks was sold on a competitive bid basis to a logging contractor who owned a track-mounted excavator with a grapple attachment, a Hydro-Ax 411 feller-buncher with a shear felling head, and two grapple skidders. Logging occurred on all six replicates during the fall of 1996. Trees were directionally felled using a feller-buncher as well as a chain saw for larger diameter trees. All felled trees were then delimbed and topped using a chain saw. The shovel began at the interior of each of the three shovel treatment areas, picking up and swinging logs toward a skid road adjacent to all six treatment blocks. From here, logs were then conveyed by grapple skidder to a common landing for wood from both treatments. In the skidder treatment areas, a rubber-tired grapple skidder yarded tree-length logs to the same common skid road and continued to the landing.

After logging, the type of soil disturbance was determined and measured on linear transects located perpendicular to contours. By locating the transects in this fashion, they were more likely to cross skidroads and excavator tracks, since these features were typically located along contours. The azimuth used for each block was predetermined so that it would run perpendicular to the contour, but would not cross the main skid road adjacent to the sample blocks. Transects were spaced at 15.2 meters [50 foot] intervals, the first transect in each block located 7.6 meters [25 feet] from the main haul road. The beginning of all transects was marked with a numbered stake. A 91.5 meter [300 ft.] measuring tape was extended along the predetermined azimuth, and only disturbance types encountered along the measuring tape were recorded. Measured disturbance classes, modeled after Martin [20], included: (1) no evidence of vehicular traffic; (2) trafficked by logging equipment: (a) primary skid trail (a major yarding artery with exposed surface soil); (b) secondary skid trail (a feeder trail with surface soil generally not fully exposed); (c) excavator trail; and (d) feller-buncher trail; (3) compaction by logs; (4) coverage by slash: (a) light (few or no limbs); (b) medium (some ground visible or large limbs); and (c) heavy (ground generally not visible—tree tops); (5) nonsoil (e.g., stumps, large rocks); and (6) percent disturbance of leaf litter: (a) 0 – 25% removed; (b) 26 – 75% removed; and (c) > 75% removed.

As each new disturbance class (with the exception of heavy slash and nonsoil) was encountered along a transect, a random selection system was used to determine whether a soil bulk density core was to be sampled at that location. The selection method allowed for a one in four chance of sampling at each change in disturbance class. This procedure resulted in a total of 271 soil cores sampled over both treatments. A soil bulk density extractor with removable sample cylinders was used to collect the soil samples. For each soil sample location, three collection sites (one for "no traffic" areas) were located along the tape. In skidder- and shovel-logged sites, cores were taken in each track made by the skidder tires/shovel undercarriage. In large areas of feller-buncher disturbance, cores were collected in the depressions left by the machine's tires. If organic matter was present on a core site, it was carefully moved so that the core would contain only mineral soil. Since rock fragments have a higher density than soil, care was taken to avoid soil samples with rock fragments. If a large rock fragment was encountered, another core was taken next to the original core.

In the laboratory, bulk densities for each soil sample were determined by standard protocols described by Blake and Hartage [4].

RESULTS AND DISCUSSION

As planned, the residual stands for the two treatments were very similar. There were 43.5 trees per hectare [17.4 trees per acre] left in the skidder treatment areas and 42.3 trees per hectare [16.9 trees per acre] in the shovel treatment areas after logging. The mean residual tree dbh over both treatments combined was 37.8 cm [14.9 inches] (standard error = 0.25 cm [0.10 inches], with a range of 22.9 to 55.1 cm [9.5 to 21.7 inches]. The mean dbh was 37.1 cm [14.6 inches] in the shovel treatment (standard error = 0.38 cm [0.15 inches]) and 38.6 cm [15.2 inches] (standard error = 0.33 cm [0.13 inches]) in the skidder treatment (Table 2). Analysis of variance (AOV) and logistic regression were used to analyze litter disturbance and soil bulk density data.

Table 2. Summary of post-harvest stand conditions by treatment: number of trees, trees per acre, average dbh, basal area, and bole damage.

	Treatment	
Attribute	skidder	shovel
Number of trees	255	248
Trees/hectare	43.5	42.3
Average dbh (cm)	38.6	37.1
Basal area (m^2/hectare)	5.2	4.6

<u>Soil disturbance</u>. Results of Scheffe's multiple comparisons test indicated (a) significant differences in surface soil disturbance (alpha = 0.05) on untrafficked areas vs. that found on secondary skid trails, excavator trails, and

feller-buncher tracks; and (b) differences of borderline significance in soil surface disturbance between excavator and both feller-buncher disturbance ($p = 0.053$) and primary skid trails and untrafficked areas ($p = 0.054$). In addition, logistic regression analysis revealed that both the type of treatment (skidder vs. shovel logging) (chi-square = 63.33; $p<0.001$) and amount of slash cover (chi-square = 1305.51; $p<0.001$) were significant in explaining the amount of litter disturbance (likelihood ratio <.0001; $r^2 = 0.46$). There was a larger percent of skidder treatment area with greater than 75% litter removed (23.5%) than for the shovel treatment (7.7%) (Table 3). Moreover, AOV also revealed significant differences in the amount of litter disturbance by skidder vs. shovel logging treatment ($p<0.0001$).

Table 3. Percent litter disturbance by treatment.[1]

Treatment	0-25% litter removed	26-75% litter removed	>75% litter removed
	(Percent of transect length disturbed)		
Skidder	37.8	17.1	23.5
Shovel	43.5	19.8	7.7

[1] Percents do not add to 100 because of areas in both treatments that were covered by slash or were non-soil.

Finally, we found that approximately 31% of the skidder yarded treatment areas was occupied by primary skid trails. Because the shovel was used to "throw" tree length logs toward a major skidding artery common to both types of treatments, there were no skid trails on the shovel logged sites.

Bulk density. Although analysis of variance revealed a significant difference in average bulk density ($F = 7.460$; $p < 0.001$) among all disturbance classes studied (Table 4), there was no significant difference between sample bulk densities on combined primary/secondary skid trails (average = 1.11 g/cm^3) and sample bulk densities on shovel trails (average = 1.123 g/cm^3) ($F = 0.114$; $p = 0.737$). Average bulk density over all samples in both treatments was 1.052 g/cm^3. However, the highest bulk densities were found on secondary skid trails (average = 1.15 g/cm^3), while the lowest were on areas that were not trafficked (average = 1.02 g/cm^3) (Table 4).

Table 4. Average bulk density by disturbance class.

Disturbance	Bulk density (g/cm^3)
No traffic	1.015
Primary skid trail	1.093
Shovel	1.123
Secondary skid trail	1.147

CONCLUSIONS

The use of shovel logging in clearcuts, especially on some sensitive sites, has been demonstrated in several studies, mostly in the western US and Canada. Our results suggested that shovel logging in partial harvests that reduce residual stand stocking to 5.8 m^2 per hectare [25 ft^2 per acre] or less — as might occur in a deferment harvest, seed tree harvest, and latter stages of a shelterwood system — may be a viable alternative to more conventional ground skidding methods, especially on sites where there are concerns about soil disturbance.

Our analyses indicated that neither of the logging methods studied – rubber-tired skidding and shovel logging – can be recommended over the other based solely on short-term impacts to soil bulk density. Further studies of soil structural resiliency (i.e., the ability of the soil's structure to reform after degradation) [24] for each treatment, however, may be warranted in order to quantify potential differences in long-term soil bulk density effects. In addition, the short and long term effects of soil bulk density on residual trees needs clarification.

However, where mitigating soil disturbance is an objective, results of this study indicate that shovel logging has significant advantages over rubber-tired skidding. Shovel logging may be a viable alternative when harvesting in streamside management zones, for example, where some states' BMP guidelines often limit or suggest completely avoiding surface soil disturbance in these areas [e.g., 19, 29]. In addition, when used in an application similar to the one in this study (i.e., shovel logging tree length wood to a major skidding artery, rather than traversing the ground with rubber-tired skidders), shovel logging may help to mitigate the construction of primary skid trails.

Finally, although shovel logging may be economical in some clearcut situations [5], and anecdotal information suggests the same in some thinnings [1], further studies over a variety of residual stand densities and soil and slope conditions are warranted in order to determine the merit of the method over a broad spectrum of conditions.

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