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CABLE LOGGING DISTURBANCE ON AN UNSTABLE SLOPE : A CASE STUDY

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Figure 1 - The slopes of the cable logged setting, showing mid-span ridges

ABSTRACT

Disturbance assessment on an unstable slope in Mangatu Forest showed that deep disturbance caused by uphill cable logging occurred predominantly on mid-span ridges. LoggerPC analyses indicated that ground hauling was the likely cause, and predicted that rigging tail trees would not ensure partial drag suspension over these ridges.

Disturbance caused by cable logging was compared with skidder logging disturbance in an adjacent setting. Cable extraction caused less deep disturbance and was less likely to cause accelerated slope erosion than skidder extraction.

INTRODUCTION

Logging on unstable slopes in Mangatu Forest, East Cape challenges harvest planners and logging contractors to minimise site disturbance that accelerates slope erosion. Long convex slopes, with a hummocky relief (Figure 1), are common throughout the forest, often resulting in inadequate deflection for cable logging systems (Saunders 1992). In addition, many of these slopes are prone to slip and flow failures (Pearce and Gage 1977).

Previous research at Mangatu indicated that surface soils influence slope stability by reducing the chemical and physical weathering of underlying materials (Gage and Black 1979; Black 1981). Slope instability can result where deep weathering weakens the mudstones, limestones and sandstones of the Mangatu and Tikihore Formations.

Trials performed at Mangatu in 1984, assessed site disturbance caused by a FMC FT180 low-ground-pressure skidder (Bryan, Gaskin, and Phillips 1985). The logging trial site comprised a 3.9 ha block of 15 year old radiata pine, with an unlogged control on each side (Figure 2a).

In 1994, cable logging in a similar setting immediately to the east of the FMC trial (Figure 2b) allowed comparison of disturbance caused by the two extraction systems.

The objectives of this study were to:

- quantify logging disturbance caused by uphill cable extraction
- relate the disturbance to the landform shape and the logging system
- compare the disturbance caused by uphill cable extraction with downhill skidder extraction.

This report details the study of the cable logged setting, and discusses the effects of cable and skidder extraction on unstable slopes.

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STUDY AREA

The 6.9 ha cable logged setting was on a north facing upper slope segment, with an estimated mean slope of 17°. These slopes occur on highly fractured muddy sandstones of the Tikihore Formation.

Mapping of terrain stability by Gage and Black (1979), and Bryan *et al.* (1985) showed that the upper slopes, close to Airstrip Road, comprise inactive earthflows and slumps, with moderately to well-drained soil. Lower on the slopes, active earthflows, slumps and eroding gullies were evident within hummocky depressions. They are flanked by small ridges orientated downslope, as shown in Figure 3, taken at Mangatu Forest prior to planting. Typically, the soils in the

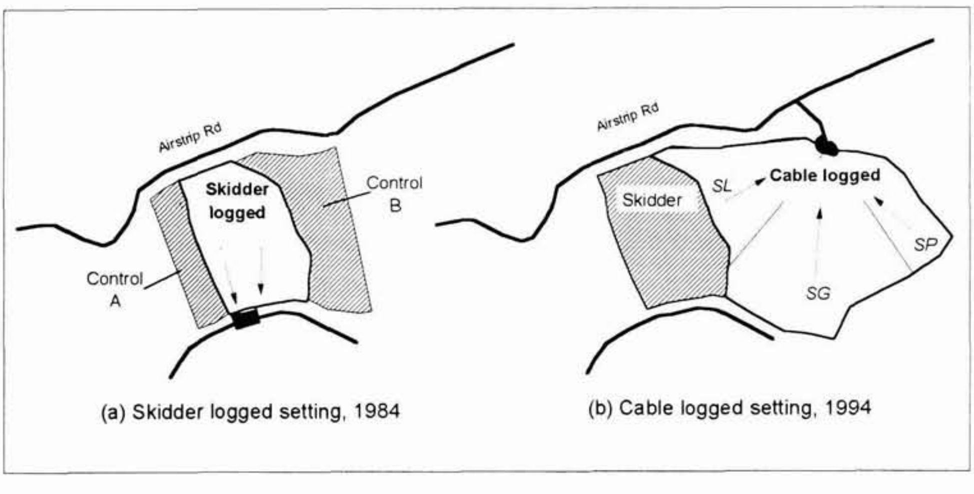

Figure 2 - The relative locations of the skidder logged and the cable logged settings. The dashed arrows indicate the extraction directions. The areas logged by the three cable systems are also indicated: SL - slackline, SG - shotgun, SP - slackpuller

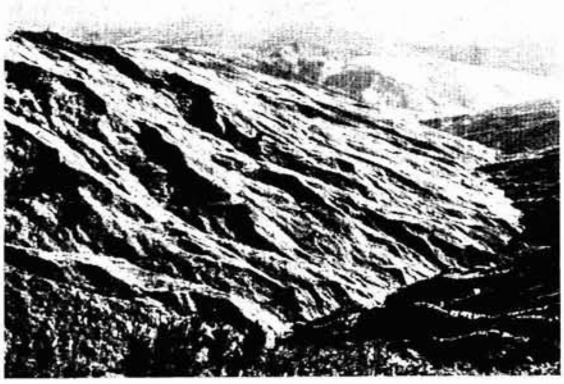

Figure 3 - Mangatu Forest landscape before planting (Photo: M. Gage)

depressions are poorly to very poorly drained and waterlogged.

The cable logged stand was radiata pine, planted in 1969 and managed to a final stocking of 300 stems/ha. Mean stand volume was 643 m^3/ha, equating to a mean tree volume of 2.1 m^3. Mean tree height was 33 m, and the mean diameter at breast height was 42 cm.

During September 1994, the study area was felled and tree lengths were extracted uphill to the landing by a Madill 171 hauler. Three skyline systems were used for the setting: a Maki slackpulling carriage with a haul back line, a shotgun carriage system, and slackline using a two sheave carriage. A tractor was used for the skyline tailhold. Trimming and delimbing were carried out in the cutover.

METHODS

Site Disturbance Assessment

Disturbance within the cable logged setting was assessed using the point transect method of McMahon (1995). Setting and landing areas were measured from a GPS plot using DIGI software.

Assessment involves the classification of disturbance at points located every one metre along transects, using the classes shown in Table 1. Transects are orientated perpendicular to the dominant extraction direction, and are spaced at 30 m intervals, from the landing to the back of the setting. The percentage of each disturbance type was determined by the proportion of the total number of observations. Combining the disturbance types (Table 1), allows calculation of the percentages of undisturbed, shallow disturbance, deep disturbance, slash, non-soil, and compaction.

Error limits ($P<0.05$) are calculated for each disturbance class result using the following equation (Murphy 1977):

$$\%\text{occurrence} \pm 2\sqrt{\frac{\%(100-\%)}{n}}$$

The error limit indicates the likely error based on the percentage of similar observations (%), and the total number of observations made (n) .

Extraction Profiles and Disturbance Strip Maps

The terrain shape differed in the areas logged using the slackpuller, shotgun and slackline systems (Figure 2b). In each area, a profile along the line of extraction was measured using a hip chain and clinometer.

Mapping of a five metre wide strip along each profile identified the location of the landing surface, log waste, slash, and deep disturbance.

Payload Analyses

Oregon State University and the United States Department of Agriculture developed LoggerPC (version 3.0) computer software to predict payloads for cable logging systems. Typically, analyses are performed using system and machine specifications, across specific extraction profiles. Key parameters include tower and tailhold heights, rope dimensions, and carriage weight.

Table 1 - Disturbance classification scheme of McMahon (1995). The disturbance classes (shown in bold) are defined by the individual disturbance types and corresponding codes below

Disturbance Class Disturbance Type	**Code**
Undisturbed	
no evidence of machine or log passage, litter intact	1
Shallow disturbance	
litter in place	2
litter removed	3
litter and topsoil mixed	4
>5 cm topsoil on litter	5
Deep disturbance	
topsoil removed	6
erosion feature	7
subsoil puddled	8
rutted	
5-15 cm	9
16-30 cm	10
>30 cm	11
unconsolidated subsoil/base rock deposit	12
Slash/understorey residue	
10-30 cm	13
>30 cm	14
Non-soil (stumps, rocks)	15
Clarifiers	**Code**
Compacted	C
Mineral/sub soil	M

LoggerPC also has the capability to predict ground hauling or partial drag suspension. Partial drag suspension occurs when the strop attachment point on the log is at or above some specified height above the ground. For the payload analyses, this height was entered as 0.5 m.

When the payload prediction gives a zero result for a terrain point, then the 0.5 m partial suspension cannot be achieved. Any drag passing through that terrain point would be ground hauled, resulting in ground disturbance.

LoggerPC also predicted the payload result if trying to increase drag lift by rigging to a five metre tail tree.

RESULTS

Setting Disturbance Assessment

The landing area measured 0.43 ha.

The assessment of the 6.9 ha setting was completed in eight hours, with disturbance classified at 2170 sampling points. The disturbance results for the cable logged setting are shown in Table 2.

Shallow disturbance occupied 62% of the setting, mainly comprising disturbance of the litter layer, and mixing of litter and topsoil (Codes 2 and 4, Table 1, respectively). Twelve percent of the setting was deeply disturbed, being almost exclusively topsoil removed (Code 6, Table 1). Creation of ruts, puddled

Table 2 - Percentage disturbance classes and error limits (P<0.05) for the cable logged setting, Compartment 35, Mangatu Forest

Disturbance class	Percentage disturbance for the cable setting (%)
Undisturbed	6 ± 1
Shallow disturbance	62 ± 2
Deep disturbance	12 ± 1
Slash	13 ± 1
Non-soil	7 ± 1
	100%
Compacted	1± 1

subsoils, and unconsolidated subsoils accounted for 3% of the setting area. Slash covered 13% of the setting. Only 1% of the setting was compacted, these areas occurring where topsoil had been removed.

Extraction Profiles and Disturbance Strip Maps

Extraction profiles and associated disturbance strip maps for the three areas are shown in Figure 4 (a) to (c). The strip maps show the location of the landing surface, log waste, and bench track relative to disturbance along the profile.

The slackpulling carriage was used on concave slopes. On the extraction profile (Figure 4a), shallow disturbance predominated. Minor deep disturbance did occur below the landing, where there was a benched access track and a small naturally formed rise. Slash was uniformly distributed along the profile.

Ridges and depressions orientated downslope - similar to those shown in Figure 3 - were a feature of the area logged using the shotgun system. The extraction profile angled downslope, crossing one of these ridges. This ridge can be seen mid-span on the extraction profile (Figure 4b). Deep disturbance along the profile was most evident on the top of this ridge. Rather than occurring as discrete ruts, the deep disturbance was more widespread covering the entire ridge. Thick slash was only seen in the depressions upslope of the ridge. Below the ridge, towards the tailhold, slash was more uniformly dispersed.

Extraction by the slackline system was predominantly across the slope, near the top of the setting. Unlike on the lower slopes, waterlogged depressions were less common. Deep disturbance on the tailhold sides of the ridges occurred as discrete ruts (Figure 4c). In contrast, slash tended to accumulate on the landing side on the ridges, and within the depressions.

Payload Analyses

For the three extraction profiles and logging systems, payloads were predicted using LoggerPC. Two scenarios were used: a tractor tailhold (actually used), and a tail tree rigged at five metres above the ground.

Using the slackpuller, partial suspension could be achieved over most of the span, with ground hauling occurring within 20 m of the tailhold. However, when using a tail tree, partial suspension would occur, with a minimum payload of approximately six tonnes.

Prediction of payloads for the shotgun system over the second profile indicated

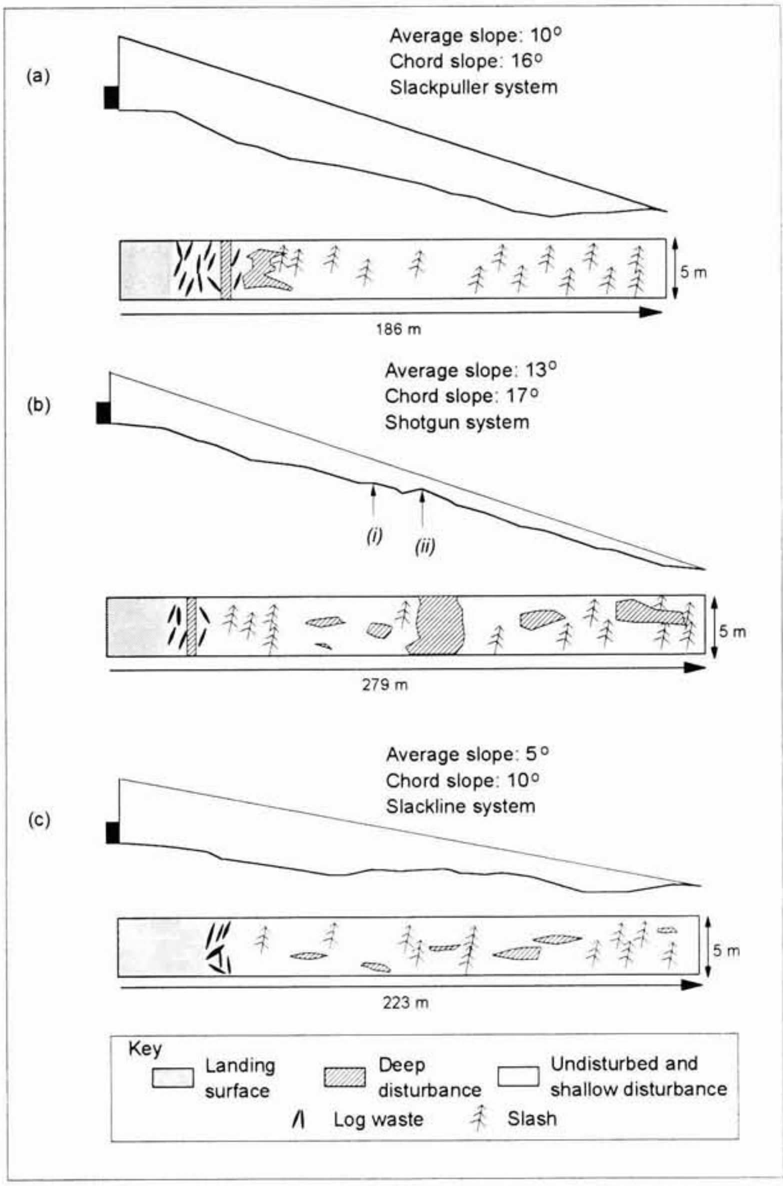

Figure 4 - Extraction profiles and disturbance strip maps for the three areas logged using a different system

ground hauling downslope from the mid-span ridge (Figure 4b, point (*i*)). No significant additional lift over this part of the span resulted from using a tail tree. However, the portion of the span where partial suspension was achievable increases marginally downslope (Figure 4b, point (*i*) to (*ii*)).

Using the slackline system and tractor tailhold, partial suspension could not be achieved within the last 40 m of the span. However, the increased lift using a tail tree does allow partial suspension, with a minimum payload of approximately five tonnes.

DISCUSSION

Cable Logging Disturbance

Twelve percent of the setting exhibited deep disturbance resulting in subsoil exposure (Table 2). Most of this disturbance occurred on the top of mid-span ridges in the area logged using the shotgun system. These were areas where LoggerPC predicted that ground hauling occurred. This was because of the short distance between the chord slope and the ground surface over the lower part of the span (Figure 4b), resulting in inadequate drag lift. In addition, LoggerPC predicted that a 5 m tail tree was unlikely to result in partial suspension over the mid- to lower-span.

Cable and Skidder Extraction

Comparison of disturbance caused by cable logging with the previous disturbance results of Bryan *et al.* (1985), showed that skidder logging of the 15 year old stand caused more disturbance than cable logging of the 25 year old stand (Figure 5).

The results shown in Figure 5 differ from those shown in Table 2, as a different disturbance classification was used for the skidder logging assessment. However, reinterpretation of the disturbance type results for the cable logged setting, using the disturbance classes of Bryan *et al.* (1985), does allow comparison of the two.

Skidder logging caused significantly more light and severe disturbance compared to cable logging. Slash covered more of the skidder logged setting, reflecting the greater stocking in this setting (624 versus 300 stems/ha).

The differences in stand ages and stocking levels are likely to have contributed to the differences in the disturbance results. Despite these factors, there remained two overriding differences in the nature of disturbance caused by the two logging systems.

First, the location of deep disturbance differed in the two settings. Within the cable logged setting, deep disturbance occurred on the tops of the mid-slope ridges. In contrast, skidder logging resulted in deep disturbance within unstable slope depressions, primarily along the skid trails.

Second, the deep disturbance in the skidder logged setting was more continuous than in the cable logged setting. These two points are illustrated in Figure 6, which shows the skid trail pattern and areas of active instability.

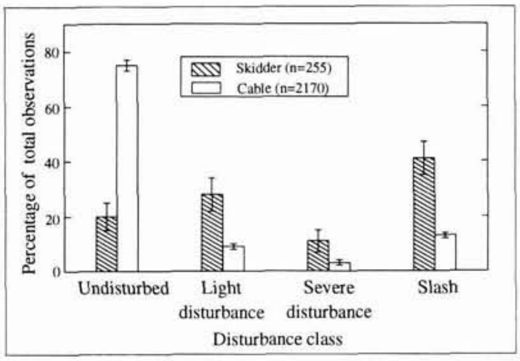

Figure 5 - Comparison of cable and skidder logging disturbance

Skidder extraction aimed to avoid travelling over unstable soils in the depressions. However, unstable areas could not be entirely avoided as they allowed access to the upper portions of the setting. This is most evident on the western side the setting (Figure 6).

Deep disturbance along skid trails can channel runoff. This is more pronounced where skid trails are orientated, and are continuous downslope. Figure 6 shows that access from the cutover led directly on to the landing area. At the time of logging, runoff and mud from the cutover tended to flow down this trail on to the landing area, posing problems for processing and truck access (Bryan *et al.* 1985).

The downhill skidder extraction pattern necessitates the installation and maintenance of adequate drainage control after logging is completed. This will reduce erosion of the skid trail surfaces and the access road below. This type of remedial work is not required in the cable logged setting, as the deep disturbance was unlikely to channel runoff, and cause erosion.

Planning Considerations

Two factors controlling site disturbance on the cable logged setting were the terrain shape and logging system characteristics. The LoggerPC programme effectively demonstrated ground hauling on the mid to lower-slopes. Furthermore, the

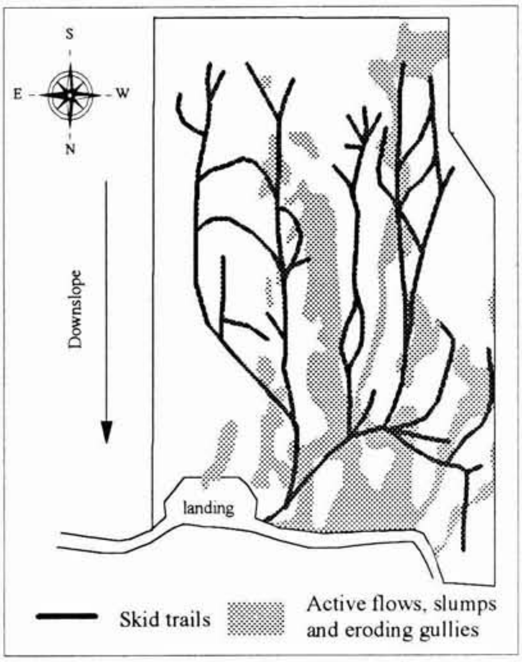

Figure 6 - Skid trail pattern, and terrain stability in the skidder logged setting (after Bryan et al. 1985)

feasibility of alternative logging systems can be assessed using LoggerPC. These alternatives include the use of different tower heights, carriages, tail trees, and intermediate skyline supports.

Accurate terrain information is necessary when planning to minimise site disturbance. In this study, detailed slope profiles drawn in the field, showed the presence of the mid-slope ridges. The recognition of these ridges was important because most of the deep disturbance occurred here. For instance, using 1:5000 or 1:10000 topographic maps to draw extraction profiles would not have identified these features.

CONCLUSIONS

Site disturbance assessment on an unstable slope in Mangatu Forest, showed that the predominant disturbance class in an uphill cable logged setting was shallow disturbance (62%). Deep disturbance (12%), resulting in topsoil removal, occurred mainly on mid-span ridges.

LoggerPC software evaluated the effects of three cable systems on drag suspension and payloads. Relating drag suspension with disturbance along extraction profiles, showed that ground hauling was the cause of the deep disturbance. Furthermore, LoggerPC predicted that partial drag suspension over these ridges would not occur when anchoring the skyline to a five metre high tail tree.

Comparison of the uphill cable logging disturbance with that caused by skidder logging in an adjacent setting, showed that cable extraction caused less deep disturbance. Deep disturbance in the cable logged setting occurred on stable ridge tops, and was discontinuous. Therefore, uphill cable logging is less likely to cause runoff and accelerate erosion, relative to downhill skidder extraction.

REFERENCES

Black, R.D. (1981) : "Upper Cretaceous and Tertiary Geology of Mangatu State Forest, Raukumara Peninsula, New Zealand." New Zealand Journal of Geology and Geophysics 23: 293-312.

Bryan, D.G., Gaskin, J.E., Phillips, C.J. (compilers) (1985) : "Logging Trials - Mangatu State Forest, East Coast, New Zealand." Logging Industry Research Association Report, 64p.

Gage, M. and Black, R.D. (1979) : "Slope Stability and Geological Investigations at Mangatu State Forest." New Zealand Forest Service, Forest Research Institute Technical Paper 66: 37p.

McMahon. S. (1995) : "Survey Method for Assessing Site Disturbance." LIRO Project Report 54, Logging Industry Research Organisation, Rotorua, 16p.

Murphy, G. (1977) : "Activity Sampling - A Handy Work Study Tool for Forestry." New Zealand Forest Service, Forest Research Institute, Production Forestry Division, Economics of Silviculture Report No. 102. 11p.

Saunders, H. (1992) : "Case Study of Planning: Mangatu Forest, Who got it right". In: Smith, M. (ed) Harvesting and Re-establishment of Difficult Terrain. Proceedings of a Seminar held in Hastings and Gisborne, June. Logging Industry Research Organisation, Rotorua.

Pearce, A.M. and Gage, M. (1977) : "Landscape Zoning, Erosion Control and Forest Management." What's New in Forest Research 55, New Zealand Forest Research Institute, Rotorua, 4p.

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