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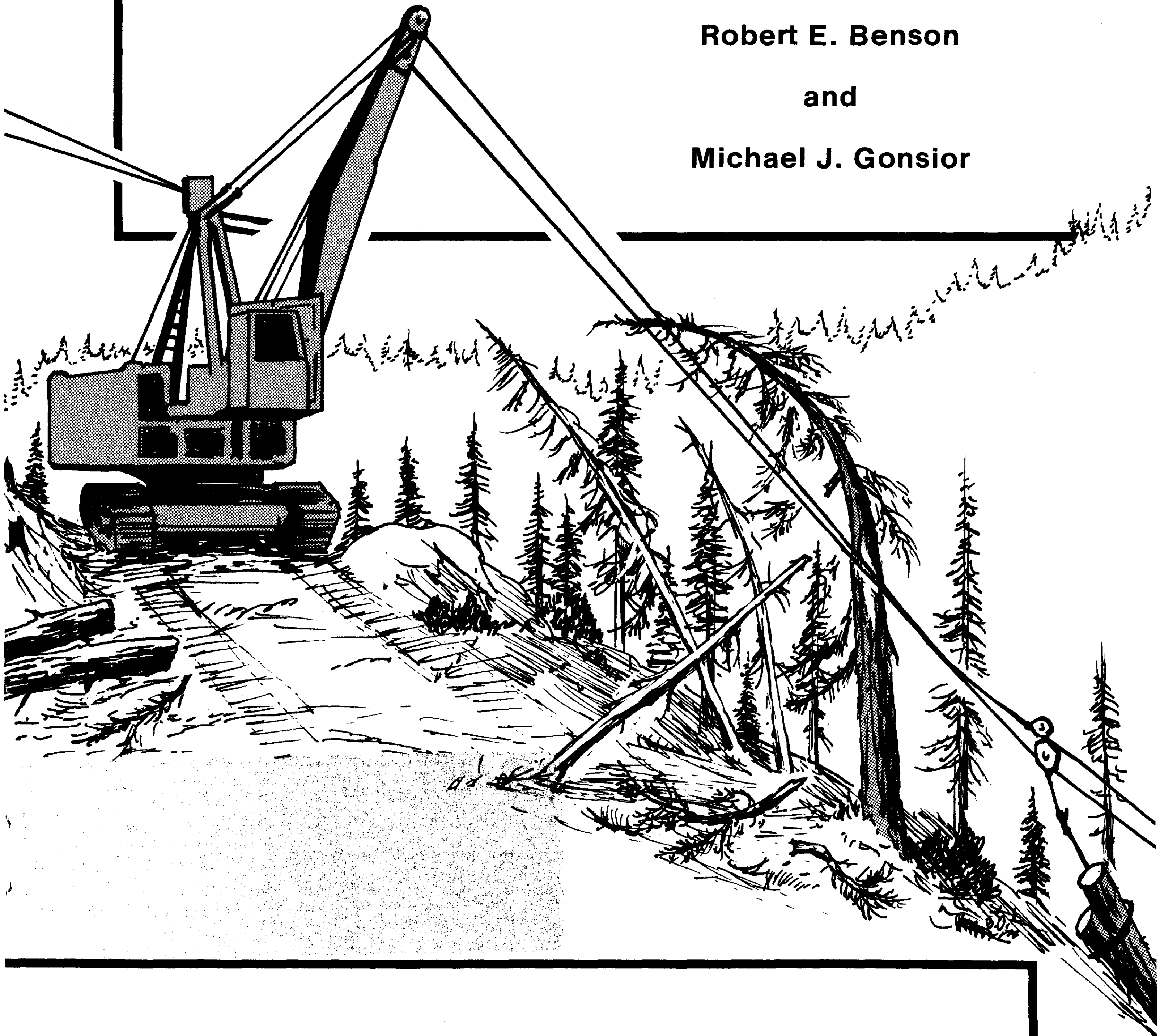

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RESEARCH SUMMARY

Six cutting units in Douglas-fir/larch logged to various utilization specifications with skyline yarders were examined for damaged trees after logging was completed. Damage appeared to be related to the total number of stems in the stand, number of marked leave trees (7.0 inches d.b.h., 18 cm) and to yarding conditions such as slope.

About 23 percent of the leave trees in two shelterwood cutting units were killed in logging. About 66 percent were damaged to some extent, but only about 10 percent had moderate to serious damage. In treatments where loggers attempted to protect the understory trees, about 40 percent were killed or seriously damaged.

CONTENTS

INTRODUCTION

Recently there has been renewed interest in partial cutting in western conifer stands. Historically, much of the virgin forest was initially logged selectively—removing only trees of high value—but for most of the past three decades clearcutting has predominated. With more complex management objectives and environmental concerns, managers are now frequently turning to some type of partial cutting. They are asking questions about the impacts of partial cutting on costs, silvicultural success, esthetics, wildlife, and other management considerations.

This paper reports initial logging damage to residual trees in six harvest units in Douglas-fir/western larch *(Pseudotsuga menziesii/Larix occidentalis)* forests at the Coram Experimental Forest (Flathead National Forest) near Hungry Horse, Mont. The appraisal includes damage to marked "leave" trees in two shelterwood units, and damage to understory conifers in clearcut and group selection cutting units where the understory was to be protected.

The logging was part of a larger program of studies dealing with impacts of residue utilization and disposal. (Detailed plans on other studies are available at the Hungry Horse Ranger District or Forestry Sciences Laboratory, Missoula.)

The damage reported here was observed within the first year of logging. Secondary effects of windthrow, insects, and disease are beyond the scope of this report, but are being followed in long-term studies.

SHELTERWOOD LEAVE TREE DAMAGE

Description of the Area and Cutting Units

Two shelterwood cutting units (blocks 11 and 21) were marked so as to leave about half of the volume of trees 7 inches d.b.h. (18 cm) and larger, and to provide good vigor, spacing, and species diversity. Within each cutting unit, four utilization and postharvest treatments were used:

Treatment	Specifications
1	All material at least 8 feet (2.4 m) long with at least a 3-inch (7.6-cm) diameter (small end) was removed (this included trees down to a 5-inch [12.7-cm] d.b.h.). Residue was burned after harvest.
2	Trees down to a 7-inch (18-cm) d.b.h. were cut, logs down to a 6-inch (15.2-cm) top diameter were removed; residue was burned after harvest.
3	All trees down to a 1-inch (2.5-cm) d.b.h. were cut and removed; the area was left "as is" after harvest.
4	Trees down to a 7-inch (18-cm) d.b.h. were cut, logs 8 feet (2.4 m) long down to a 3-inch (7.6-cm) diameter were utilized; remaining trees were protected as far as possible and left as advanced regeneration.

Although the two units had many similarities and the treatments were identical, differences in terrain possibly influenced logging damage. The units are reported here as separate "case studies" rather than as replications.

A summary of the preharvest stand conditions is shown in table 1. This is a fairly typical fir-larch stand, and like most natural stands, fire, disease, blowdown, etc., have left a mosaic of old and young trees. This is reflected in the variation in volumes among treatments. The cut tree volume as cruised varied from 4.5 to 9.5 M bd. ft./acre (approximately 63 to 133 m^3/ha). We anticipated that about 15 percent of the leave tree volume would be lost in the logging process; therefore somewhat more volume was removed than was shown in the cruise.

Table 1.—Description of shelterwood units preharvest, Coram Experimental Forest, 1974

Item	Unit and subtreatment							
	11-1	11-2	11-3	11-4	21-1	21-2	21-3	21-4
Number of trees/acre								
Cut trees, 7+ inches	49	39	59	46	74	71	50	64
Leave trees, 7+ inches	66	51	73	51	98	78	65	89
Subtotal	115	90	132	97	172	149	115	153
(Trees/ha)	(284)	(222)	(326)	(240)	(425)	(368)	(284)	(378)
Other trees								
5-7 inches	85	100	65	69	155	75	115	145
<5 inches	1,090	1,045	1,215	1,063	1,005	960	2,490	2,060
Total	1,290	1,135	1,412	1,229	1,332	1,184	2,720	2,358
(Trees/ha)	(3 186)	(3 050)	(3 488)	(3 036)	(3 290)	(2 924)	(6 718)	(5 824)
Volume								
Total standing, 3+ inches								
cubic feet/acre	6,033	3,854	4,574	3,835	5,404	2,958	3,286	4,232
cubic meters/ha	(422)	(279)	(320)	(268)	(378)	(207)	(230)	(297)
Cruised volume of cut trees M bd.ft./acre	9.5	6.0	8.4	5.7	8.7	6.9	4.5	5.5
Average volume of cut trees, bd.ft.	193	155	142	118	117	97	89	86

Logging Operations

The areas were logged during the summer of 1974. Some of unit 21 was logged early when the sap was still rising and the trees were particularly susceptible to debarking damage.

The logging units and skyline corridors were located as shown in figure 1. A running skyline yarder was used for both uphill and downhill yarding, and in these units the skyline spans ranged between 450 and 1,200 ft (137 and 366 m) (fig. 2). A live skyline yarder was used only in uphill yarding on spans ranging between 500 and 800 ft (152 and 244 m).

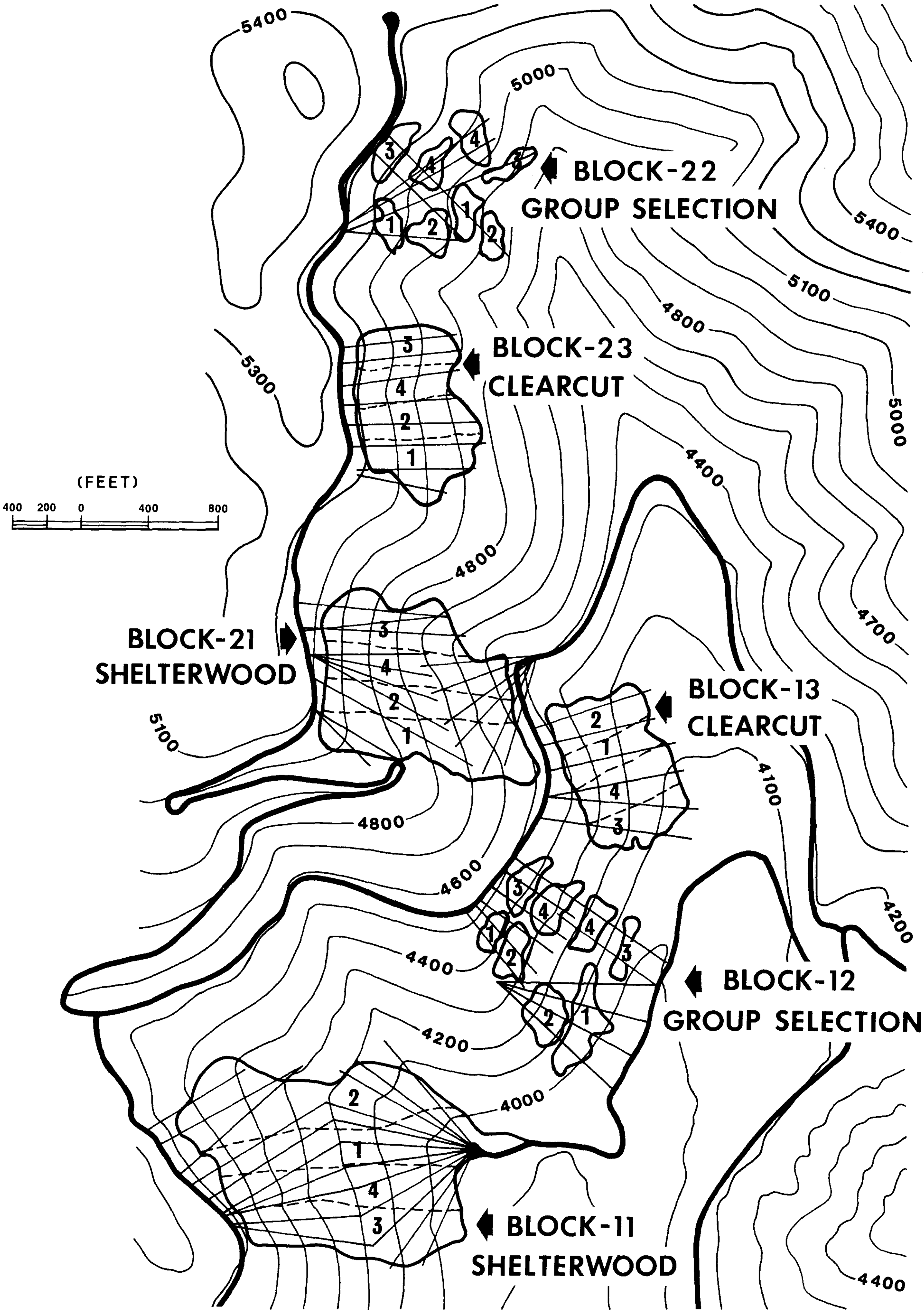

Figure 1.—Logging units and skyline corridors, Coram Experimental Forest, 1974.

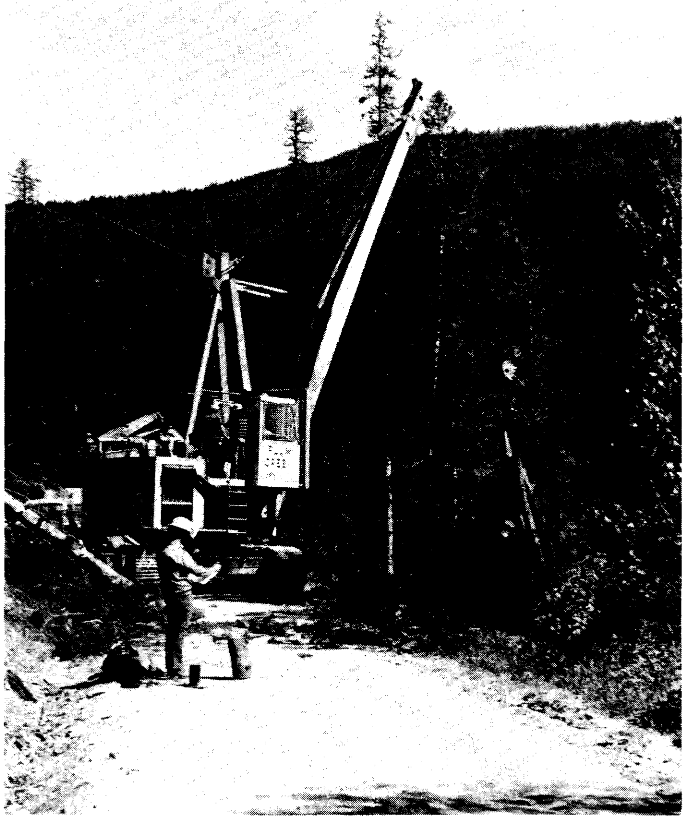

Figure 2.—Yarding with running skyline.

Damage to Leave Trees

The damage to remaining trees is summarized in table 2. These are called leave trees here, although some of the remaining trees were not originally marked as leave trees.

The type of damage on individual trees was recorded in great detail and is on file at the Forestry Sciences Laboratory. We categorized damage according to how seriously it might affect the tree:

Group I - Marked leave trees missing, used for spars, or will die.
Group II - Stump scars 10 in^2 (64 cm^2) or greater, and/or heartwood damage; **OR** broken top 20 percent or more tree height; **OR** bole scar <5 ft height (1.5 m), 100 in^2 (645 cm^2) or greater.
Group III - Stump scar <10 in^2 (64 cm^2); **OR** broken top <20 percent.
Group IV-V - Light bole scars, broken branches
No damage - No damage due to 1974 logging.

On the average, 23 percent of the marked leave trees were killed and 34 percent of all remaining leave trees had no damage:

Unit	Percentage marked leave trees killed	Percentage remaining trees undamaged
11-1	19	32
11-2	24	50
11-3	24	37
11-4	21	41
21-1	23	28
21-2	26	33
21-3	16	21
21-4	34	32
Average	23	34

Some of the cut trees were subsequently left to replace the missing leave trees, as indicated in table 2. When these are taken into account, about 45 percent of the trees over 7 inches d.b.h. remained after logging.

Table 2.—Status of shelterwood trees after harvest

Description	Unit and subtreatment							
	11-1	11-2	11-3	11-4	21-1	21-2	21-3	21-4
	Trees per acre							
Preharvest marked leave trees/acre	66	51	73	51	98	78	65	89
(No./ha)	(163)	(126)	(180)	(126)	(242)	(193)	(161)	(220)
Postharvest								
Leave trees missing or killed (Group I)	12.7	12.5	17.4	10.5	22.5	20.3	10.2	30.7
(No./ha)	(31)	(31)	(43)	(26)	(56)	(50)	(25)	(76)
Damage on remaining trees								
Group II	5.4	2.1	5.1	3.4	12.2	9.2	8.2	5.2
Group III	3.1	.5	2.0	.8	5.1	0.4	2.6	.6
Groups IV-V	30.5	16.5	28.1	25.8	37.0	28.3	32.5	40.7
None	18.2	19.4	20.4	20.6	21.2	19.2	11.5	21.7
Total trees remaining[1]	57.2	38.5	55.6	50.6	75.5	57.7	54.8	68.3
(No./ha)	(141)	(95)	(137)	(125)	(186)	(142)	(135)	(169)

[1]In units 11-1 and 21-1 the marked leave trees minus the killed or missing leave trees do not equal the total trees remaining because in some cases unmarked smaller trees were left as replacement for leave trees killed in logging or as additional leave trees.

Damage and Stand Conditions

We hypothesized that stand conditions might affect logging damage, and to test this we devised a scheme for making simple rank correlation tests. Each of the eight subtreatment units was rated from "1" (most favorable) to "8" (least favorable). We used four measured stand conditions as follows:

Stand Conditions

Cut volume per acre: (lowest volume = 1, highest volume = 8)

Total number of trees per acre 7 inches + d.b.h.: (fewest = 1, most = 8)

Number of marked leave trees per acre: (fewest = 1, most = 8)

Expected damage, based on treatment and number of stems removed per acre: (1 = best combination, 8 = difficult combination)

As an example, we expected treatment 3 to have highest damage because small trees were bundled and yarded in addition to the cut trees marked for cutting. Unit 21-3 had the most small trees and ranked "8" on the expected damage, and unit 11-3 was ranked 7. Treatment 4 called for protecting the understory, and was ranked "1" for unit 11-4 and "2" for unit 21-4, based on number of stems.

The ranking for each of these stand conditions was then compared to the subtreatment rankings on actual damage observed, using the following measures:

Measure of Damage

A. Percentage of damaged leave trees: (lowest = 1, highest = 8)
B. Percentage of serious damage (Group II and III): (lowest = 1, highest = 8)
C. Percentage with no damage: (highest = 1, lowest = 8)

The rankings of the eight subtreatment units are shown in table 3. Out of the 12 pairings tested (4 conditions x 3 damage measures), we found several that were moderately well correlated, as follows (1.0 = perfect correlation):

Pair tested	Correlation coefficient	Significant at:
		Percent
[Percentage with serious damage] x [Expected damage]	0.641	95
[Percentage with serious damage] x [Fewest leave trees]	.570	90
[Percentage with serious damage] x [Fewest total trees]	.548	90
[Percentage with no damage] x [Fewest leave trees]	.559	90
[Percentage killed] x [Lowest cut volume]	.405	80

Table 3.—Ranking of stand conditions and logging damage ("1" is most favorable and "8" is least favorable)

	Stand condition				Measure of damage		
Unit	Expected damage (Col. 1)	Cut volume (Col. 2)	Total 7+-inch trees (Col. 3)	Fewest marked leave trees (Col. 4)	Killed (Col. 5)	Seriously damaged (Col. 6)	Not damaged (Col. 7)
11-2	3	4	1	1	2	1	1
11-3	7	6	5	5	4	4	2
11-4	1	2	2	2	7	2	3
21-1	5	7	8	8	5	8	7
21-2	4	5	6	6	8	5	4
21-3	8	1	3	4	1	7	8
21-4	2	3	7	7	3	3	6

Rank correlation coefficients:

col. 4 x col. 7 = 0.559, significant at 90 percent
col. 3 x col. 6 = 0.548, significant at 90 percent
col. 2 x col. 5 = 0.405, significant at 80 percent
col. 4 x col. 6 = 0.570, significant at 90 percent
col. 1 x col. 6 = 0.641, significant at 95 percent.

Keeping in mind the limitations of these simple tests, it is notable that the most difficult treatments coupled with more stems did, in fact, result in more damage as we expected. Predicting actual killing of leave trees was less dependable; the best correlation (only 0.405) was with the volume cut.

These relationships of stand conditions and damage sustained are not surprising; the ranking tests do, however, provide a quantified and statistically significant measure of what is generally assumed—namely, more stems in the stand and more stems marked for leave increase the chance of damage.

Damage and Logging Conditions

Damage to leave trees is also influenced by the yarding operation itself. We examined the relationship of yarding and tree damage by plotting on maps missing leave trees and seriously damaged trees, and relating these to logging conditions. The conditions examined were: slope; the angle between the "fall line" (direct downslope) and the skyline; and the load capacity computed for each skyline setting. These selected logging factors were then drawn as zones on mylar overlays. Within these overlays the number of seriously damaged or missing trees was tallied. An example is shown in figure 3. The relationship of these factors to damaged or missing trees is summarized in table 4.

SLOPE

We hypothesized that damage should increase with steepness of slope, because logs would be more likely to roll or slide downslope during lateral yarding. This hypothesis is weakly supported in block 21, but contradicted by data from block 11. However, in block 11 most of the gentle slopes are near the bottom of the block where numerous corridors radiated out from a single common landing (fig. 1). Most of the damage in this zone was attributed to missing leave trees that were probably cut in creating the numerous corridors and was not related to lateral yarding.

If we omit the data from block 11 for 0 to 25 percent slopes and combine the remaining data from block 11 with that from block 21, we do find a greater incidence of damage on steep slopes than on moderate or gentle slopes. It is doubtful, however, that we can draw a firm conclusion, given the relatively small area of steep slopes and the limited accuracy of plotting the damaged trees.

ANGLES BETWEEN CORRIDORS AND FALL LINE (CROSS-SLOPE ANGLE)

We hypothesized that damage is greater when the cross-slope angle increases. In particular, we expect the damage to be more evident adjacent to, and on the downslope side of, the corridors as cross-slope increases under conditions of partial suspension. This is because logs tend to slide downhill during the yarding operation.

The combined data from blocks 11 and 21 show that damage frequency increases as cross-slope angle increases, except for the angle class 60-90 percent, where damage was low. However, there was less than 1 acre in this angle class (about 2 percent of the total area of blocks 11 and 21) and it seems reasonable to conclude the data from the area support our hypothesis.

We noted also that plots of missing trees align well with some downhill corridors in the lower portion of block 11; in particular, with corridors that are at moderate to high angles with the contours. Personal observations during the yarding operation also confirmed a relatively high incidence of tree uprooting in such circumstances. Therefore, we expect a greater incidence of damage adjoining corridors where cross-slope angles are great—especially in downhill yarding situations when logs are not fully suspended. Perhaps a distinction between types of damage would more strongly reinforce this expectation. And perhaps the basis for determination should be number of damaged trees per unit **length** of corridor—rather than per unit area of treatment—to test this hypothesis. However, the accuracy of plotting damaged trees was not reliable enough to make this type of analysis.

LOAD CAPACITY

We hypothesize that damage incidence should be reduced with increasing load capability. Our rationale is that the greater the load capability the

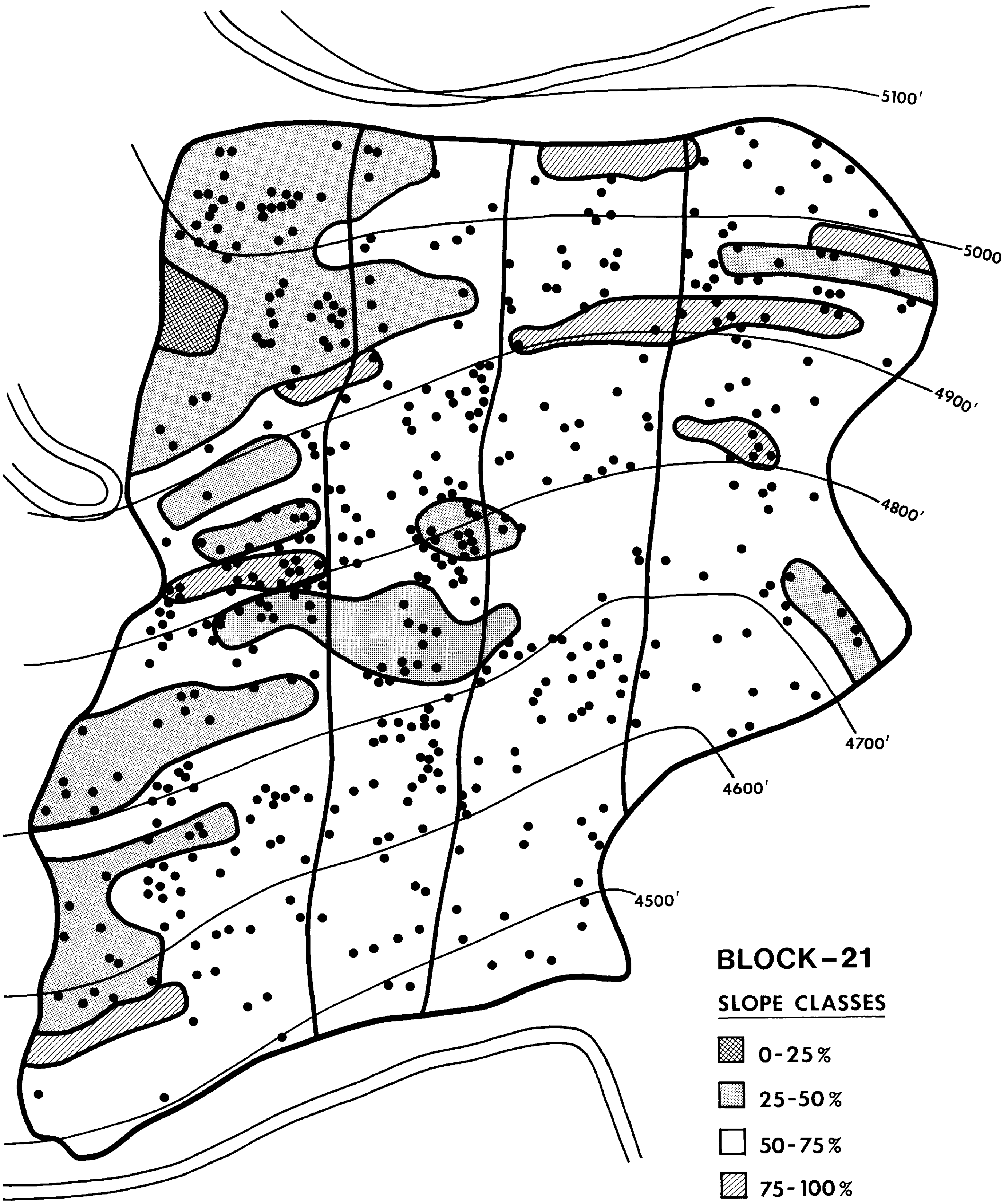

Figure 3.—Schematic map showing damaged trees and slope class. Example: Block 21, Coram Experimental Forest.

Table 4.—Summary of missing or seriously damaged leave trees by logging characteristics, shelterwood units

Characteristic	Block 11		Block 21		Blocks 11 and 21
	Acres	*Trees/acre*	*Acres*	*Trees/acre*	*Trees/acre*
Slope, percent					
0-25	3.72	23.9	0.15	0	23.0
25-50	20.65	13.4	5.26	26.1	16.0
50-75	9.79	10.0	15.00	20.1	16.1
75-100	0.95	11.6	1.19	32.8	23.4
Cross slope angle, percent					
0-15	15.81	13.56			
0-15	15.81	11.0	6.64	19.4	13.5
15-30	13.56	13.9	4.38	21.0	15.7
30.45	4.76	17.9	4.49	2.7	20.2
45-60	.39	18.0	5.96	26.5	26.0
60-90	.58	15.9	.39	2.6	10.4
Load capacity, lb					
Over 10,000	18.01	16.3	12.25	22.2	18.7
5,000-10,000	11.99	10.0	7.51	22.2	14.7
2,500-5,000	3.44	7.6	.50	16.0	8.16
2,000-2,500	1.50	14.7	.19	21.1	15.4
<1,000	.16	6.2	1.15	32.2	29.0

greater the clearance of the carriage above the ground and, during lateral yarding, this should mean greater control over the movement of the logs. Moreover, during longitudinal yarding, the angle between the logs and ground should be greater—approaching full suspension—and this should reduce the likelihood of damage adjacent to the corridor.

There is only weak support for this hypothesis in the data from block 21, and it is contradicted somewhat by the data from block 11. Combining the data from blocks 11 and 21 indicates that damage is minimized at intermediate load capabilities, and increases with both high and lower load capabilities. One explanation may be that above a certain load capability, the potential advantages of large carriage clearance during lateral yarding cannot be realized due to the limited length of dropline. That is, it is necessary for the carriage to be relatively close to the ground—at least during the lateral yarding phase—simply because of the limited amount of line for lateral extension in the systems used at Coram. If this is true, then the onset of lateral inhaul would result in pronounced lateral excursion of the carriage and supporting cables, which could damage trees adjoining the corridor.

We also speculate that where load capability is high the system tends to be loaded heavily and operated at high speeds—thereby increasing propensity for damage during both the lateral and longitudinal yarding phases. In any event, we are unable to draw any firm conclusions regarding the influence of load capability on incidence of damage.

In summary, our Coram data support the hypothesis that damage to residual trees in partial cuts, where yarding is conducted with cable systems, increases with steeper slope and greater cross-slope angle. Regarding the influence of system load capability, our data are inconclusive.

Overall, about 23 percent of the marked leave trees were killed in logging, and consequently some "cut" trees were left as replacement. This indicates the importance in marking timber sales under these conditions that an adequate allowance be made for leave trees that must be cut for skyline corridors or are killed in the yarding operation.

UNDERSTORY TREE DAMAGE

Description of Cutting Units

In the two shelterwood units discussed above, subtreatment 4 called for logging to protect the understory trees below the cutting diameter limit (7 inches [18 cm] d.b.h.). This same subtreatment was also prescribed in two group selection cutting units (units 12 and 22, each composed of 8 cutting groups of about 1 acre) and in two clearcut units (units 13 and 23).

The area and volume of logs removed from subtreatment 4 in the six units were as follows:

Unit and subtreatment	Area of subtreatment 4		Volume of logs removed	
	Acres	*ha*	*Ft³/acre*	*m³/ha*
11-4 (shelterwood)	6.2	2.5	2,950	206
21-4 (shelterwood)	4.6	1.9	2,570	180
12-4 (group selection)	1.7	.7	7,655	536
22-4 (group selection)	1.5	.7	6,241	437
13-4 (clearcut)	3.2	1.3	4,962	347
23-4 (clearcut)	3.4	1.4	3,533	247

The understory trees were measured on 20 sample plots in each unit, so it was not possible to map individual trees relative to skyline roads as was done with the shelterwood trees. The damage reported is an average that varies, depending on whether the plot was in or near a skyline road or lateral skid trail.

Damage to Understory

Because understory trees are usually small, we considered virtually any substantial damage likely to kill or to render the tree unsuitable for management. Therefore, we classed damage in only a few categories as follows:

No damage - A few scrapes, or broken branches.

Serious damage - Bent, debarked bole, top broken.

Cut or missing - Tree no longer present.

Buried or broken - Whole tree broken off, uprooted, or buried under slash.

Serious damage and tree killing averaged more than 40 percent in selection and clearcut units, and under 30 percent in shelterwood units (table 5). Units were too few to draw statistically valid conclusions on this difference, but it is consistent with logging activities. The process of carefully yarding to avoid damaging large shelterwood trees probably protected some understory trees. Furthermore, the larger leave trees in the shelterwood units probably prevented logs from sliding or rolling downhill during lateral yarding.

Table 5.—Percentage of live understory trees damaged by logging, by cutting unit, and by type of damage

Cutting unit		Serious stem or branch damage	Broken or buried	Cut or missing	Total damaged	No damage
		Percentage of understory trees				
Shelterwood	11-4	3	15	10	28	72
	21-4	5	17	8	30	70
Group selection	12-4	17	6	19	42	58
	22-4	26	12	5	43	57
Clearcut	13-4	5	7	25	37	63
	23-4	5	7	33	45	55

The group selection units and clearcut units showed a definite and consistent pattern of damage. The larger the trees, the greater the chance that they were killed or seriously damaged (table 6). The percentage of trees damaged did not appear to be related to total number of green understory trees, as stocking ranged from 540 to 1,280 live trees per acre (1 330 to 3 160/ha). Detailed summary of damage by diameter and cutting unit is shown in table 7a, b, c.

Table 6.—Percentage of live understory trees damaged by d.b.h. class of tree

Cutting unit		D.b.h. class 0-09 inches (0-2.4 cm)	D.b.h. class 1.0-4.9 inches (2.5-12.6 cm)	D.b.h. class 5.0-6.9 inches (12.7-17.6 cm)
		Percentage of this class damaged		
Shelterwood	11-4	24	29	40
	21-4	20	41	23
Group selection	12-4	20	52	64
	22-4	32	78	82
Clearcut	13-4	22	69	75
	23-4	31	85	73

Table 7a.—Logging damage to live understory trees, Coram shelterwood cutting units treatment 4 (protect understory)

Damage	D.b.h. class 0-0.9 inches (0-2.4 cm)	1.0-4.9 inches (2.5-12.6 cm)	5.0-6.9 inches (12.7-17.6 cm)	Total
	Number of trees			
Block 11-4				
Serious damage	0	30	0	30
Broken, buried	35	85	10	130
Cut, missing	20	55	10	85
Subtotal	55	170	20	245
No damage	170	415	30	615
Total - per acre	225	585	50	860
(per ha)	(556)	(1 445)	(123)	(2 124)
Percent damaged or killed	24	29	40	28
Block 21-4				
Serious damage	10	40	10	60
Broken, buried	55	160	10	225
Cut, missing	40	50	10	100
Subtotal	105	250	30	385
No damage	430	345	100	895
Total - per acre	535	615	130	1,280
(per ha)	(1 321)	(1 519)	(321)	(3 162)
Percent damaged or killed	20	41	23	30

Table 7b.—Logging damage to live understory trees, group selection cutting units treatment 4 (protect understory)

Damage	D.b.h. class 0-0.9 inches (0-2.4 cm)	1.0-4.9 inches (2.5-12.6 cm)	5.0-6.9 inches (12.7-17.6 cm)	Total
	Number of trees			
Block 12-4				
Serious damage	10	80	0	90
Broken, buried	10	15	5	30
Cut, missing	20	45	40	105
Subtotal	40	140	45	225
No damage	160	130	25	315
Total - per acre	200	270	70	540
(per ha)	(494)	(667)	(173)	(1 334)
Percent damaged or killed	20	52	64	42
Block 22-4				
Serious damage	220	85	10	315
Broken, buried	65	80	5	150
Cut, missing	10	15	30	55
Subtotal	295	180	45	520
No damage	630	50	10	690
Total - per acre	925	230	55	1 210
(per ha)	(2 285)	(568)	(136)	(2 989)
Percent damaged or killed	32	78	82	43

Table 7c.—Logging damage to live understory trees, Coram clearcut cutting units treatment 4 (protect understory)

Damage	D.b.h. class			
	0-0.9 inches (0-2.4 cm)	1.0-4.9 inches (2.5-12.6 cm)	5.0-6.9 inches (12.7-17.6 cm)	Total
	Number of trees			
Block 13-4				
Serious damage	15	30	0	45
Broken, buried	20	35	5	60
Cut, missing	100	90	25	215
Subtotal	135	155	30	320
No damage	470	70	10	550
Total - per acre	605	225	40	870
(per ha)	(1 494)	(556)	(99)	(2 149)
Percent damaged or killed	22	69	75	37
Block 23-4				
Serious damage	20	25	5	50
Broken, buried	40	20	0	60
Cut, missing	140	100	50	290
Subtotal	200	145	55	400
No damage	445	25	20	490
Total - per acre	645	170	75	890
(per ha)	(1 593)	(420)	(185)	(2 198)
Percent damaged or killed	33	85	73	45

DISCUSSION AND CONCLUSIONS

At Coram the terrain was fairly steep and not entirely ideal for skyline yarding; also some demanding removal specifications were applied to some units. Despite this, shelterwood trees came through pretty much intact, and we feel that the following factors will influence the amount of damage incurred in similar situations:

1. Damage to leave trees is related to stand conditions. The fewer trees in the stand and the fewer marked for leaving, the less the damage. Curiously, though, the number of trees actually killed was only weakly related to cut volume.

2. Damage is related to the logging specifications. We expressed this as "expected damage," which collectively included utilization specifications and understory protection requirements.

3. Damage appears to be related to slope steepness, cross-slope angle to the skyline, and load capacity of the skyline setting. Data only moderately supported this idea, but observations tell us these three factors are important and could be more precisely assessed with different approaches to study.

4. On portions of cutting units where protection of the understory was specified, two factors influenced damage. Fewer understory trees were damaged in the shelterwood units than in group selection or clearcut units (but data are too limited for statistical validity). In all types of cutting units, the larger the understory tree, the greater the proportion sustaining serious or fatal damage. This was true even though small (seedling) trees were much more numerous than poles. Apparently larger trees are less resilient and thus more easily damaged than small trees.

As cautioned at the outset, these findings are based on a "case study" approach, but should be useful as a first estimate of likely damage under similar conditions. We would suggest that to refine these data, studies be specifically designed to monitor logging damage and operations, for example, to separate damage from falling, lateral yarding, main line lifting and hauling, and so on.

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1981. Tree damage from skyline logging in a western larch/ Douglas-fir stand. USDA For. Serv. Res. Pap. INT-268, 15 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Damage to shelterwood leave trees and to understory trees in shelterwood and clearcut logging units logged with skyline yarders was measured, and related to stand conditions, harvesting specifications, and yarding system-terrain interactions. About 23 percent of the marked leave trees in the shelterwood units were killed in logging, and about 10 percent had moderate to serious damage. About 40 percent of the understory trees were killed. Heaviest damage in shelterwood was associated with steeper slopes, more trees per acre, and cross-slope angle to the skyline. Understory damage was greater on larger saplings than on seedlings.

KEYWORDS: logging damage, skyline logging, scars, tree damage

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