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ARTICLES

Vegetation recovery and indicative sediment generation rates by sheetwash erosion from hauler-logged settings at Mangatu Forest

M. Marden and D. Rowan¹

ABSTRACT

Soil disturbance, vegetation recovery and sediment generation by sheetwash erosion on hauler-logged settings were evaluated at Mangatu Forest. Three disturbance indices were recognised: undisturbed, shallow disturbance and deep disturbance. The latter is here referred to as areas of exposed mineral soil (EMS). Groundcover vegetation recovery was slowest on sites of EMS. Based on plot-sized areas (9 m²), EMS per cent cover averaged 31%, two years after clearfelling. Setting-based measurements showed that overall groundcover recovery was rapid, and resulted in an 83% reduction in areas of EMS within two years of clearfelling.

Mean rate of sediment generation from areas of EMS averaged 11 (SE 3.5) kg/m² for the first year and 4 (SE 2.4) kg/m² during the second year after logging. Annual rates of sediment generation from areas of EMS on logged setting were 8 (SE 2.5) tonnes/ha in year one and one (SE 0.5) tonne/ha in year two. Most sediment mobilised from areas of EMS was relocated on slopes immediately downslope of source areas, where it was effectively entrapped by surviving groundcover vegetation and slash and in microtopographic hollows. Only those riparian areas of EMS with a direct connection to a watercourse contributed much sediment to stream channels, from which 2 (SE 0.6) tonnes of sediment per hectare of logged setting was generated in the first year after logging, declining to 0.2 (SE 0.1) tonnes/ha within two years. Sediment generated by sheetwash erosion from logged settings one year after clearfelling was at least several orders of magnitude less than that generated from non-forestry-related sources, especially gullies; it was not there-

fore particularly significant, given the high background rates of sediment production within Mangatu Forest. Similar amounts of forest-related sediment entering streams where background rates of sediment production are low would, however, be regarded as unacceptable. It would be advantageous for the forest industry to minimise soil disturbance and consequent sediment production from hauler-logged settings, particularly within 10 m of stream channels.

INTRODUCTION

The clearance of indigenous forest from unstable hill country of the North Island's East Coast 70-100 years ago to provide pastureland heralded the beginning of a period of accelerated erosion. The principal sediment-producing mechanisms were mass movement (e.g. slumps and earthflows) and gully erosion. Within three decades major stream channels had become severely aggraded, thus increasing the risk and severity of flooding. With erosion control as the primary objective, much of this hill country has, since the early 1960s, been reforested with exotic conifers, principally *Pinus radiata*. Slope stability research undertaken in the East Coast Region clearly shows that reforestation has greatly reduced the rate of slope erosion through the combined processes of root reinforcement of soil, canopy interception of rainfall, and extraction and utilisation of soil moisture. The net effect is increased soil strength and enhancement of slope stability (Pearce *et al.* 1987). As a consequence, sediment delivery to stream channels by mass movements has declined significantly, although gullies continue to be the major contributor of substantial volumes of sediment, and account for the high background rates of sediment yield in this region today.

Harvesting of these forested areas commenced in 1990, renewing fears that forest removal would result in the reactiva-

¹ Manaaki Whenua – Landcare Research, P.O. Box 445, Gisborne.

tion of movements on a scale similar to that at the time of the clearance of the indigenous forest. In addition to these concerns, the introduction of the Resource Management Act (1991), with its emphasis on protection of the environment and on "effects" of activities, has once again turned the spotlight on the East Coast forests and on those whose responsibility it is to harvest forests on erosion-prone terrain while avoiding or mitigating undue on-site and off-site impacts on the environment.

The timing and incidence of new and reactivated pre-existing mass movement features associated with clearfelled slopes in Mangatu Forest are currently the focus of ongoing investigations by Landcare Research. Mass movement processes (e.g. slumps and earthflows) and their associated potential for greatly accelerating sediment delivery to streams, particularly between forest rotations, will be the subject of future papers.

An aim of this paper has been to establish the relative order-of-magnitude contribution of sediment generated from hauler-logged settings by sheetwash erosion for comparison with that generated from non-forestry-related point sources, especially gullies.

This paper assesses the on-site impact of hauler logging on rates of groundcover regeneration and its consequences for sediment production rates and sediment mobility. Conclusions are drawn on indicative sediment yields to streams by sheetwash erosion processes from areas of deep site disturbance where mineral soil was exposed during the harvesting operation.

METHOD

Site selection was dictated by the availability of simultaneously logged hauler settings at the time of initiating this study. Using the disturbance classification scheme of McMahon (1995) three site disturbance classes were identified:

- 1) Undisturbed Groundcover vegetation flattened but otherwise unaffected by logging operations; litter layer and topsoil intact
- 2) Shallow disturbance Some surviving grasses/weeds; needle litter removed or reworked; topsoil scarified but largely intact
- 3) Deep disturbance No surviving vegetation; surface soil removed to expose parent materials (e.g. colluvium or bedrock); these sites are referred to in this paper as areas of exposed mineral soil (EMS)

For each site disturbance class a single pegged plot 9 m² (subdivided into m² subplots) was established on each of four different logged areas (settings) immediately following harvesting, giving a total of 12 plots. For each plot the amount and type of surviving groundcover vegetation was assessed at the time of installation and then at approximately six-weekly intervals for a period of two years. Analysis of vegetation recovery within plots was by an abundance/sociability technique developed by Blanquet (1974), whereby the four corner subplots and the central subplot are analysed in detail. For each subplot all the species present, their relative abundance, and average height were recorded and the percentage of vegetation cover was assessed.

The data were transformed using an arcsine function before analysis by repeated measures analysis of variance (ANOVA).

It was apparent that of the undisturbed and shallow disturbance classes, sediment could be generated only from the latter, and that even in the short term the small volumes likely to be produced would not mobilise downslope for any great distance before being entrapped by surviving groundcover vegetation. Thus, in keeping with the aim of this paper, we elected to monitor sediment generation rates from sites of deep disturbance (EMS) only, as we considered these most likely to generate the greatest volumes over time.

Two of the four plots located on sites of EMS were framed on all four sides with timber to double as runoff plots. A trough constructed at the lower end of each plot was lined with roading fabric that allowed surface runoff from the plot to dissipate while

trapping all except the finest-grained sediment fraction. The uppermost side of each of the two sediment traps was located on the spine of midslope ridges where drainage from upslope of the traps was unlikely to enter them, and where site disturbance as a result of ground leading ('dragging') was most severe. Sediment samples were collected from runoff plots at irregular intervals over a two-year period, oven-dried, weighed and used to calculate volume and rate of sediment production from areas of EMS. Following a heavy rainfall event sediment was collected from one runoff plot, weighed and wet sieved (NZS 4402: 1986) to determine the range of particle sizes dislodged and mobilised from EMS sites during an event of known magnitude and frequency. Results from these runoff plots are indicative only, and are used here to establish relative order-of-magnitude sediment generation rates from hauler-logged settings for comparison with background rates.

EMS sites are visible on low-altitude aerial photographs at <1:5000 scale. Sequential photographs were taken of each logged setting at approximately yearly intervals. Within each logged setting areas of exposed mineral soil were measured over consecutive years using a dot grid. Undisturbed and shallow disturbance sites were not measured separately. EMS sites with direct connection to a watercourse were measured separately.

Soil pits were excavated at each plot site and their profiles were measured and described. Site aspect and slope angle were recorded.

SITE DESCRIPTION

Plots were all located on terrain of stability type 5 (Gage & Black 1979), the most widespread type (48% of total forest area) within Mangatu Forest. This terrain is characterised by the presence of recently active but shallow earthflows and moderately deep slumps in parent material of Cretaceous to Paleocene age. Typically this terrain can be described as having 'hump' and 'hollow' microtopography. Logged settings studied here are all located within first-order catchments where streams are predominantly ephemeral.

It was not the intention of this study to cover the full range of slope angles, slope aspects or soil types. The mean slope of the plots was 24° but ranged between 20° and 33°. The two sediment traps were located on a northwest- and a south-facing slope.

The East Coast Region has a history of extreme river floods, often resulting from large rainfall events of high intensity. At least one extreme flood-producing storm in the Waipaoa Catchment area is expected each decade (Kelliher *et al.* 1995). The last extreme event occurred nine years ago.

Soils are Orthic Recent Soils, and are typical of land that was being eroded or has received sediment deposited mainly as a result of slope processes (Hewitt 1992), and correlate with the Inceptisols of soil taxonomy (Soil Survey Staff 1992).

Before harvesting, the settings consisted of 30-year-old *Pinus radiata*.

RESULTS AND DISCUSSION

(a) Plot-based vegetation recovery

There was very strong evidence that vegetation recovery was different for the three disturbance classes ($F_{28,56} = 5.08$, $p < 0.0005$). The vegetation on undisturbed plots recovered the quickest, increasing from an average of 14% immediately following logging to 89% within one year, and had fully recovered within two years of clearfelling (Fig. 1). Shallow disturbance plots also recovered rapidly, increasing from an average of 5% at the time of logging to 73% in the first year and to 97% after two years (Fig. 2). There is no evidence that the rates of recovery for undisturbed and shallow disturbance differ ($F_{1,4} = 0.09$, $p > 0.5$). Recovery was due largely to rampant germination, particularly where the soil had been slightly scarified.

In contrast, there was evidence that the rate of recovery was slower for areas of EMS than for the other two disturbance classes ($F_{1,4} = 18.16$, $p < 0.05$). Vegetation on EMS plots

increased from zero cover immediately following logging to 21% after one year and 31% after two years (Fig. 1). Recolonisation of areas of EMS was slowest because the parent material had little moisture storage capacity, and such sites are subject to extremes of temperature. As a consequence, seedling mortality on these sites was high, particularly during summer. In addition, seedlings tended to be undermined by raindrop impact during heavy rainfall events.

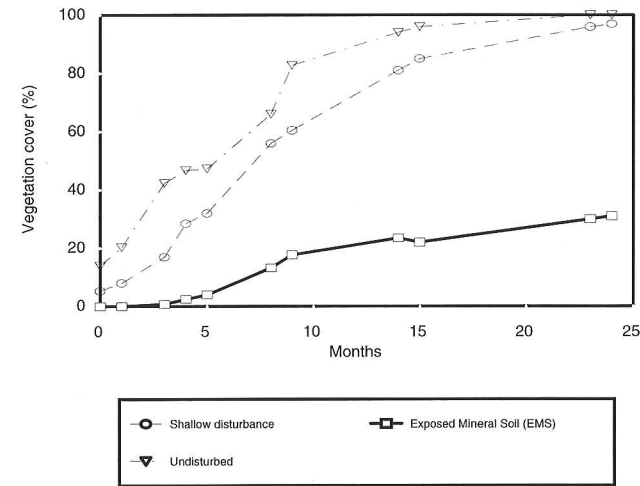


Figure 1. Plot-based rates of groundcover vegetation recovery on hauler-logged settings, Mangatu Forest.



Figure 2: An example of vegetation recovery on a partially-disturbed plot. The view above was taken immediately following clearfelling of 30-year-old *Pinus radiata* by haulers. The view below is the same plot two years after clearfelling. The dominant early colonisers of the plot were sweet vernal (*Anthoxanthum odoratum*), sorrel (*Rumex acetosella*), scotch thistle (*Cirsium vulgare*) and Yorkshire fog.



Early colonisers common to all the plots were sorrel (*Rumex acetosella*), sweet vernal (*Anthoxanthum odoratum*), and scotch thistle (*Cirsium vulgare*). After two years sweet vernal dominated the recovered plots. Other significant species present included *Holcus lanatus*, *Prunella vulgaris*, *Plantago lanceolata*, *Dactylis glomerata*, *Pteridium esculentum*, *Solanum nigrum*, *Senecio bipinnatisectus*, *Senecio jacobaea*, *Phytolacca octandra*, *Coprosma robusta*, *Pinus radiata* (wildings) and *Acaena novae-zelandiae*. Logged settings were replanted with *Pinus radiata* seedlings within one year of being clearfelled, and after three years radiata became the dominant canopy species. Some seasonal variations in species occurrence and relative abundance were apparent, particularly for those affected by frost (e.g. inkweed), although the overall percentage of groundcover was largely unaffected.

(b) Setting-based site disturbance and vegetation recovery
On average, 88% of the combined area of all four logged settings assessed (29 ha) was undisturbed or only slightly disturbed. Thus, over much of these settings typical of terrain of stability type 5, physical conditions of surface soil were largely unaffected. At the time of clearfelling the total area of EMS (3.5 ha) was 12% of total logged setting area (Table 1). This corresponds closely with the findings of McMahon (1995), in which 12% of observations on a hauler setting at Mangatu Forest showed deep disturbance. Similar studies in the USA, including that of Dyness (1965), found that on terrain of similar steepness 9% of high-lead settings were deeply disturbed as a consequence of logging, while Wooldridge (1960) established that 11.1% of skyline settings was disturbed, and Garrison & Rummell (1951) found that mineral soil occurred over 15.2% of the total area of cable settings assessed. Measurements from aerial photographs show that within one year of clearfelling the total area of EMS had declined to 2.4% (0.71 ha) of total clearfelled setting and within two years to 2% (0.58 ha) (Table 1); these represent reductions in area of EMS of 80% and 83%, respectively.

Table 1: Sediment generated from areas of exposed mineral soils (EMS) on hauler-logged settings over a two-year period, Mangatu Forest.

	Time after clearfelling	
	Year 1	Year 2
Total combined area of 4 logged settings (ha)	29	29
Total combined area of EMS (ha) and % of logged setting (in parentheses)	3.51 (12.1) - 0.71 (2.4)	0.71 (2.4) - 0.58 (2.0)
Mean rate of sediment generation (kg/m ²) from EMS plots; SE value in parentheses	11.3(3.44)	4.4 (2.36)
Annual sediment total (tonnes) from sites of EMS; SE value in parentheses	239 (72.68)	28 (15.23)
Rate of sediment generated per hectare of logged setting (tonnes/ha); SE value in parentheses	8.2 (2.50)	0.98 (0.525)
Total combined area of EMS (ha) with direct access to streams and % of logged setting (in parentheses)	0.76 (2.6) - 0.19 (0.6)	0.19 (0.6) - 0.11 (0.4)
Annual sediment total (tonnes) from sites of EMS with direct access to streams; SE value in parentheses	54 (16.3)	6.6 (3.54)
Rate of sediment generated per hectare of logged setting (tonnes/ha); SE value in parentheses	1.9 (0.56)	0.23 (0.122)
Annual sediment input to streams per kilometre of streambank (tonnes/km); SE value in parentheses	9.6 (2.92)	1.2 (0.63)

This reduction appears to be contrary to the measured 31% reduction in EMS within plots over the two-year period after clearfelling (Fig. 1). The explanation lay, in part, in the patchy nature and highly variable extent of areas of exposed mineral soil. On Class V terrain at Mangatu, areas of EMS occurred primarily on steeper-than-average midslope ridges and on steep slopes adjacent to incised channels of both ephemeral and permanent streams; they were separated by large areas of shallow disturbance and undisturbed sites. The majority of EMS sites were small (<10 m²) and surrounded by extensive areas of shallow disturbance and undisturbed ground from which groundcover veg-

etation spread rapidly. Within one year of logging few remained identifiable as former sites of EMS. The more extensive areas ($>10\text{ m}^2$) of EMS, despite partial vegetation recovery, remained clearly discernible on aerial photographs and therefore continued to be a source of sediment generation for longer than the two-year monitoring period of this study. The selection of a standard plot size (9 m^2) may therefore have introduced a bias towards the larger areas of EMS, and groundcover spread onto these sites could be expected to be slower than for the setting as a whole.

(c) Sediment generation from sites of EMS

Sediment generated from the two EMS runoff plots was highly variable from year to year and probably reflected differences in aspect and localised soil variability. The data nonetheless highlighted two important trends. First, most of the sediment (72% of the two-year total) was generated within the first year after harvest. Second, at the end of the two-year monitoring period the two plots had generated similar amounts of sediment (132 kg and 152 kg). This equates with a mean lowering of surface areas of EMS by 7.6 mm (range 7.1–8.1 mm) over the two-year period, of which 5.5 mm (range 3.8–7.1 mm) occurred within the first 12-month period following harvesting.

In this paper rates of sediment generation and of surface lowering have been calculated per unit area (9 m^2) of EMS plot. Normalisation of the data to account for the effects of recolonisation on sediment generation rates through time was not contemplated, as it was assumed that plot-sized and larger areas of EMS, across settings and clearly visible on aerial photography, would occur at a rate similar to that of the EMS runoff plots. Thus erosion rates have been applied to all areas of EMS visible on aerial photographs through time.

Sediment generation rates² over the first year averaged 11 (SE 3.5) kg/m^2 . In the same period the combined area of EMS across all four logged settings decreased from an initial 3.5 ha to 0.7 ha. Conservatively, therefore, 23 (SE 73) tonnes of sediment could have been generated from areas of EMS during this 12-month period (Table 1). For the second year the rate of sediment generation averaged 4 (SE 2.4) kg/m^2 and the combined area of EMS decreased in extent to 0.58 ha. Conservatively, 28 (SE 15.2) tonnes of sediment could have been generated from areas of EMS during this period (Table 1).

If the average erosion rates measured on the plots are applied to the area of EMS measured on the four logged settings (29 ha), the rate of erosion on the settings would average approximately 8 (SE 2.5) tonnes/ha for the first year and then decrease to one (SE 0.5) tonne/ha in the second year (Table 1). This represents a 83% reduction in sediment generation on these hauler-logged settings within two years of clearfelling. This reduction was due to the combined effects of decreased erosion per unit area of EMS and decreased area of EMS through time.

Comparable forest-related sediment data are difficult to find. Nonetheless, we consider that the initial (year one) rate was high, exceeding that generated from harvest roads – a major source of sediment. By year two the erosion rate from sites of EMS was equivalent to that produced from pre-harvest roads (Fahey & Coker 1992). However, as shown in this study, sediment generated from hauler-logged settings decreased rapidly with time, whereas road-related surface erosion is a more persistent source of sediment (Reid *et al.* 1981). Also, preliminary results of sediment yield from gullies within Mangatu Forest for the period 1939–92 (De Rose *et al.*, in press) showed that these gullies continued to supply sediment to stream channels at a rate several orders of magnitude greater than forest-related sources, such as hauler-logged settings or forest roads.

A single rainfall event 40 months after the completion of harvesting produced 180 mm in 72 hours. Such events are typical of this region, and have a return period of six years or less (Tom-

linson 1980). Following this event 2 kg of sediment was collected from one of the troughs; this was 25% more than the mean monthly amount of sediment produced at this time. This event demonstrated that the larger sites of EMS in particular, remained vulnerable to the influence of periodic heavy rainfall for longer than two years after logging, and that such storms have the potential to generate proportionally greater sediment volumes from these sites. The period of study did not coincide with any extreme flood-producing rainfall events, and hauler-logged settings at Mangatu Forest have not been subjected to heavy rainfall during extreme events since the commencement of harvesting. If they had, the yield rates from sites of EMS undoubtedly would have been substantially higher than those recorded here. Thus, given that this area has a high incidence of extreme storm events (Kelliher *et al.* 1995), the potential for greater sediment production from hauler-logged settings during major rainfall events has yet to be fully realised. Further, the results in this study take no account of the role of slope-derived mass movement in generating sediment on hauler-logged settings.

(d) Sediment particle size and mobility

Sediment derived from areas of exposed mineral soil, and subsequently collected from sediment traps, predominantly comprised sand-sized (0.06–2 mm) particles (46%), with gravel-sized ($>2\text{ mm}$) particles comprising 30% and silt and clay-sized ($<0.06\text{ mm}$) particles 24%. An unknown extra volume of clay and fine silt contained in turbid water would have escaped from the plots during periods of heavy rainfall. Of the largest particles only 1% exceeded a diameter of 19 mm and none were larger than 37 mm. The size of the gravel particles was largely controlled by the intensity of tectonic jointing and cleavage, while the high proportion of sand, silt and clay-sized particles was a reflection of the fine-grained sedimentary lithologies that predominate in this area. These fine-grained and intensely sheared lithologies are susceptible to rapid weathering. Areas of exposed mineral soil were therefore potentially a significant source of readily available sediment, of which the bulk of particle sizes produced by weathering were capable of being mobilised by overland flow, rainsplash or gravity from steep slopes devoid of groundcover vegetation.

Downslope sediment mobility was, however, effectively constrained by the presence of significant volumes of on-site slash, surviving groundcover vegetation, the hummocky nature of the microtopography and the fact that the majority of individual sediment source areas were small and patchy in distribution. Sediment mobility was greatest during the first three months following harvesting, but declined rapidly as groundcover vegetation spread to colonise accumulation zones of loosely aggregated materials dislodged during harvesting or subsequently loosened and transported downslope by raindrop impact and/or weathering processes. Consequently, transport distances were short, with little of the coarse-grained sediment mobilised more than 3–5 m downslope of source areas. The exception, however, occurred along furrows created by the dragging of logs along haul lines. Mid-slope furrows tended to be long (20–30 m) and discontinuous. Sediment mobilised within these furrows soon dissipated at the distal end amongst slash or groundcover vegetation or was trapped in hollows. Shorter furrows ($<10\text{ m}$), predominantly on lower slopes, showed signs of downcutting caused by concentrated surface flow during periods of heavy rainfall. They were considered to be sites of sediment generation and conduits for the transportation of appreciable volumes of coarse-grained sediment to stream channels.

Silt and clay-sized particles (24% of total sample) are readily carried in suspension for long distances, but require pathways of concentrated flow. The absence of rilling on most sites of EMS, however, suggested that these sites are highly porous and that concentrated flow was not an important process for transporting 'fines' except during periods of heavy rainfall. Concentrated surface flow did occur, however, along haul lines, perhaps as a result of the compaction of materials in the furrows. Haul lines there-

² Sediment generation rates for the first and second years were the average of the two plots. SE is the standard error of the mean.

fore may become important conduits along which sediment can be readily transported, and much of the sediment they transport is likely to be deposited into stream channels. Neither the specific climatic conditions under which concentrated flow develops, nor the volume of sediment generated by concentrated flow along hauler lines, was studied.

(e) Sediment contribution to streams

Haul lines along extraction corridors predominantly occurred on mid-slope ridges, and provided little risk of sediment mobilisation and transportation to streams. However, the lack of lift for logs across some stream channels resulted in the furrowing of steep-sided streambanks, creating conduits for sediment mobilisation to streams. The measurement of areas of EMS created by log 'dragging' in close proximity to watercourses, and in particular those with a direct connection to the watercourse, was therefore a key factor in ascertaining potential sediment contribution to streams. Such areas were riparian and occurred within 10 m of the watercourse. The combined area of EMS across the four logged settings and with direct connection to watercourses was 0.76 ha immediately following logging; one year later the area was 0.19 ha, declining to 0.11 ha two years after logging (Table 1).

Applying the average erosion rates measured on the plots, the total amount of sediment potentially generated from sites of EMS with direct connections to stream channels was calculated at 54 (SE 16.3) tonnes in the first year and 7 (SE 3.5) tonnes in the second year. This represented approximately 23% of sediment generated from the total logged setting during each respective period. Potentially, therefore, about 2 (SE 0.6) tonnes/ha of sediment could be generated from these logged settings and deposited into stream channels in the first year after logging, declining to 0.2 (SE 0.1) tonnes/ha within two years of logging (Table 1). These figures should be considered conservative, as they do not include sediment eroded from the base of haul lines by concentrated flow during periods of heavy rainfall or sediment derived from stream-bank erosion.

Sediment delivery into stream channels (ephemeral and permanent) was also related to the length of stream bank adjoining logged settings. Length of stream bank is used in preference to length of stream channel, as some logged settings occur on slopes flanking one side of a stream channel while others flank both banks of the same reach. The total length of stream bank adjoining the four logged settings assessed for this paper was 5.6 km. For every kilometre of stream bank within, or adjacent to, a logged setting approximately 10 (SE 3.0) tonnes of sediment generated from sites of EMS could potentially have entered watercourses within the first year since clearfelling, declining to one (SE 0.6) tonne in the second year (Table 1). For these settings approximately half (46%) of this sediment would probably have entered directly into a permanent watercourse, the balance accumulating in ephemeral channels. Sediment deposited into ephemeral channels would likely remain as part of the storage component of first-order basins until mobilised during periods of stream flow. Residence time is likely to be short (one to 10 years), as this area is subject to frequent high-intensity rainfall events often resulting in flooding (Kelliher *et al* 1995).

CONCLUSIONS

The combined areas of undisturbed and shallow disturbance sites occupy 88% of hauler-logged settings in the terrain studied, but are not considered to be important areas of sediment generation. The extent of exposed mineral soil (12% of logged settings) within first-order basins on terrain of stability type 5 at Mangatu Forest is comparable with that found on hauler-logged sites in the USA (Dyrness 1965, Wooldridge 1960) and by McMahon (1995) at Mangatu. Though the area of EMS was small, it does not necessarily follow that the amount of sediment generated will be negligible. EMS sites located on mid and upper slopes generated appreciable volumes of sediment by sheetwash erosion for at least

two years after clearfelling, although the bulk of this sediment was redistributed a short distance downslope of source areas, where it was effectively entrapped by slash and surviving ground-cover vegetation, and in microtopographic hollows. Areas of EMS with direct connections to watercourses are the most likely source of sediment entering streams during the post-harvest period. Approximately 2 (SE 0.6) tonnes of sediment per hectare of logged setting were generated from riparian EMS areas within the first year since completion of harvesting, decreasing to 0.2 (SE 0.1) tonnes/ha in the second year. These contributing sites of EMS were predominantly created by the dragging of logs across watercourses, and therefore generally occurred within 10 metres of the streambank. They were characteristically channelised, and surface water tended to concentrate in volumes sufficient to mobilise all available sediment.

Sediment yields do not include sediment derived from mass movement processes or stream-bank undercutting during the post-harvest period. Also, these yields should be regarded as indicative only of volumes of sediment generated by sheetwash erosion from hauler-logged settings and perhaps typical only for periods of non-extreme climatic events.

For comparison, sediment generated by sheetwash erosion from logged settings one year after clearfelling was several orders of magnitude less than that estimated from non-forestry-related sources, especially gullies. In addition gullies, once initiated, have continued to supply high volumes of sediment to watercourses for five decades, whereas sediment supply by sheetwash erosion from logged settings decreased by more than 80% within two years of completion of harvesting. Thus, although in the short term the visual impact of harvesting can be dramatic, and sediment production from sites of EMS was high for forest-related sources, the off-site impact of small volumes of additional sediment to already sediment-laden watercourses, such as the Waipaoa River, was not particularly important when compared with background rates. Similar amounts of forest-related sediment entering streams where background rates of sediment production are low would, however, be regarded as unacceptable. It would be advantageous for the forest industry to minimise soil disturbance and consequent sediment production from hauler-logged settings, particularly within 10 m of stream channels.

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A survey of afforestation intentions in New Zealand between 1996 and 2010

Bruce P. Glass^{1,2}

Abstract

A survey of New Zealand industrial forest growers, local government authorities and industry experts was carried out to ascertain new land planting intentions to the year 2010. Industry experts expect nationwide intentions of all ownership groups for all forest species to decrease from about 72,000ha in 1996 to nearly 66,000ha in 2000, and to level out at about 56,000ha/yr between 2001 and 2010. It is anticipated that more than 80% of the area involved will be planted with radiata pine. New land planting intentions of individual owners, either independently or through partnerships, joint ventures, trusts, etc., are expected to exceed those of either industrial growers or local government authorities. Estimates of the new land planting intentions of the industrial growers indicated a drop from about 27,000ha in 1996 to 16,000ha/yr between 2001 and 2010.

INTRODUCTION

The aim of this project was to obtain bounded estimates of the afforestation (new land planting) intentions of forest owners in New Zealand to the year 2010. The data were to be used to model trends in carbon absorption by New Zealand's exotic plantation forest estate. New land planting was defined as: "Planting of commercial forest species into areas currently in pasture, scrub, or non-commercial forest species." It does not include replanting of logged commercial forest areas. This report summarises data submitted in response to a questionnaire survey.

METHODOLOGY

A survey was undertaken in November, 1995 to obtain an overview of the new land planting intentions of New Zealand

forest owners. A nonprobabilistic sampling method (Kalton, 1983) was used because it was not possible to identify all potential respondents before it commenced. Three main groups were targeted:

- Industrial growers (IG)** - Central Government, State-Owned Enterprises, registered public companies, registered private companies.
- Local government authorities (LGA)** - District councils, regional councils, local authority trading enterprises.
- Industry experts (IE)** - Including forestry consultants and Ministry of Forestry staff. These respondents were asked to estimate nationwide new land planting intentions on the basis of their professional knowledge.

The intentions of owners outside the IG and LGA groups, defined as **Other forest owners (OFO)**, were not sought directly because difficulties involved in identifying respondents could have led to double-counting. These owners include individuals investing independently, or through partnerships, joint ventures, trusts, etc.

Initial contact with respondents was by telephone, and responses were obtained by telephone interview where possible. Questionnaires were sent out if the telephone approach was not appropriate. Each respondent was asked to provide:

- A bounded best estimate (ha) of annual new planting intentions, by species, for each of the five years from 1996 to 2000; and 2010.
- A bounded best estimate (ha) of the anticipated rate of new land planting during the period 2001-2010.

Additional questions sought information about:

- net stocked areas (ha);
- areas of new land planted in 1994 and 1995 (ha);
- time periods used for planning new land planting (years);
- extent of land banks secured for planting (ha); and
- anticipated rotation lengths (years).

New land planting intentions of the IG and LGA groups were obtained for their own forest holdings only. Estimates of planting intentions for these two groups were obtained by summing data from individual responses. The mean of estimates for nationwide new land planting intentions was used to describe the overall response from the IE group. Estimates of new land planting intentions of the OFO group were derived as the difference between the IE group response and combined (i.e., summed) estimates for the IG and LGA groups.

¹ Formerly with the New Zealand Forest Research Institute, Rotorua. Present address: Resource Planning and Asset Management, Washington State Department of Natural Resources, PO Box 47014, Olympia, Washington, USA 98504-7014.

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