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Gregory T. Holman

Fred B. Knight

Roland A. Struchtemeyer

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Gregory T. Holman, Fred B. Knight,
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FOREWORD

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Mr. Holman is an Instructor of Forestry at Paul Smith's College, Paul Smiths, New York. Dr. Knight is Director of the School of Forest Resources, University of Maine at Orono. Dr. Struchtemeyer is a Professor in the Department of Plants and Soils and the School of Forest Resources, University of Maine at Orono, Maine.

THE EFFECTS OF MECHANIZED HARVESTING ON SOIL CONDITIONS IN THE SPRUCE-FIR REGION OF NORTH-CENTRAL MAINE

by

Gregory T. Holman, Fred B. Knight, and Roland A. Struchtemeyer

INTRODUCTION

Labor shortages and other economic pressures have tended to stimulate the automation of wood harvesting operations. In the past decade, harvesting in the spruce-fir region of Maine has undergone significant change with large feller-bunchers, delimbers, forwarders, and rubber-tired skidders replacing individual or team chain saw operators.

The impact of the new harvesting methods on soil with respect to soil disturbance is largely unknown. One objective of this study was to determine the extent of soil compaction and disturbance to the organic cover of the soil resulting from the use of mechanical harvesters and rubber-tired skidders during logging operations in north-central Maine.

METHODS AND PROCEDURES

Location

The study area was located in northern Piscataquis County, Maine, in the area east of Chesuncook Lake, west of Baxter State Park, north of Ripogenus Dam, and south of the Chamberlain-Telos Lakes. Timber on this land was harvested by the Great Northern Paper Company, Millinocket, Maine.

Sampling Procedure

To determine the effect of soil compaction and disturbance caused by mechanical harvesting, data were collected on clearcut strips in which approximately 100-foot wide strips were mechanically harvested using Drott feller-bunchers and Logma delimbers. The cut and delimbed trees were hauled to roadside by rubber-tired grapple skidders.

The clearcut strips were perpendicular to access roads and separated by 100-foot wide uncut strips. Harvested strips used as sampling units were selected so as to be as uniform as possible. All had an east-west orientation and a slope of less than 8 percent, and where possible, were randomly selected.

Four categories of clearcut strips were sampled. These categories were based on interactions between season and age of cut as outlined below:

1. Two seasons of cut
   a. winter (with snow)
   b. summer
2. Two ages of cut
   a. first growing season after cut
   b. third growing season after cut

All categories were replicated four times.

A base line was laid out along the length of a clearcut strip and marked into 100-foot sections for a distance of 1000 feet. Care was taken to avoid obvious landing areas at the roadside end of the strip. A point of departure was randomly selected within each 100-foot section. From these ten points, line transects, perpendicular to the base line, were extended across the width of the cut strip and for an equal distance into the adjacent uncut strip.

Three random sample points were established along the line transect in both the cut and uncut portions of the stand. All easily distinguished skidder tracks served as additional sample points.

The depth of organic matter cover was measured (in inches) at each sample point along the line transect. Undisturbed soil clods from the upper six inches of the mineral soil profile were collected for bulk density analysis to measure any compaction that might have occurred. The clods were divided into two 3-inch depth classes, i.e., 1-3 and 3-6 inch depths, then labeled and stored.

Laboratory Analysis

Bulk density was determined by the clod method described by Blake (1968) with minor modifications. The paraffin, which had a density of 0.86 gm/cc, was kept at 61°C (just above its melting point) so that penetration into the pores of the clod was minimal and so that the wax solidified quickly after dipping. Alcohol, with a density of 0.79 gm/cc, instead of water, with a density of 1.00 gm/cc, was used as the liquid for immersion for two reasons. First, the density was closer to that of paraffin and had less influence on the clods when immersed; second, it allowed for the measurement of low bulk densities (0.80 - 1.00 gm/cc) without the use of special apparatus.

Occasionally, a wax-coated clod floated on the alcohol due to its low bulk density. When this occurred a weight of known mass and volume was added to immerse the clod into the alcohol. This modification appears in the following equation used to determine bulk density. The bulk density of three clods per depth was measured at each sample point.

$$\text{Bulk Density} = \frac{\text{Air dried weight of clod}}{\dfrac{\text{Wa-Wal}}{\text{Dal}} - (\text{VP}+\text{VW})}$$

$$\text{Volume of Paraffin (VP)} = \frac{\text{Wa - W}}{0.86\ \text{gm/cc}}$$

Wa = Weight of paraffined clods (+known mass) in air

Wal = Weight of paraffined clods (+known mass) in alcohol

Dal = Density of alcohol

VW = Known volume of mass

W = Air dried weight of clod

Statistical Analysis

The data for the three random sample points on each transect in the cut and uncut strips and the skid trail sample points for a transect were averaged to give mean values for any given transect. The adjacent uncut transect served as control.

Duncan's New Multiple Range Test at the five percent level was used to test for differences among means. Mean comparisons were made between season and age of cut for the skid trail, random cut, and random uncut samples.

RESULTS AND DISCUSSION

It should be noted that the control for each clearcut strip was the adjacent uncut strip. Although these control areas may not have been identical to the pre-harvest conditions of the cut strip, they did provide an excellent base for measuring relative changes. Graphic results are plotted as the average of the ten transect values along a clearcut strip.

Well drained and poorly drained areas were present in both summer and winter harvest areas. Soil drainage was not related to the season of harvest; therefore, it did not influence the results of this study. Likewise, there were no significant differences in the texture of the soil among the various harvest areas. Hydrometer analysis indicated that the soils on the study area would be classified as loam. Other researchers have found textural influences on soil compactability (Hatchell *et al.* 1970, Meredith and Patrick 1961, Swanston and Dyrness 1973, and Weaver and Jamison 1951).

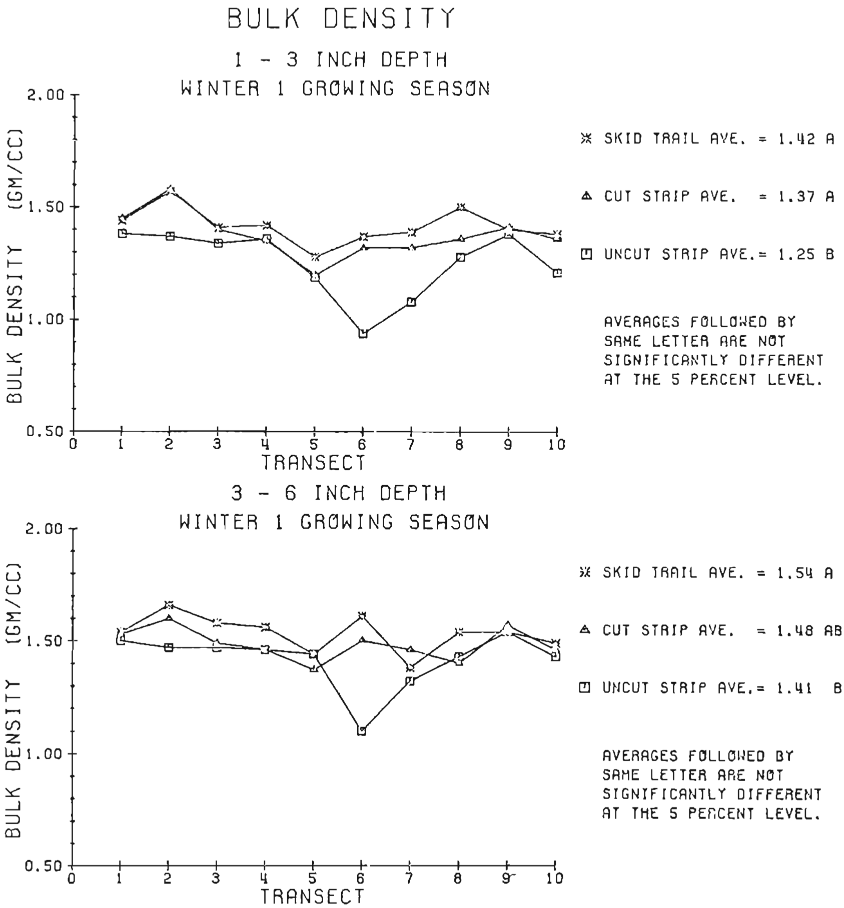
Bulk Density

Bulk density of the soil, as an indication of relative compaction, was measured. Bulk densities were greater at the 3-6 inch depth, but the relative degree of compaction due to the harvesting operation at this depth was not as great as at the 1-3 inch depth. Discounting season or age interactions, bulk densities on the skid trails increased 12 percent at the 1-3 inch depth but only 9 percent at the 3-6 inch depth. In the random cut areas bulk densities increased about 5 percent and a non-significant 3 percent at the 1-3 and 3-6 inch depth classes, respectively. The surface three inches of mineral soil absorbed a greater degree of the compactive force associated with harvesting than did the lower three inches.

Compacted soils can be restored to their original bulk density by freezing and thawing, wetting and drying, root penetration, and faunal activity. It was assumed that freezing and thawing played the major role in the restoration of these soils to pre-harvest conditions.

Skid trail bulk density averages for the first growing season after a winter harvest were significantly greater than similar samples from uncut stands at both the 1-3 and 3-6 inch depths. Bulk density values for the random cut areas were significantly greater than the random uncut values at the 1-3 inch depth but not at the 3-6 inch depth (Figure 1). It should be noted that these clearcut strips had not yet been exposed to one complete overwintering period at the time of sampling. Not having been exposed to a complete freeze-thaw cycle would explain why the random cut samples remained significantly greater than uncut values regardless of the season or age of the cut.

Three growing seasons after a winter operation, there were no significant differences in bulk density among the skid trail, random cut, and random uncut samples at either sampling depth (Figure 2). After winter harvests, soils were not as compacted as after summer harvests. Furthermore, in Maine, areas harvested in the winter may

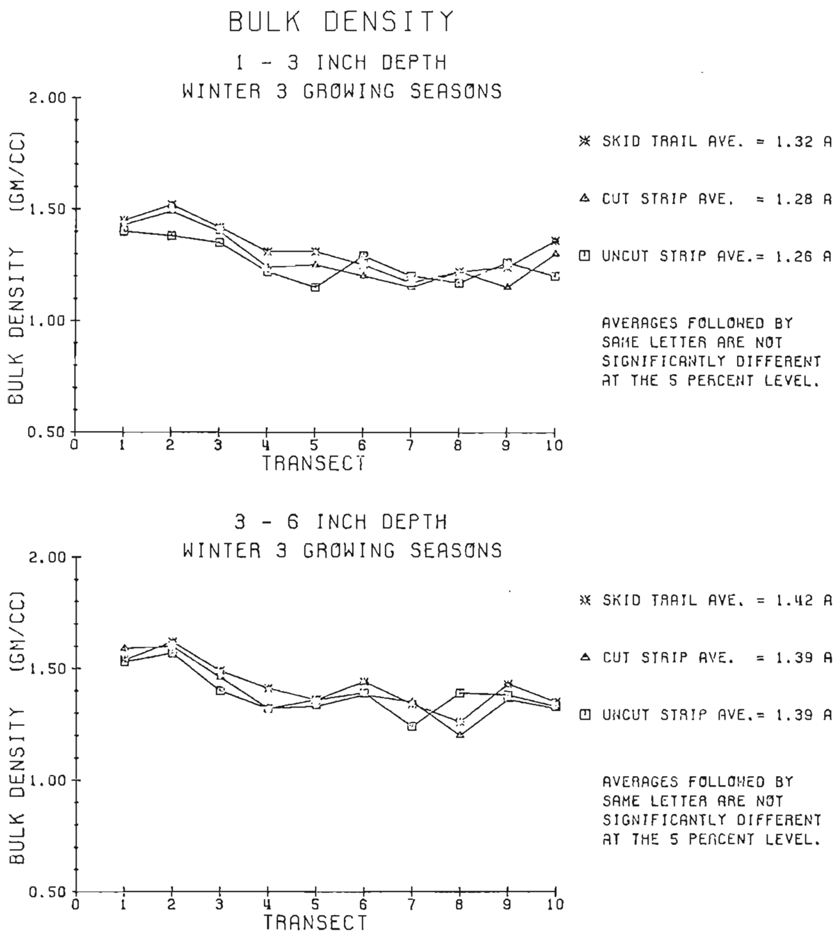


BULK DENSITY WINTER 1 GROWING SEASON:

Figure 1. Soil bulk density at the 1-3 and 3-6 inch depths in the skid trail, random cut, and uncut areas one growing season after a winter operation.

show a greater degree of freezing and thawing as a result of increased soil moisture. Mace (1971), in a similar study conducted in Minnesota, suggested that the soil moisture may be higher following winter operations due to the residual slash retarding evaporation and understory vegetative growth. Thus, when harvesting was done in the winter, compacted soils were restored to pre-harvest conditions after only two complete overwintering periods.

One growing season after a summer harvest, the random cut and uncut bulk density values showed no significant differences at either sampling depth. However, skid trail bulk densities were significantly greater than those in the uncut stand at both sampling depths (Figure

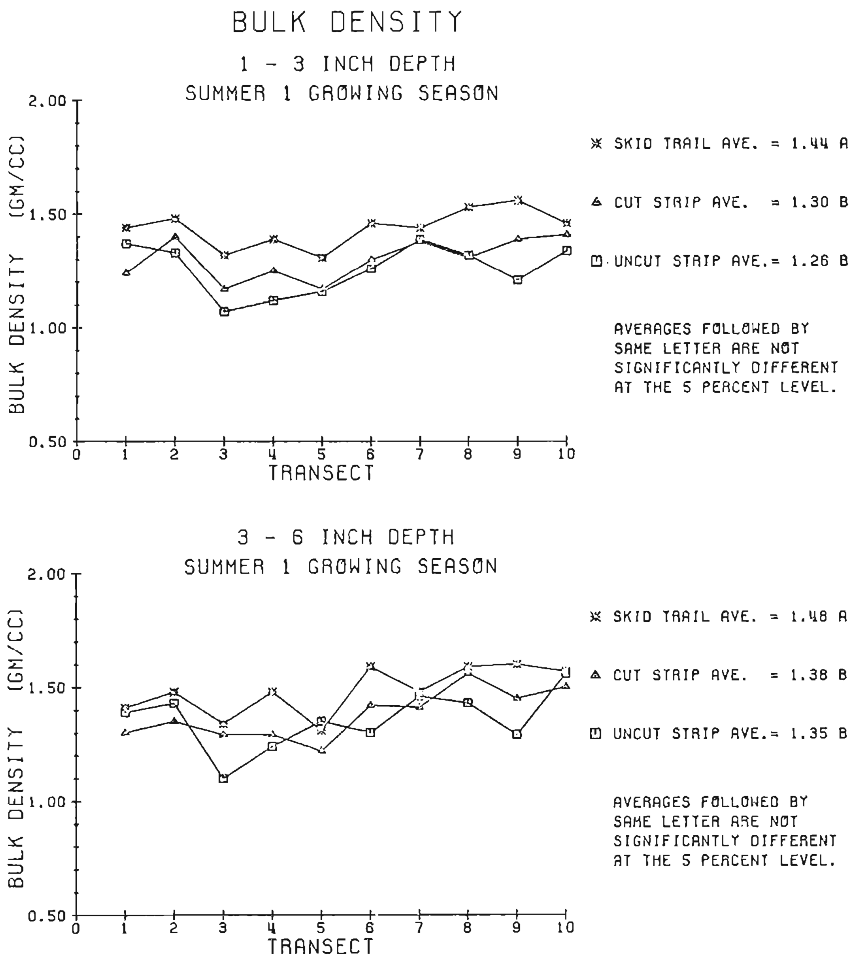


BULK DENSITY WINTER 3 GROWING SEASONS:

Figure 2. Soil bulk density at the 1-3 and 3-6 inch depths in the skid trail, random cut, and uncut areas three growing seasons after a winter operation.

3). Soils sampled after summer harvests had the advantage of one complete overwintering period. It was further assumed that one complete overwintering period may have been sufficient to restore soils in the random cut areas of winter harvests, also.

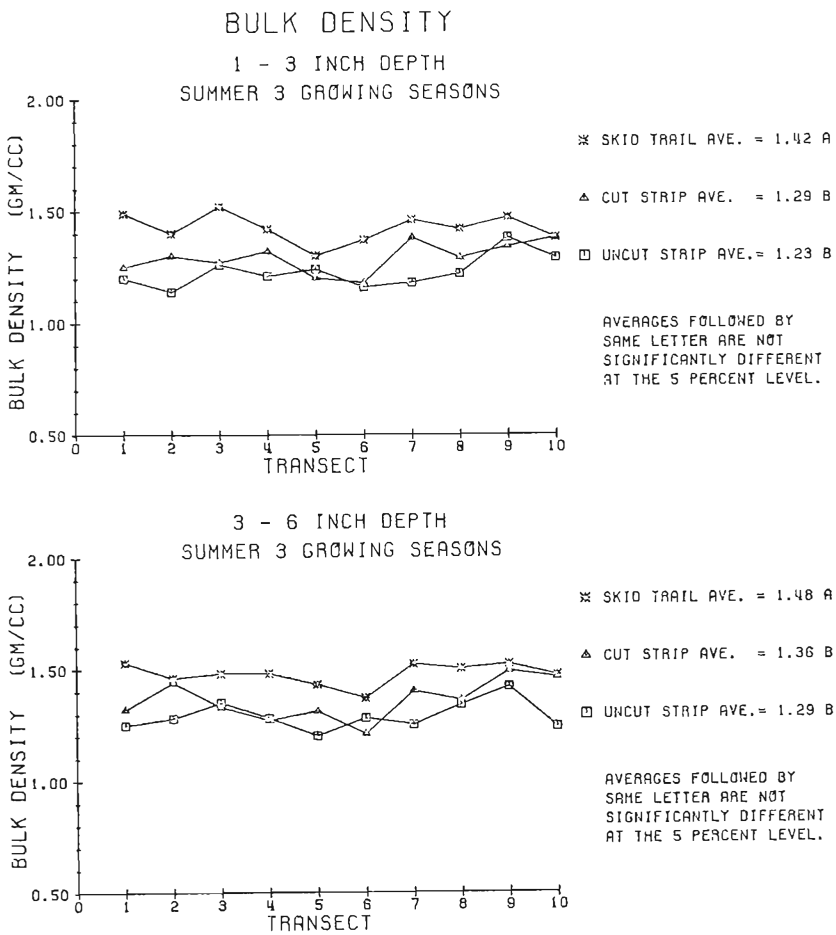
Three growing seasons after a summer harvest, the skid trail bulk density values were still greater than the control values at both sampling depths (Figure 4). Skid trails made during summer operations were not restored to pre-harvest conditions even after three complete overwintering periods (the time frame of this study).



BULK DENSITY SUMMER 1 GROWING SEASON:

Figure 3. Soil bulk density at the 1-3 and 3-6 inch depths in the skid trail, random cut, and uncut areas one growing season after a summer operation.

Relative to the uncut stand, skid trails were compacted almost twice as much during summer harvests as during winter harvests (15.3 versus 8.7 percent). In winter, the frozen soil was not easily compacted, and a protective layer of snow was usually present, even during skidding. Another explanation for higher bulk density values after summer operations could be due to the windrowing effect of skidders on slash accumulation, an effect also noted by Frank and Putnam (1972).



BULK DENSITY SUMMER 3 GROWING SEASONS:

Figure 4. Soil bulk density at the 1-3 and 3-6 inch depth in the skid trail, random cut, and uncut areas three growing seasons after a summer operation.

Slash tended to be brushed aside by skidders, baring the forest floors or mineral soil to compaction. In the winter, the slash was compacted into the snow below the wheels adding protection against severe compaction. Furthermore, as noted by Zasada and Tappeiner (1969), the higher bulk densities after summer harvests may, in part, be due to the removal or mixing of a portion of the light A-horizons of mineral soil.

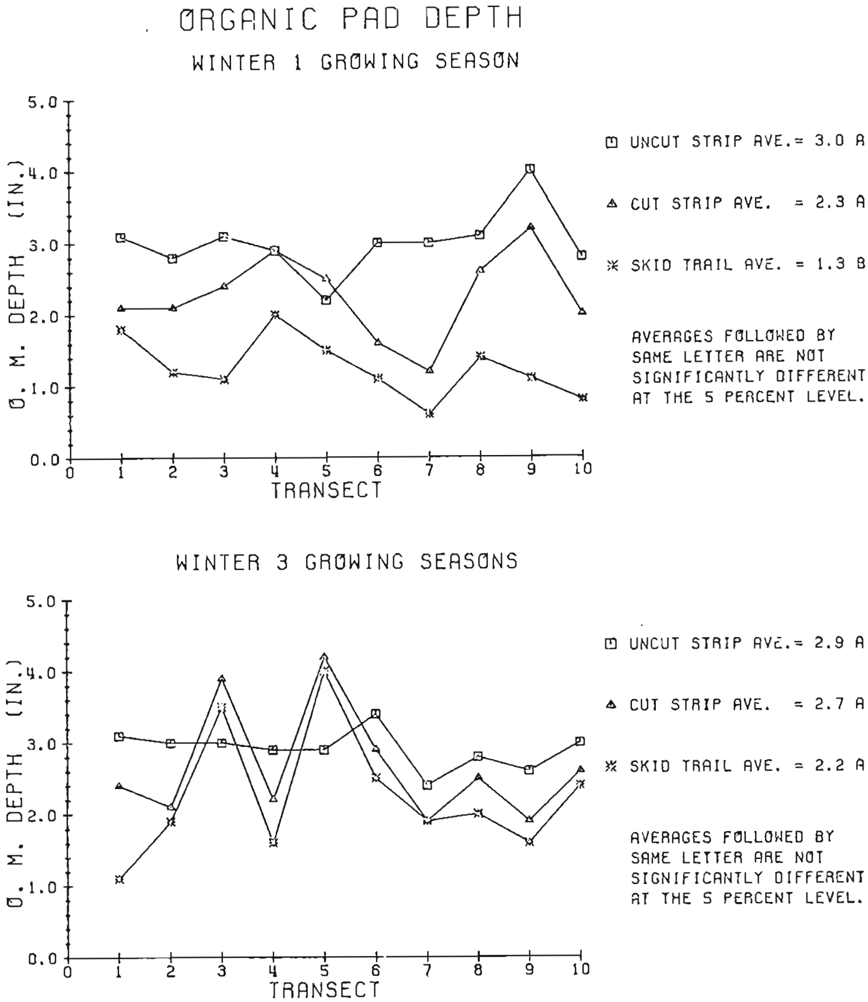
Organic Pad Depth

The organic pad depth was determined to be the depth of organic material above the mineral soil. Lunt (1937) felt that the organic pad helped to maintain the soil in good condition by protecting it from compaction and erosion. Its removal made the soil more susceptible to compaction, thereby decreasing infiltration rates.

The trend observed for organic pad depth at the sampling points was that it was least on the skid trail, greatest on the uncut areas, and between these two depths at the random cut sample point—regardless of the season or age of the harvest. These differences, however, were not always statistically significant. There may be a slight decrease in organic pad depths on both winter and summer operations due to increased humus decomposition in clearcut areas as was noted by Marquis (1972) and Reinhart (1972). Also, the reduced vegetative cover would produce less litter to add to the organic pad after harvesting. Furthermore, mechanical compression and/or scarification by the mechanical harvesting system would also tend to decrease the organic pad depth.

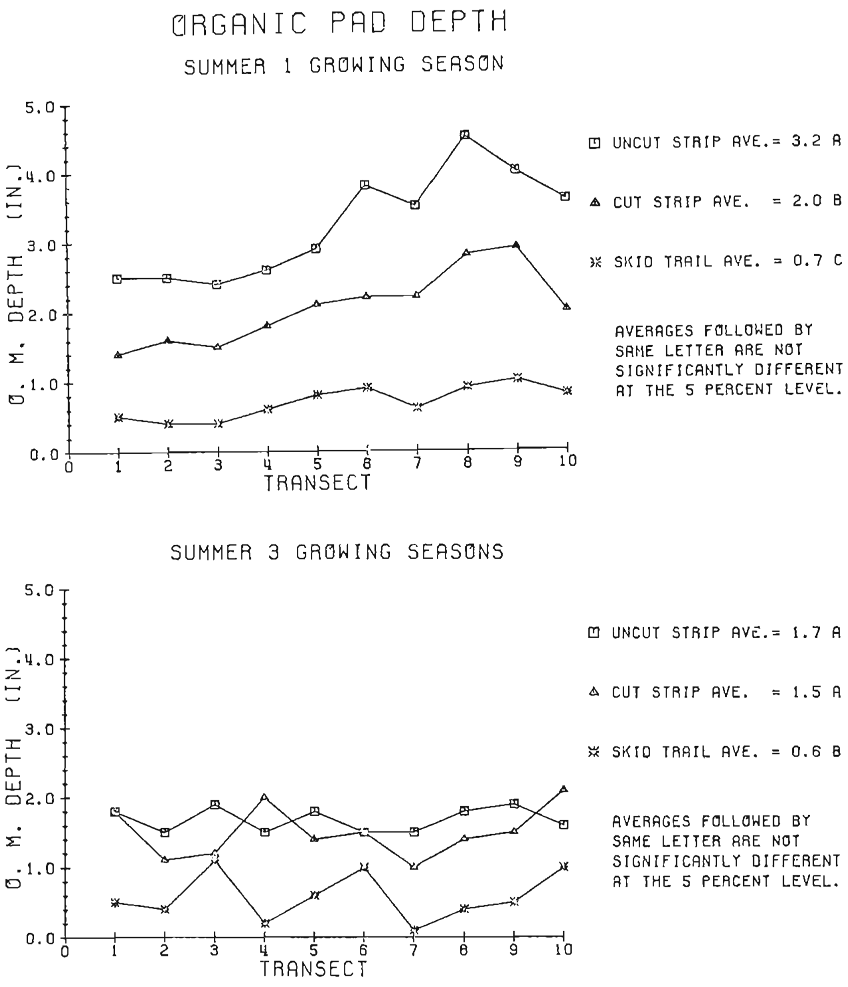
The first growing season after a winter harvest, the organic pad depth of the skid trail was significantly less than that of the random cut and uncut samples. Three growing seasons after winter harvests, there were no significant differences among the skid trail, random cut, and uncut organic pad depths (Figure 5). The reduction of organic pad depths on the skid trails, in areas one growing season after the harvest, was probably due to the mechanical compression of the organic layer. Once again, the lack of significant differences in organic pad depths among the skid trail, random cut, and uncut areas three growing seasons after the harvest indicates that the site disturbances on winter harvested areas were relatively light and quickly restored.

One growing season after a winter harvest, the organic pad depth was significantly less along skid trails than on random cuts, and less there than on uncut areas. Three years after summer harvesting the organic pad depth on the skid trails remained significantly less than the uncut and random cut sample points (Figure 6). On these areas the decrease in pad depth would be due not only to mechanical compression, but also to a greater degree of scarification where there was no protective snow cover. The summer sites tended to be more disturbed than winter harvested areas; mixing of organic matter into the mineral soil was frequently observed. However, a depth of organic matter of only one-half inch will tend to hinder erosion along skid trails.



ORGANIC PAD DEPTH WINTER

Figure 5. Organic pad depths on the skid trail, random cut, and uncut areas one and three growing seasons after winter operations.



ORGANIC PAD DEPTH SUMMER

Figure 6. Organic pad depths on the skid trail, random cut, and uncut areas one and three growing seasons after summer operations.

SUMMARY AND CONCLUSIONS

Soil bulk density and organic pad depth measurements were made after mechanized harvesting operations in the spruce-fir region of north-central Maine. Both age and seasonal interactions were observed. From these measurements the following conclusions are drawn:

1) The top three inches of mineral soil absorbed more of the compactive force of the mechanized harvesting system than did the 3-6 inch depth. This is important for future root penetration and infiltration capacity.

2) In terms of compaction, a) bulk densities in random cut areas returned to pre-harvest levels after one overwintering period; b) skid trails in winter harvested strips were restored after two overwintering periods; and c) skid trails on summer harvests, however, which were compacted twice as much as those on winter harvests, were not restored to pre-harvest levels after three complete overwintering periods (the time frame of the study).

3) The organic pad depth decreased, at least along the skid trails, but probably not enough to create erosional hazards.

In general, the mechanically harvested tree-length operation in north-central Maine seemed to be disruptive to the site and soil conditions for a relatively short period of time.

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