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CLEARCUTS, SHELTERWOOD CUTS, AND SELECTION CUTS IN THE TURKEY LAKES WATERSHED

P.S. Hamilton, R.P.F.*

Abstract

FERIC studied manual and mechanized felling operations with extraction by cable skidder within the Turkey Lakes Watershed in central Ontario. The study compared manual and mechanized clearcutting and partial-cutting operations (shelterwood and selection cuts) and found that felling and extraction productivities were greatest in clearcutting. However, site disturbance depended as much on how the operation was conducted as on the harvesting system used. From the perspective of riparian-zone management, each cut intensity and harvest system offers different advantages with respect to slash distribution and mineral-soil exposure, and their respective merits must be considered in light of the silvicultural objectives.

Introduction

Since late 1979, the 10.5-km² Turkey Lakes Watershed in the Algoma region of central Ontario has been the site of an interdisciplinary study on the impacts of acid rain on the biology of forests, lakes, and streams. A knowledge base on forest growth, soils, and hydrology has been developed, with detailed climate and precipitation chemistry records dating back nearly 20 years. It has been almost 40 years since any harvesting occurred within the Watershed. As part of a multi-agency study to assess various silvicultural prescriptions within the watershed, FERIC monitored a harvesting trial (Figure 1) carried out by a local company (Domtar Inc., Agawa Division) and their contractor (Meakin Forest Enterprises Ltd.) in the late summer of 1997. This report describes the machine productivities and the levels of site disturbance and slash coverage that resulted from mechanized and manual clearcutting

Figure 1. Harvest operations in the Turkey Lakes Watershed.

* Peter Hamilton, R.P.F., is a Researcher, Eastern Division.
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and partial-cutting (shelterwood and selection cuts) operations. Although clearcutting is not a normal silvicultural treatment in tolerant hardwoods, it was included in this study to provide a basis for comparison. The Canadian Forest Service is currently conducting biological and hydrological studies on the effects of these operations on the watershed's riparian environments. The overall objective is to guide forest managers on the impacts that can result from forest operations in riparian zones as a function of the forest type, harvesting system, and silvicultural prescription.

Stand and Site Descriptions

The Turkey Lakes Watershed lies 60 km north of Sault St. Marie (Ont.) and 13 km east of Lake Superior. The terrain varies from gentle slopes to areas inaccessible to ground-based harvesting equipment. Steep slopes and rocky conditions can make travel difficult, particularly where the operational layout requires uphill extraction. Soils are shallow at the height of land, and deeper towards the bottom of slopes, but generally have good trafficability. The forest is primarily uneven-aged, mature to overmature, low-quality tolerant hardwood stands. Scattered softwoods are present, with primarily white pine on the upland sites, and fir, spruce, and cedar as minor components on the lower slopes. A summary of the stand and terrain conditions appears in Table 1.

Silvicultural Prescriptions and Harvest Systems

The study compared three silvicultural systems with different removal intensities (clearcutting, shelterwood cuts, and selection cuts) and two operating systems (feller-buncher and manual felling, both with cable skidding). Sixteen study blocks, (ranging from 6 to 60 ha in size), several of which formed individual catchment basins within the watershed, were randomly assigned to a combination of the silvicultural and operating systems (Figure 2). Harvest crews were instructed to follow their normal practices, and make no attempts to minimize the impacts associated with their normal work methods.

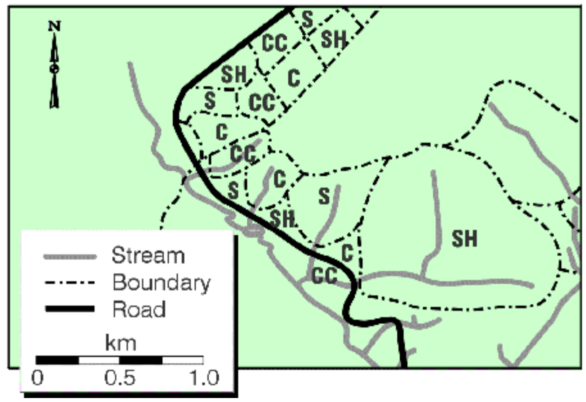

Figure 2. A map of the study area.
(SH = shelterwood, CC = clearcut,
S = selection cut, C = control.)

Clearcutting operations harvested all merchantable trees ≥10 cm in DBH. In contrast, the shelterwood cuts were designed to remove pre-marked, poorly formed trees, promote seed production from quality residuals, and prepare a seedbed for natural regeneration of yellow birch; the target basal area reduction (around 50%) was based on silvicultural guidelines for shelterwood

Table 1. Summary of terrain and stand conditions for the study blocks[a]

	Clearcut		Shelterwood		Selection cut	
	Mechanized	Manual	Mechanized	Manual	Mechanized	Manual
CPPA terrain class	1.1.1–2.3.2 (3)	2.2.3	1.1.1(2)–1.1(2).2	1.3.2(3)	1.2.2–1.4.4	1.3.4
Density (stems/ha)	635–1035	700	865–1030	1035	680–1130	860
Basal area (m^2/ha)	25–31	27	27–31	26	26–29	27
Avg. DBH (cm)	16–20	18	15	14	13–19	16
Avg. volume/ha (m^3)	200–245	220	215–255	210	210–240	215

[a] Stand inventory data were supplied by the Canadian Forest Service (Sault Ste. Marie, Ont.).

marking, and helped make the harvesting more economical. The marking guidelines provided by OMNR concentrated on larger diameter classes (average harvested DBH of 30 cm), which generally included merchantable trees with high levels of defect and low growth potential. The selection cuts targeted a 30% basal area reduction across all diameter classes with the goal of removing pre-marked low-quality or competing stems and improving the growth of residual stems, but the actual removal averaged 35 to 40%. Selection followed OMNR guidelines, and although the objective was uniform single-tree selection, some removal more closely resembled shelterwood or patch selection as a result of the irregular stand structure and the quality of the stems.

Mechanized harvesting used a Timberjack 2618 feller-buncher equipped with a self-leveling cab. The Timbco sawhead's accumulator arms had been removed, so operators felled only one tree per cycle. The machine generally worked two shifts, with experienced operators, and manual delimbing occurred before extraction. Operators mostly restricted clearcutting to the night shift so that partial cuts could be performed during the day, when visibility is greater, so as to improve machine productivity and the protection of residuals. The results presented in this report are based on daytime operations only.

The feller-bunchers typically established parallel felling corridors, which subsequently became extraction trails for the skidders. This approach concentrated machine traffic, though skidders often strayed from the extraction trails. In both partial-cutting operations, feller-buncher operators removed broken limbs of residual trees to reduce the hazard to the skidder crews. The feller-buncher spent significant time bunching to facilitate subsequent winching. Various mid-sized skidders (75 to 112 kW = 100 to 150 hp) extracted tree-length stems to relatively small landings or formed piles running parallel to the roads for subsequent processing by a mobile slasher. (FERIC did not study the slashing phase.)

In the manual operation, fellers used chain saws, and felled and delimbed trees for extraction by cable skidder. FERIC studied both one- and two-worker skidding crews.

Results and Discussion

Because of the large numbers of small harvest areas and of harvest prescriptions being conducted concurrently, it was not possible to study all equipment working in all operating systems. As such, some consolidation of data between similar harvesting systems and operating techniques was conducted.

Felling Productivity

The productivity of mechanized felling is generally greatest in clearcutting operations and decreases in partial-cutting treatments, largely because of encumbrance from the residual stand and increased travel time in partial cuts. FERIC's study supported this generalisation (Table 2), though the marking pattern and lack of underbrush in the selection cuts minimized the productivity losses therein.

Table 2. Summary of feller-buncher productivity

	Clearcut	Shelterwood cut	Selection cut
Average vol./tree (m^3)	0.69	0.66	0.65
Productivity			
Trees/PMH	40	30	37
m^3/PMH	27.6	19.8	24.0
Work cycle time elements (min)			
Travelling	0.56	0.83	0.83
Brushing	0.17	0.34	0.18
Felling	0.28	0.27	0.26
Bunching	0.28	0.46	0.12
Operational delays	0.20	0.09	0.23
Total cycle time	1.49	1.99	1.62

In the partial cuts, the "travelling" time element was around 50% larger than in the clearcuts because only part of the stand volume was harvested. Bunching time increased by 65% in the shelterwood treatment because the operator had to maneuver trees between residual stems before bunching. Bunching time actually decreased in the selection cuts because tree marking in some areas more closely approximated group or patch selection; where true single-tree selection occurred, the trees were too scattered to make bunching practical or necessary. Moreover, visibility at ground level in the selection cuts was exceptionally good, thereby facilitating both bunching and the identification of the next tree to be removed.

FERIC did not study the productivity of the manual felling operations, but because the fellers worked with the skidders in a hot-logging operation, their productivities were considered to be equivalent to those of the skidders.

Extraction Productivity

Table 3 summarizes cable skidder productivities for the various operations. Note that these results represent a range of operators, machines, and particularly operating conditions; the results should thus be interpreted with caution.

In the mechanized partial-cutting operations, cable skidder productivity decreased by almost 30% compared with that in clearcutting for comparable skidding distances. With both tree volume and skidding distance standardized across treatments, shelterwood and selection cutting productivities decreased by 15 and 20%, respectively, compared with clearcutting. This decrease resulted from the increased time required to gather a full load. In the manual partial-cutting operations, skidder productivity decreased by less than 5% in the shelterwood cuts compared with clearcutting, versus a decrease of almost 30% in the selection cuts. However, for comparable tree volumes, the respective decreases were larger or comparable: 17 and 26%.

Skidder productivity in the mechanized operations was only 10 to 15% greater than that in the manual operations. Manual delimbing of bunched trees in the mechanized operation was sufficiently difficult that it eliminated much of the anticipated productivity gain from bunching the trees.

Table 3. Summary of cable skidder productivity[a]

	Mechanized operation			Manual cut-and-skid operation			
	Clearcut	Shelter-wood cut	Selection cut	Clearcut: 1 worker	Clearcut: 2 workers	Shelter-wood cut	Selection cut
Average							
Vol./tree (m^3)	0.67	0.56	0.61	0.76	0.70	0.81	0.67
Vol./cycle (m^3)	5.4	3.9	5.3	6.2	4.0	4.1	3.3
Extraction distance (m)	215	80	285	290	278	290	140
Productivity (m^3/PMH)	11.1 (12.2)	9.9 (8.6)	7.6 (8.5)	7.9 (8.6)	9.2 (10.9)	8.8 (10.5)	7.9 (7.8)
Work cycle elements (min)							
Travelling	6.32 (4.40)	3.95 (7.41)	9.52 (5.00)	7.36 (3.80)	8.56 (4.63)	10.58 (5.94)	6.06 (6.58)
Maneuvering	3.09	4.43	5.30	2.68	2.12	3.69	2.29
Winching	6.61	6.55	13.56	6.96	5.77	6.07	7.09
Assisting feller	2.96	0.75	1.69	20.48	4.32	1.45	4.19
Unloading	4.77	5.23	5.79	4.94	3.31	3.89	2.55
Operational delays	5.28	2.39	5.92	4.63	1.84	2.07	2.81
Total time	29.03 (27.11)	23.30 (26.76)	41.78 (37.26)	47.05 (43.49)	25.92 (21.99)	27.75 (23.11)	24.99 (25.51)

[a] Numbers in brackets represent the value for a standardized skidding distance of 150 m.

Soil Disturbance

Clearcutting was expected to produce the greatest site disturbance in terms of mineral-soil exposure and disruption of the general vegetative cover, followed by the shelterwood cuts; in contrast, the selection cuts were expected to have relatively little effect on the site. Comparing soil disturbance between the three silvicultural prescriptions (Table 4) was difficult because the disturbance was created by both the felling and the skidding operations; moreover, the size of the skidders and the operator skill levels also varied. Thus, the trends reported in Table 4 are generalisations. Moreover, the disturbance levels must be considered in the context of the silvicultural prescription; for example, mineral-soil exposure may be desirable to create seedbeds on flat ground, but undesirable on steep slopes because of the increased risk of erosion.

Slash coverage was greatest in the clearcuts (40 to 45%), lowest in the shelterwoods (15 to 19%), and intermediate in the selection cuts (15 to 26%). The low level of slash coverage in the shelterwood blocks resulted from bunching the stems; this concentrated slash near the bunches, with crowns piled vertically after manual delimbing rather than spread horizontally on the ground. In the selection blocks, stems were bunched less often, but slash still covered less area than in the clearcuts because fewer stems had been felled.

With mechanized harvesting, the shelterwood treatment produced the greatest levels (61%) of undisturbed soil; levels of undisturbed soil were similar in the clearcut (37%) and selection cut (39%) blocks. The feller-buncher and the skidder confined their travel to fairly well-defined trails in the shelterwood operation, and this maximized the proportion of undisturbed area. Soil disturbance was greater in the clearcut because the machines travelled throughout the site, and the scattered trees to be harvested in the selection blocks led to more-random skidder travel.

With manual harvesting, the shelterwood and selection operations produced the highest levels of undisturbed soil (57 and 65%, respectively); these levels were more than twice the levels (28%) in the clearcutting operation. Again, this was because the skidder travelled throughout the clearcuts rather than staying on well-defined trails.

Patterns of mineral-soil exposure were more complicated. In both the mechanized and manual operations, *deep* mineral-soil exposure was greatest in the shelterwood operations, probably because of the concentration of machine traffic on established trails; in contrast, operators often ignored the harvest trails in the clearcut and selection blocks. In the clearcut, this could be done when an alternate route provided more direct or easier passage, as no residuals had to be protected. In the selection cuts, there tended to be fewer established trails and more secondary trails not subject to repeated travel.

Table 4. Soil disturbance summary

	Mechanized operation			Manual operation		
	Clearcut	Shelter-wood cut	Selection cut	Clearcut	Shelter-wood cut	Selection cut
Ground disturbance class (%)						
Slash-covered[a]	40	15	26	45	19	15
Undisturbed	37	61	39	28	57	65
Litter disturbed, no mineral-soil exposure	5	1	4	3	2	7
Shallow mineral-soil exposure (<5 cm)	9	7	19	20	1	11
Deep mineral-soil exposure	3	9	2	4	11	2
Muck caused by machine travel	2	0	0	0	0	0
Stream	4	7	10	0	10	0
% of plots with:						
Signs of machine traffic	26	24	30	45	16	24
Hardwood regeneration	54	78	55	46	78	76
Softwood regeneration	10	14	24	15	1	3
Plantable microsite available	38	30	37	50	19	25

[a] Also includes areas where disturbance was not possible (e.g., rocks, stumps, etc.).

For the mechanized operation, *total* mineral-soil exposure (shallow plus deep) increased from the clearcut blocks (12%) to the shelterwood (16%) and selection (21%) blocks. The relatively low level of soil exposure in the clearcuts probably resulted from machine travel on areas classified as slash (brush mats) or not capable of disturbance, which covered around 40% of the site, roughly double the level in the partial cuts. The higher exposure levels in the partial cuts probably resulted from the increased machine travel required to obtain full loads and the decreased coverage by slash. In the manual operation, total mineral-soil exposure increased from around 12% in the partial cuts to nearly twice that level (24%) in the clearcuts, despite the greater proportions of the clearcuts that were covered by slash or not capable of disturbance. The vast majority of mineral-soil exposure on clearcut sites arose on machine trails.

Conclusions

Productivity

The results indicate that feller-buncher productivity decreased in the partial-cutting scenarios. If we assume that clearcutting represents the baseline productive potential of these machines, then the shelterwood and selection systems reduced productivity by around 30 and 13%, respectively. The unexpectedly greater reduction in the shelterwood operation probably arose because more time was required for bunching the wood to facilitate skidding than was required in the selection operation. Skidder productivity in the mechanized operations decreased by around 15 to 20% in partial cuts.

In the manual operations, skidder productivity also decreased as removal intensity decreased. The reduction compared with clearcutting was about 15% for shelterwood cuts, and 30% for selection cuts. This resulted primarily from increased travelling and winching times associated with the lower volumes removed per unit of area.

Soil Disturbance

Harvesting within riparian zones such as the Turkey Lakes Watershed poses environmental concerns because of the risk of affecting water quality. Therefore, once managers choose a removal intensity, harvesting operations must minimize the resulting environmental impacts. However, workers can only control slash distribution and mineral-soil exposure, since other impacts (e.g., reduced cover, changes in water chemistry) depend on the prescription itself and thus are beyond their control. For this reason, FERIC's study focused on slash distribution and soil disturbance.

In general, manual operations resulted in less disturbed ground and fewer signs of machine travel than mechanized operations, except during clearcutting. The increased opportunity for feller-bunchers to concentrate wood in clearcutting operations reduces the amount of skidder traffic required. Slash distribution was also generally greater on manual operations because of the lack of bunching.

In terms of the silvicultural prescriptions, slash distribution was much lower in the partial-cut scenarios, and more ground was left undisturbed. However, deep mineral-soil exposure generally increased in response to the concentration of machine travel that occurred in the shelterwood cuts.

Overall, the manual selection harvesting operation produced the highest level of undisturbed area, and low levels of mineral-soil exposure. This suggests that manual selection cuts should merit consideration in riparian zones or on steep sites, where disturbance can cause problems with erosion and stream sedimentation.

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