Forest Research
Extension Note

Vancouver Forest Region
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EN-010 Geomorphology October 2001

KEYWORDS:

forestry, forest management, soil erosion, mass wasting, helicopter harvesting, silvicultural systems, partial cutting

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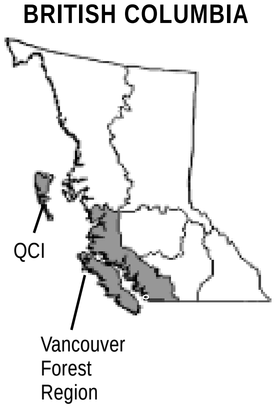
Citation

Millard, T. and S. Chatwin. *Using Helicopter Harvesting on Steep Slopes to Reduce Erosion, Preliminary Results: Case Study on Queen Charlotte Islands, British Columbia.* Research Section, Vancouver Forest Region, BC Ministry of Forests. Nanaimo, BC. Extension Note EN-010. 8pp.

BRITISH COLUMBIA



Using Helicopter Harvesting on Steep Slopes to Reduce Erosion, Preliminary Results: Case Study on Queen Charlotte Islands, British Columbia

By Tom Millard and Steve Chatwin

INTRODUCTION

Forestry is a major economic activity on the Queen Charlotte Islands (QCI), an archipelago located off the northwest coast of British Columbia (BC). For some time, the effects of forestry activities on erosion, and in particular mass wasting (or landslides) in the Islands have been of concern.

At 0.12 landslides/km^2/y on forested terrain (Rood 1984), natural landslide events are relatively frequent on QCI due to a combination of steep terrain and a mild, wet climate characterized by intense precipitation from frequent, long-lasting winter storms (Karanka 1986). Traditional forestry operations increased the frequency of landslides in steep terrain, often to the detriment of fish habitat and other resources (Hogan et al. 1998). In an assessment of cutblocks harvested from 1970 to 1982, Rood (1984) found that clearcut harvesting had the effect of increasing the volume of sediment from landslides by four times over the natural landslide rate, and road building resulted in a 62 times increase in the volumetric landslide rate. Overall, about 75% of the harvesting-related landslides in the QCI have been occurring in clearcuts, and 25% originating from roads (Rollerson 1992).

Using Alternative Harvesting Methods to Minimize Terrain Instability and Soil Disturbance

As the consequences of traditional harvesting and road building became known, forest managers began to look at using alternative methods of harvesting in order to avoid causing landslides and to minimize soil disturbance. There was also interest in accessing some forested terrain that was excluded from the Timber Supply Area because it was considered too unstable to withstand harvest by conventional methods.

Using helicopters to yard timber from steep slopes appeared to be the most likely method for reducing the number of landslides and the extent of soil disturbance because it does not require roads to be built on the steep slopes and because logs are fully suspended during yarding. Also, helicopter yarding is compatible with a variety of partial-cutting methods; retaining some trees on a slope maintains a portion of the live root network, and therefore should maintain a portion of the apparent cohesion gained from root strength. However, a concern about partial harvesting methods is that they may lead to greater amounts of windthrow and therefore soil disturbance. Finally, helicopter yarding allows trees to be harvested from small areas of relatively stable ground that may be adjacent to unstable ground.

STUDY OBJECTIVES

After a series of harvesting-related landslides occurred in 1978 in the Rennell Sound area (on the west side of Graham Island), research was initiated to investigate the use of alternative harvesting methods for reducing the number of forestry-related landslides (Poulin 1984). The research included a study of the use of partial-cutting methods combined with helicopter yarding on steep slopes; this combination had not been explored previously in BC.

One objective was to study the effectiveness of a variety of steep-slope harvesting methods, ranging from single-tree selection to group selection and clearcuts. Another objective was to investigate the success of helicopter yarding in conjunction with these different harvest methods.

This report examines and evaluates the erosion response of these sites to the combination of various silvicultural systems with helicopter yarding, including the following:

1. Amounts of post-harvest erosion vs. pre-harvest erosion.

2. Amounts of erosion associated with each harvesting method.

3. Significance of post-harvest windthrow as a contributor to erosion.

In addition to this report, Krag (1998) examined the efficiency and costs of harvesting and yarding, and D'Anjou (2000) examined regeneration success on these sites.

SITE DESCRIPTIONS

Two locations in the Rennell Sound area, Hangover Creek and Gregory Creek, were selected for the study (Figure 1). Both sites had been previously rejected for harvesting by conventional means due to concerns about slope stability.

Precipitation in Rennell Sound ranges from about 2300 mm/y to almost 4000 mm/y (Hogan and Schwab 1991). Both blocks are in the Very Wet Hypermaritime variant of the Coastal Western Hemlock biogeoclimatic zone (CWHvh). The forest was comprised of a dense cover of western hemlock (Tsuga heterophylla) and sitka spruce (Picea sitchensis), plus small amounts of western redcedar (Thuja plicata) and yellow cedar (Chamaecyparis nootkatensis) (Krag 1998).

The Hangover Block is on a southwest-facing hillslope that ranges from about 50 to 750 m in elevation. The Gregory Block is on a south-facing hillslope that ranges from 25 to 450 m in elevation. Both blocks are underlain by the basaltic Masset Formation, and argillite (presumably of the Triassic-Jurassic Kunga Formation) is exposed in the lower elevation areas of the Gregory Block (Maynard 1991). Surficial materials in both blocks include glacial till, colluvium, and exposed bedrock (Maynard 1990 and 1991). Both blocks had been mapped as a mix of terrain stability Class IV and Class V (Townsend 1978).

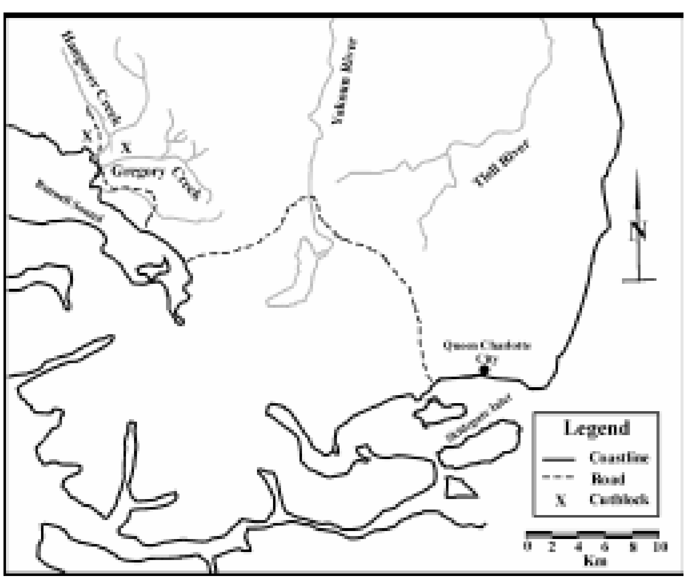


Figure 1. Location of Hangover and Gregory Blocks (after D'Anjou 2000).

STUDY DESIGN AND HARVESTING METHODS

Surveys and Mapping

In 1990, the initial planning of the study blocks included detailed 1:2500 terrain mapping and soil-disturbance mapping (Maynard 1990 and 1991). Both study blocks were mapped using a 25-m grid system, with 100% of the terrain units and soil-disturbance features field checked. Terrain was classified on the basis of surficial material type, slope steepness, surficial expression, and evidence of geomorphic processes. A slope-stability interpretation map, using the mapped terrain polygons, assigned one of five stability classes, with Class I the most stable and Class V the least stable (Table 1). This mapping exceeds the criteria of Level A terrain mapping (BCMOF and BCMOE 1999). This mapping is used to rate the likelihood of post-harvest landslides occurring.

The pre-harvest soil-disturbance maps show areas of mass wasting, erosion, and windthrow. Width, length, and depth of the disturbance were measured on site, and the pathway of the sediment noted. Three main types of disturbance were defined in these maps:

1. Areas mapped as entirely or predominantly bare soil. These were assumed to be areas of recent mass wasting or erosion.

2. Areas mapped as predominantly bare rock. These were assumed to have been stable for long periods of time, although it is possible they were subject to recent mass wasting or erosion.

3. Areas mapped as predominantly moss covered. These areas showed evidence of past mass wasting or erosion, but had been stable in recent years.

Only areas identified as entirely or predominantly bare soil were selected for further analysis. Within this category, five classes of disturbance were shown on the map:

1. Mass wasting sites larger than 100 m^2.

2. Mass wasting or erosion sites smaller than 100 m^2. These sites were depicted only with a symbol in the pre-harvest maps, and therefore may be any size <100 m^2. (Based on data from post-harvest erosion surveys, the average size of pre-harvest events was estimated at 30 m^2.)

3. Windthrow patches. Typically, 5–15% of the area was disturbed. An average of 10% of the windthrow patch area was assumed to be exposing sediment.

4. Windthrow areas larger than 100 m^2.

5. Windthrow areas smaller than 100 m^2. These sites were depicted only with a symbol in the pre-harvest maps, and therefore may be any size <100 m^2. (Based on data from post-harvest erosion surveys, the average size of these events was estimated at 16 m^2.)

In 1995 and 1999, observers conducted post-harvest surveys of disturbance from a helicopter flying slowly, and relatively low, in a grid pattern over the study areas. Locations of new disturbances were marked on the 1:2500 maps and later ground truthed. Size, sediment path, and disturbance type were recorded. Only sites that had not been marked on the previous surveys were included for the analysis. For sites that increased in size, the additional area was included in the appropriate survey.

Harvest Methods

Figures 2 and 3 show the layout of the study blocks and harvest treatments. For harvesting, the blocks were subdivided into five treatments:

1. A control area, with no harvesting.
2. A 25% single-tree-selection area.
3. A 25% group-selection area.
4. A 50% group-selection area.
5. A clearcut area.

The Gregory Block had two additional treatments:

1. A 15% single-tree-selection area. This 15% cut was not part of the original design, and is included in the control area for this analysis because the boundary between the two units is not well defined on maps.

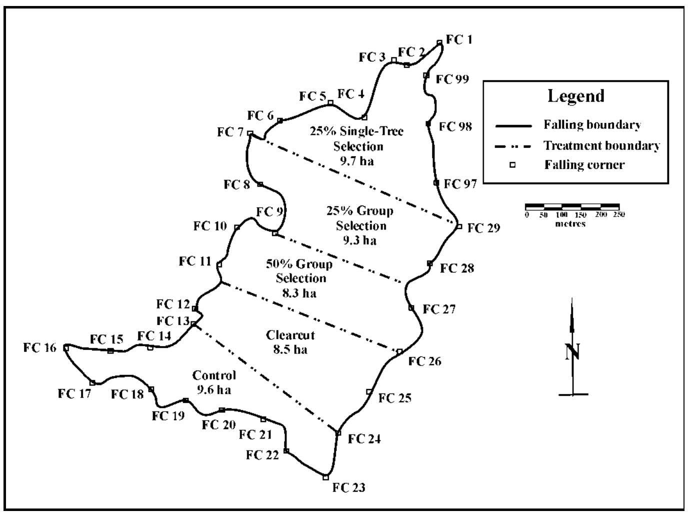


Figure 2. Treatment units in Hangover Block (after D'Anjou 2000).

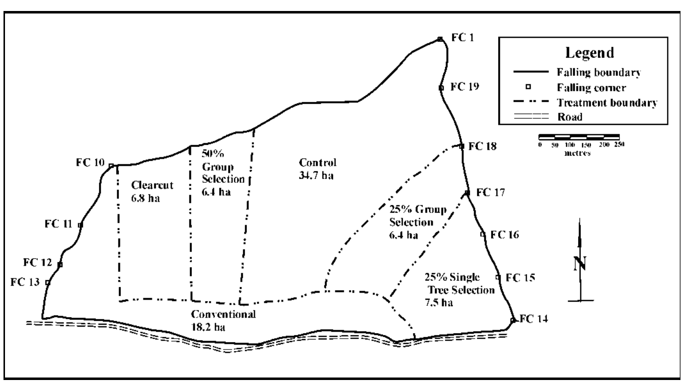


Figure 3. Treatment units in Gregory Block (after D'Anjou 2000). Note: The lower portion of the control has a 15% single-tree selection cut.

2. A conventional grapple-yarded clearcut on the lower, more stable slopes

In 1992, the timber was felled by crews experienced in selective harvesting, and a Sikorsky S-64E Skycrane yarded the timber to nearby roads. Harvesting and yarding are described in Krag 1998.

Evaluation of Pre-Harvest Terrain and Soil Disturbance

The 1:2500 terrain stability mapping (Maynard 1990 and 1991) can be used to characterize the landslide sensitivity of the terrain in each study block and in each treatment unit. Similarly, the soil-disturbance maps can be used to summarize the amount of pre-harvest soil disturbance. Table 1 shows the total amount of terrain in each stability class for each of the study blocks. Overall, the Gregory Block contains less hazardous terrain than the Hangover Block. Almost half of the terrain in the Hangover Block (43%) is either Class IV or Class V terrain, while at the Gregory Block, it is 31%.

Table 2 shows the amount of area in each terrain stability class by treatment. In general there is no clear pattern in the distribution of terrain stability classes between the different harvesting treatments, other than the tendency for the Control areas and helicopter-clearcut areas to have a greater proportion of Class V terrain.

Just over 2% of the Hangover Block incurred recent soil disturbance prior to harvesting, whereas 5% of the Gregory Block had recent soil disturbance prior to harvesting (Table 3). Large mass-wasting events were the largest component of soil disturbance in both of the cutblocks. The Hangover Block has incurred little soil disturbance as a result of windthrow, whereas pre-harvest windthrow in the Gregory Block constituted about one-quarter of the total soil disturbance. The top of the Gregory Block is adjacent to an older cutblock, and much of the windthrow in the Gregory Block is located adjacent to this older block.

The amount of soil disturbance varies considerably between treatment units in the two blocks (Table 4). In the Hangover Block, recent pre-harvest soil disturbance accounted for between 0.1 and 4.1% of the treatment area prior to harvesting. In the Gregory Block, recent soil disturbance accounted for between 1.2 and 9.3% of the treatment unit prior to harvesting. Although the Control units of both blocks had the greatest proportion of Class V terrain, the amount of recent soil disturbance was not the greatest here. In the Hangover Block, the Control area incurred only 0.1% recent soil disturbance prior to harvesting, while the Gregory Block Control unit incurred 6.7% and the helicopter-clearcut incurred over 9%. Thus it appears that the extent of Class V terrain was not necessarily associated with the extent of pre-harvest soil disturbance.

Post-Harvest Soil Disturbance

The 1995 and 1999 surveys identified only areas that were entirely or predominantly bare soil, and did not include areas identified in the previous surveys. Table 5 summarizes the overall results of the soil-disturbance surveys. The mass-wasting areas identified as <100 m^2 include areas of bare soil that resulted from falling and yarding disturbance as well as small mass-wasting events. In both of the study blocks, the amount of pre-harvest soil disturbance far exceeds the amount of post-harvest soil disturbance. In both the Hangover Block and the Gregory Block the total amount (1995 and 1999 results combined) of

Table 1. Terrain Stability Classes, and total area for each class, by study block (mapped at 1:5000).

Terrain Stability Class and description		Hangover Block ha	Hangover Block %	Gregory Block ha	Gregory Block %
I	No problems of instability expected.	2.3	5	2.9	4
II	No significant problems of instability expected.	11.4	25	34.2	43
III	Minor slumping and small debris slides expected along roads and following clearcutting.	12.2	27	18.3	23
IV	Low to moderate potential of road-associated landslides in certain areas of the polygon. The potential for significant landslides in clearcut areas is low, but minor debris slides are expected.	11.5	25	12.0	15
V	Moderate to high potential for landslides in certain areas of the polygon during and following road construction and following conventional clearcutting.	8.2	18	12.6	16
Total		45.5	100	80.0	100

Table 2. Terrain stability, by treatment.

Study block	Terrain Stability Class	Control ha	Control %	25% single-tree selection ha	25% single-tree selection %	25% group selection ha	25% group selection %	50% group selection ha	50% group selection %	Helicopter yard / clearcut ha	Helicopter yard / clearcut %	Grapple yard / clearcut ha	Grapple yard / clearcut %
Hangover	I	0.2	2	0.1	1	0.1	1	1.6	19	0.4	4	n.a	n.a
	II	2.8	29	2.5	26	2.6	28	2.2	26	1.3	16	n.a	n.a.
	III	2.0	20	3.3	34	3.1	33	1.4	17	2.4	28	n.a	n.a
	IV	2.0	22	2.3	24	2.9	31	1.7	20	2.4	29	n.a	n.a
	V	2.6	28	1.5	16	0.6	7	1.5	18	1.9	23	n.a	n.a
	Total	9.6	100	9.7	100	9.3	100	8.3	100	8.5	100	n.a	n.a
Gregory	I	0.4	1	0	0	0	0	0	0	0	0	2.5	14
	II	14.0	40	2.9	38	2.1	34	2.2	34	1.3	19	11.8	64
	III	6.2	18	4.0	53	2.0	32	1.3	20	2.3	34	2.4	13
	IV	4.5	13	0.6	9	1.7	27	2.5	39	1.4	21	1.2	7
	V	9.6	28	0.0	0	0.5	7	0.5	7	1.8	26	0.3	2
	Total	34.7	100	7.5	100	6.4	100	6.4	100	6.8	100	18.2	100

Table 3. Pre-harvest recent soil disturbance in Hangover and Gregory Blocks.

Type of soil disturbance	Hangover Block No. of sites	Hangover Block Area (m^2)	Hangover Block % of block	Gregory Block No. of sites	Gregory Block Area (m^2)	Gregory Block % of block
Mass wasting						
>100 m^2	13	9 210	2.0	37	31 980	4.0
<100 m^2	12	370	0.1	33	990	0.1
Windthrow						
Patches	0	0	0.0	11	2 945	0.4
>100 m^2	0	0	0.0	4	3 070	0.4
<100 m^2	14	230	0.1	43	670	0.1
Total	39	9 820	2.2	128	39 655	5.0

Table 4. Pre-harvest soil disturbance, by treatment.

Type of soil disturbance	Treatment					
	Control (m^2)	25% single-tree selection (m^2)	25% group selection (m^2)	50% group selection (m^2)	Helicopter / clearcut (m^2)	Grapple yard / clearcut (m^2)
Hangover Block						
Mass wasting						
>100 m^2	0	1 840	2 780	3 350	1 850	n.a.
<100 m^2	30	160	120	30	0	n.a.
Windthrow						
Patches	0	0	0	0	0	n.a.
>100 m^2	0	0	0	0	0	n.a.
<100 m^2	60	60	30	60	0	n.a.
Total	90	2 060	2 930	3 440	1 850	n.a.
% of treatment unit	0.1	2.1	3.2	4.1	2.2	n.a.
Gregory Block						
Mass wasting						
>100 m^2	19 530	1 670	1 020	2 230	5 640	1 890
<100 m^2	460	0	190	60	190	90
Windthrow						
Patches	2 325	460	0	80	0	80
>100 m^2	770	0	0	1 940	360	0
<100 m^2	200	50	80	90	110	140
Total	23 290	2 180	1 280	4 410	6 300	2 200
% of treatment unit	6.7	2.9	2.0	6.9	9.3	1.2

Table 5. Total soil disturbance: results of soil-disturbance surveys, by block.

Block	Pre-harvest survey		1995 survey		1999 survey	
	Area (m^2)	% of block area	Area (m^2)	% of block area	Area (m^2)	% of block area
Hangover	9 820	2.2	1 580	0.3	650	0.1
Gregory	39 650	5.0	3 340	0.4	5 540	0.7

post-harvest soil disturbance is about 22% of the pre-harvest amount.

After harvesting, mass-wasting events continued to be a major component of soil disturbance in both study blocks. Windthrow became a significant soil disturbance factor in the Hangover Block, whereas the Gregory Block has experienced little post-harvest windthrow. Between 1995 and 1999, the Hangover Block shows a reduction in the amount of post-harvest soil disturbance, whereas it increased in the Gregory Block. This increase is the result of one 3520-m^2 landslide that occurred in the Control area of the block (but not part of the 15% single-tree selection). If this slide is excluded from the 1999 results, then the Gregory Block also shows a reduction in soil disturbance from 1995 to 1999. Thus it appears that the majority of the post-harvest soil disturbance occurred within the first three years after harvesting.

Table 6 shows that the amount of post-harvest soil disturbance is generally a small fraction of the recent pre-harvest soil disturbance. In both cutblocks, most treatment units had about 0–20% additional post-harvest soil disturbance. One exception to this average was the control unit of the Hangover Block, where a small amount of pre-harvest soil disturbance, coupled with a moderate amount of additional post-harvest soil disturbance, almost tripled the amount of soil disturbance. The con-

Table 6. Post-harvest soil disturbance, by treatment.

Type of soil disturbance	Treatment					
	Control (m^2)	25% single-tree selection (m^2)	25% group selection (m^2)	50% group selection (m^2)	Helicopter / clearcut (m^2)	Grapple yard / clearcut (m^2)
Hangover Block						
Mass wasting						
>100 m^2	0	400	0	0	0	n.a.
<100 m^2	0	0	20	0	190	n.a.
Windthrow						
Patches	0	0	350	0	0	n.a.
>100 m^2	250	0	120	100	0	n.a.
<100 m^2	10	20	60	110	0	n.a.
Total	250	420	550	210	190	n.a.
% of area (1990 results)	0.3 (0.1)	0.4 (2.1)	0.6 (3.2)	0.3 (4.1)	0.2 (2.2)	n.a.
Post-/pre-harvest ratio	2.8	0.2	0.2	0.1	0.1	n.a.
Gregory Block						
Mass wasting						
>100 m^2	4270	0	470	0	590	3070
<100 m^2	390	0	210	10	440	210
Windthrow						
Patches	0	0	0	0	0	0
>100 m^2	0	0	0	0	0	0
<100 m^2	50	0	0	40	0	0
Total	4700	0	680	50	1030	3280
% of area (1990 results)	1.3 (6.7)	0 (2.9)	1.1 (2.0)	0.1 (6.9)	1.5 (9.3)	1.8 (1.2)
Post-/pre-harvest ratio	0.2	0	0.6	0.0	0.2	1.5

ventionally harvested clearcut unit of the Gregory Block had post-harvest soil disturbance of 1.5 times the amount of pre-harvest soil disturbance, which was the highest ratio for any of the harvested treatments. About half of the post-harvest soil disturbance (1610 m^2) in the conventional clearcut was the result of one debris flow. As well, the 25% group-selection treatment in the Gregory Block had a higher-than-average increase in soil disturbance after harvesting. However, both the pre- and post-harvest amounts were small, and therefore this is not a very significant result.

DISCUSSION

Soils on upper and mid slopes in the QCI disturbed by landslides are usually dominantly revegetated within about 25 years (Smith et al. 1986). The 1990 and 1991 map areas that are shown as dominantly bare soil are assumed to be areas of recent erosion, and are therefore assumed to be generally less than about 25 years old. However, the amount of pre-harvest soil disturbance is about five times the amount of post-harvest soil disturbance (Table 5). Almost a decade has passed between the first soil-disturbance mapping and the 1999 survey. If pre- and post-harvest rates of erosion were similar, this would suggest that the pre-harvest mapping of bare soil areas actually records about 50 years of erosion. It may be that many of these sites that were assumed to be recent erosion are actually much older and maintain a constantly ravelling, bare soil surface. An alternative explanation is that one or more severe events occurred a short time prior to the surveys, and that elevated rates of erosion occurred prior to harvesting. For example, the 1978 storm event in Rennell Sound may account for much of the recent landslide scars in the area (Schwab 1983).

There is no clear relationship between increased soil disturbance and area harvested. If this was the case, the control units would have the smallest increase in the amount of post-harvest soil disturbance, the clearcut units would have the largest increase in the amount of post-harvest soil disturbance, and the single-tree selection and group-selection areas would have an intermediate amount of post-harvest soil disturbance. However, the data suggest otherwise. The helicopter-clearcut treatment units had the greatest amount of combined Class IV and V land of all of the units (including the control units) and yet they had some of the lower post-harvest/pre-harvest soil-disturbance ratios. However, the amount of soil disturbance in the conventionally yarded clearcut in the Gregory Block had the greatest amount of post-harvest soil disturbance of any of the treatments, despite having a very low percentage of Class IV and V terrain. This suggests that the helicopter harvesting was successful in reducing yarding-related soil disturbance.

There is no clear relationship between the amount of windthrow and the treatment type. Clearcuts obviously do not incur windthrow, except at their edges. In the Hangover Block, the various group-selection treatments incurred approximately equal amounts of windthrow, while the single-tree selection area incurred almost no windthrow. Interestingly, the most post-harvest windthrow occurred at the Hangover Control. In the Gregory Block there was almost no post-harvest windthrow in any of the treatment units.

The landslide in the control area of the Gregory Block comprised 40% of the block's post-harvest erosion and was the largest pre- or post-harvest mass-wasting event that predominantly exposed soil. Yet, relative to most forestry landslide events, this was not a large event. Rood (1990) reports an average open-slope, debris-slide volume of 1450 m^3 in the QCI. Assuming an average depth of 0.3 m, this results in an average area of 4800 m^2, which is considerably larger than the 3520-m^2 event in the Gregory Block. Thus if additional landslides occur, they are likely to change the results of this study significantly.

The post-harvest results cover only the first seven years after harvesting. Post-harvest landslides typically occur up to 15 years after harvest, and therefore the results of this study must be regarded as preliminary. An additional survey of the study areas should be done sometime between 2005 and 2007.

The low amount of post-harvest erosion indicates that helicopter yarding of these cutblocks has been successful at maintaining natural rates of erosion on these steep slopes up to this point in time. The amount of tree removal—whether 25% from single-tree selection or group selection, or 100% from clearcutting—does not seem to have affected the amount of erosion.

CONCLUSION

In 1990, under the Fish/Forestry Interaction Program (FFIP), a study was initiated in the Queen Charlotte Islands to examine and evaluate the erosion and mass-wasting responses of steep, unstable slopes to combinations of various silvicultural systems with helicopter yarding.

The two study blocks were terrain mapped with soil-disturbance surveys prior to being harvested in 1992. Soil-disturbance surveys were repeated in 1995 and 1999. The results show that the amount of soil disturbance that occurred from 1990 to 1999 is about 22% of that present prior to harvesting. It is not known whether the amount of soil disturbance surveyed in 1990 represents several decades of erosion, or whether it reflects one or more extreme events in more recent years such as the storm event of 1978.

The silvicultural treatments that were harvested by helicopter did not reveal any significant differences in soil disturbance. The one clearcut treatment area that was grapple yarded had the greatest amount of post-harvest soil disturbance.

Windthrow does not appear to be affected by treatment type.

The amount of post-harvest erosion may change if one or more large storms occur within approximately the next decade, before tree root strength has recovered significantly. An additional survey of the cutblocks should be done between 2005 and 2007.

ACKNOWLEDGEMENTS

Funding for this research was provided initially by the Fish Forestry Interaction Program (FFIP) and later by the South Moresby Forest Replacement Account (SMFRA). The authors would like to thank Alan Phillip for his field work and mapping assistance and Greg Wiggins for the administration of SMRFA funds that allowed the completion of this study.

The South Moresby
Forest Replacement Account

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