SKID SITE REHABILITATION: SOIL EFFECTS, COSTS, AND EARLY GROWTH RESULTS

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ABSTRACT

The area of potentially productive land occupied by skid sites (logging landings) created during logging operations was measured at three sites in New Zealand—Kaingaroa Forest (Bay of Plenty), Golden Downs Forest (Nelson), and Berwick Forest (Otago). Several skid sites in each forest were subjected to rehabilitation treatments, either ripping or ripping plus return and spread of topsoil and woody debris. These treatments markedly improved soil physical properties related to tree growth. When topsoil was returned the soil nutrient status also improved. Rehabilitation treatments improved the growth of young trees on the landings.

Keywords: logging; landings; land rehabilitation; tree growth; sustainability.

INTRODUCTION

Skid sites (logging landings) typically occupy 5–8% of the potentially productive land in New Zealand's plantation forests (Larsen unpubl. data). A similar level of land loss has been reported for some Canadian operations (Krag 1984, in prep.).

Skid sites are usually stripped of topsoil and organic matter as well as being compacted to a degree that inhibits root growth (Mason & Cullen 1986). For successful re-establishment of trees on these sites, mechanical cultivation is necessary. However, due to the lack of topsoil, the trees planted in these cultivated areas rarely perform as well as those planted in the adjacent cutover. They are usually smaller in both height and diameter and the foliage is often yellowed (Murphy 1983; Schuster 1979).

The objective of this work was to determine the extent to which soil cultivation along with the return of displaced topsoil can rehabilitate skid sites, with *Pinus radiata* D.Don as the test species.

METHODS

Three ongoing trials were established in Kaingaroa (1992), Golden Downs (1993), and Berwick (1994) to compare the benefits of (1) cultivation alone, and (2) cultivation plus returning of topsoil and organic matter.

Each trial included eight to 10 skids (replications). In the Kaingaroa and Berwick trials the topsoil pushed off the skids during construction was recoverable for the rehabilitation operation and was spread over half of each skid surface. The two rehabilitation treatments were rip (R), and rip + return soil and debris (RSD), with the cutover (CO) as a control. At Golden Downs it was not possible to recover the skid site topsoil and woody debris was used instead.

The cutover plots were established adjacent to the skids in the harvested area. They were far enough away from the skids to be representative of normally harvested areas and were not affected by the presence of the skid sites or the operation performed on them.

Trial Sites

Kaingaroa

The first trial (Hall 1993) was established on 10 skid sites in Kaingaroa Forest (Bay of Plenty, North Island) in an area where the soil is of volcanic origin. There is a thin layer of topsoil and organic matter over a number of layers of volcanic debris deposited from a series of eruptions. Much of this material is naturally very compact and deep ripping is required to allow tree roots to penetrate below 30 to 40 cm. The standard mechanical site-preparation treatment for the cutover, where the trial was located, is ripping to an average of 70 cm and mounding with two discs mounted each side of the ripper. The terrain is flat and ground-based logging systems were used.

Golden Downs

The second trial (nine skid sites) was established in Golden Downs Forest (Nelson, South Island) in an area where the terrain is steep and hauler logging had been used. The flat skid site surfaces are created by earthworks in the middle or at the top of the steep slopes. The soil is an impoverished conglomerate gravel. Typically no mechanical site-preparation is carried out on these sites. The soil pushed off the skid sites during construction was not easily recoverable. However, there was a large volume of waste woody debris from delimbing and log-making piled next to the skids. This material was retrieved and spread out between the rip lines in piles 1 to 2 m high in order to provide some nutrition in the long term. Half of the trees had an application of fertiliser to sustain their growth until the organic material decayed and became available. The treatments were: rip (R), rip + fertiliser (RF), rip + slash (RS), and rip + slash + fertiliser (RSF), with the cutover (CO) as a control. The fertiliser treatment was an NPK + ulexite mix applied by hand immediately after planting, at a rate of 50 g/tree.

Berwick

The third trial (eight skid sites) was established in Berwick Forest (Otago, South Island) on rolling terrain where ground-based logging with some contour tracking had been used. The soil is a clay loam. Cultivation of the cutover is not undertaken in this area, although clearing of heavy slash into windrows is common.

Soil Measurements

Data collected during the establishment of the trials were soil shear strength status, rip and mound profiles, depth of the spread soil and debris. The size of the landings was also measured. Soil samples were collected from the cutover, the skid surface, and the returned material from each landing (bulked sample) and were analysed for critical nutrients.

Growth Data

Growth plots were established on the skids and the adjacent cutover immediately after the treated sites were planted. Plot sizes varied as the skids were not a uniform size or shape and varied from 50 × 60-m rectangles (0.3 ha), to circular shapes with diameters of 40 to 45 m (0.15 ha). The number of trees per plot varied from 30 to 70, depending on the size of the skid.

Heights and diameters (root collar) of trees in growth plots were measured after planting and each year after establishment. Treatment differences in growth data were tested using a randomised complete block analysis of variance, followed by a least significant difference test.

During measurement, the trees were subjectively assessed for health and form, on a scale of 1 to 5:

Health score	1 = very healthy ... 5 = dead
Form score	1 = straight single leader ... 5 = toppled multi-leader.

Production Rates and Costs

Operational time and machinery costs for skid site and track rehabilitation were assessed so that the operational costs and tree growth results could be used in a cost-benefit analysis. The costs stated in this report have been derived using the procedure published by Riddle (1994). They are indicative only and do not necessarily represent the actual costs for the operations. In Kaingaroa a 105-kW bulldozer was used to rip the skid surface and then spread the surrounding piles of soil and debris. In the other two trials the machines used were 20-tonne excavators with interchangeable fittings on the boom (rippers or slash rakes). The time to rip the skids and the area treated were measured, and so were the time to return the soil/debris and the area covered.

RESULTS

Soil Effects

Kaingaroa

Profiles of the rip shatter zone and mounds were measured (Fig. 1). The mean maximum height of the mound above the skid surface was 34 cm and the mean maximum rip depth was 74 cm.

The soil shear strength of the skid site was approximately twice that of the cutover down to a depth of 50 cm and was still markedly higher at a depth of 70 cm (Fig. 2).

The arrowed line in Fig. 2 at the 3-MPa level marks the point at which soils become resistant to *P. radiata* root growth (Mason & Cullen 1986). The skid sites had obviously been heavily compacted. It is also noticeable that the compaction level peaked at around 30 cm depth. The soil was still more compact than the soil in the cutover at 70 cm depth, although the difference was greatly reduced.

The depth of soil spread over the skid surface averaged 33 cm. This material was generally very loose and was a mixture of topsoil, mineral soil, and the woody residue produced on the skid site during logging. The soil samples were collected by hand and are unrelated to soil density. The samples from the soil/debris areas did not include any woody debris.

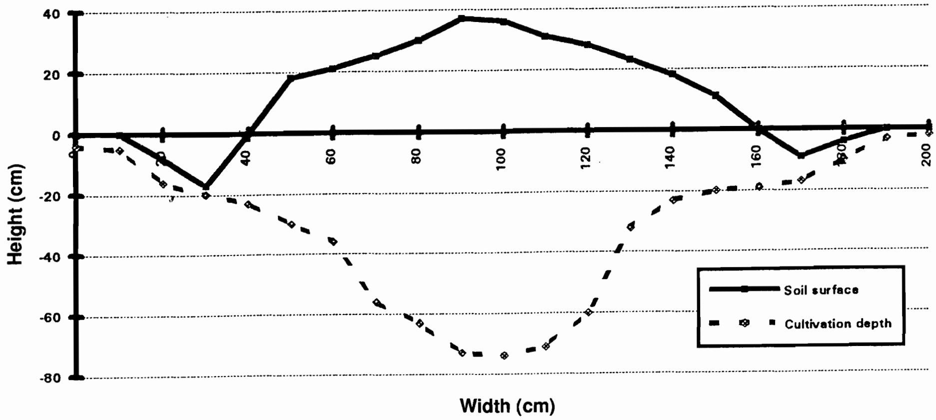

FIG. 1–Typical rip-mound profile in the Kaingaroa trial.

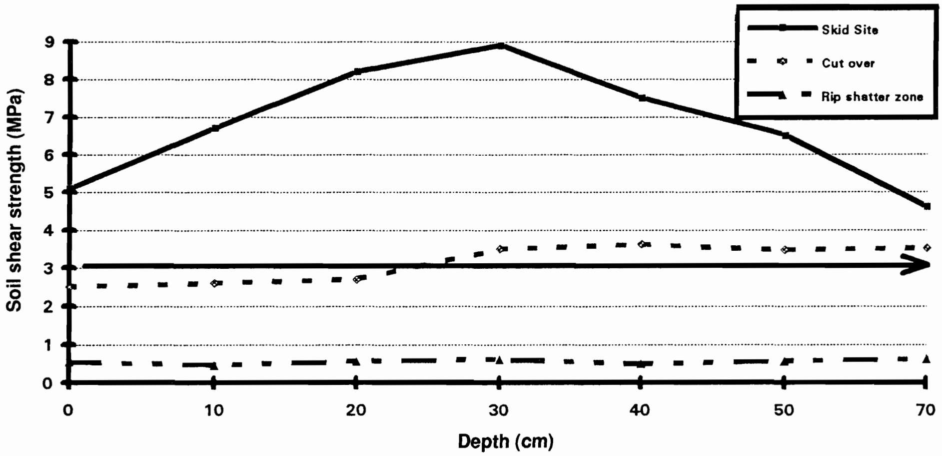

FIG. 2–Soil shear strengths by depth in the skid sites, cutover, and rip shatter zones, Kaingaroa.

There were some major differences in nutrient status among the three treatments. The most noticeable were the large decreases in nitrogen, carbon, phosphorus, calcium, and magnesium between the cutover and the skid site (Table 1). The soil in the material pushed back over the skid showed nutrient levels that generally were between those of the cutover and the skid surface.

The stripping of topsoil during construction of the skid sites had major impacts on soil nutrients. Soil nitrogen on the skid site was markedly reduced to well below the critical level for *P. radiata*. Amelioration with either chemical nitrogen or biologically fixed nitrogen (legumes) would be a prerequisite for crop re-establishment. Soil nitrogen at 0.37 g/kg was only marginally higher than that found in sand dune *P. radiata* where it is acutely nitrogen-deficient (Gadgil 1982).

Soil phosphorus status was also affected, with skid sites just on the margin for adequacy (Ballard 1974; Skinner *et al.* 1991). Although there was a marked decline in the cation status

TABLE 1–Soil chemistry, Kaingaroa.

	pH	N (g/kg)	C (g/kg)	P Bray 2 (mg/kg)	Ca	Mg	K
					Bray cations ($Cmole_c/kg$)		
Cutover topsoil	5.09	2.32	52.6	72.3	0.226	0.072	0.053
Skid surface	5.84	0.37	12.9	12.9	0.063	0.012	0.04
Soil/debris spread	5.59	1.41	30.6	17.7	0.090	0.034	0.057

(calcium, magnesium, potassium) these declines are unlikely to be of concern, except for magnesium where the change in status is likely to be significant for *P. radiata*.

In summary, *P. radiata* nutrition on these skid sites was most at risk from deficiencies in nitrogen, magnesium, and phosphorus.

By returning the displaced soil, the soil nutrient status was partially restored. However, the early growth of *P. radiata* is still at risk, particularly from nitrogen deficiency since woody debris was incorporated in the soil pushed back from the skid surrounds. The presence of wood can result in immobilisation of soil mineral nitrogen during the decay process.

The cutover and skid sites in the Kaingaroa trial were oversown with a grass (Yorkshire fog) and a legume (Maku lotus) as part of the standard management programme. The sections of skid that were ripped remained bare. The sections of skid that had the topsoil spread back over them developed a partial cover of the oversown species.

Golden Downs

No mounding was intentionally created. However, some mounding occurred as a side effect of the shattering of the soil by the ripper and subsequent heave due to the increase in volume. The rip depth was 65 to 70 cm and the mound was typically 15 to 20 cm high (Fig. 3).

The skid surface was heavily compacted, except for some surface weathering of the top 5 to 10 cm (Fig. 4). The rip zone was well shattered to 60 cm. The cutover showed a distinct rise in soil shear strength at 30 to 40 cm, and there was a noticeable change at this depth from a soil to a gravel conglomerate.

The material spread over the skid surface at Golden Downs was virtually all woody debris. There were substantial differences in all nutrients between the skid site and the cutover, perhaps the most critical being the acutely low soil-nitrogen levels on the skid site (Table 2).

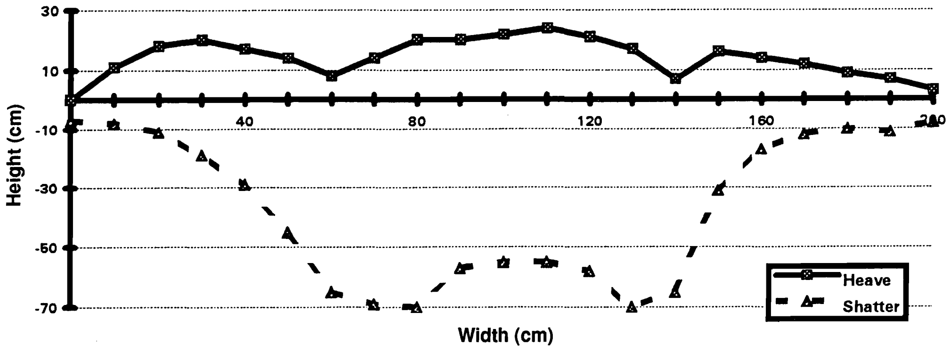

FIG. 3–Typical rip-mound profile in the Golden Downs trial.

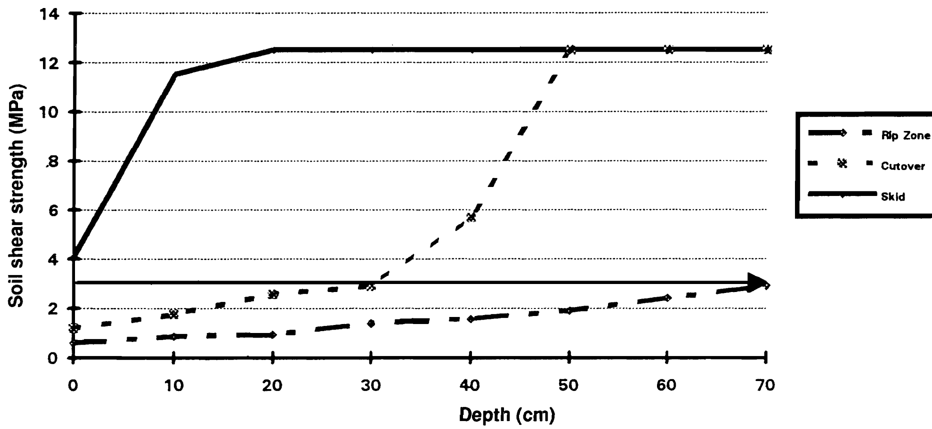

FIG. 4–Soil shear strengths by depth in the skid sites, cutover, and rip shatter zones, Golden Downs.

TABLE 2–Soil chemistry, Golden Downs.

	pH	N (g/kg)	C (g/kg)	P Bray 2 (mg/kg)	Ca	Mg	K
					Bray cations ($Cmole_c$/kg)		
Cutover	5.37	2.47	55.3	31.9	0.873	0.467	0.014
Skid surface	5.53	0.62	36.4	28.0	0.414	0.297	0.009

Berwick

The mounds created by the heave-shatter effects of the ripper were 20 to 25 cm high with the rips down to a depth of 65 to 70 cm (Fig. 5). The soil between the rips was shattered which would allow tree roots to penetrate the area between the two rip lines.

The rip shatter zone and the returned material lines both lay well below the 3 MPa level. However, the unripped skid was quite compact on the surface and at the 20 cm level a layer of rock was struck that was not measurable for shear strength but could be described as impenetrable (Fig. 6). This rock layer was found reasonably consistently at a depth of 50 to 60 cm on the cutover. The tree roots were able to penetrate the soil to a depth of 40 to 50 cm.

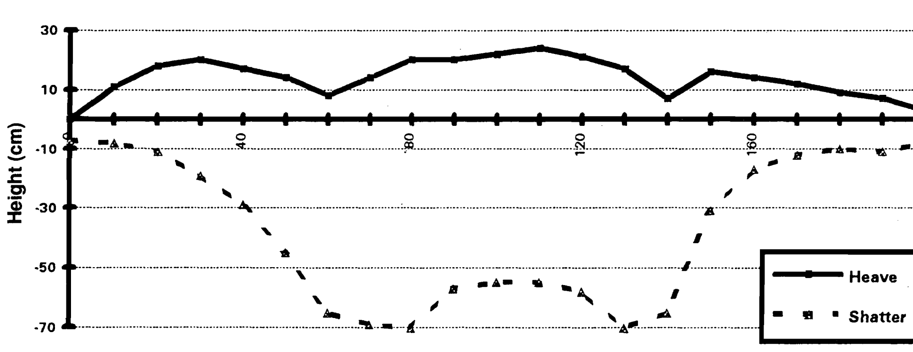

FIG. 5–Typical rip-mound profile in the Berwick trial.

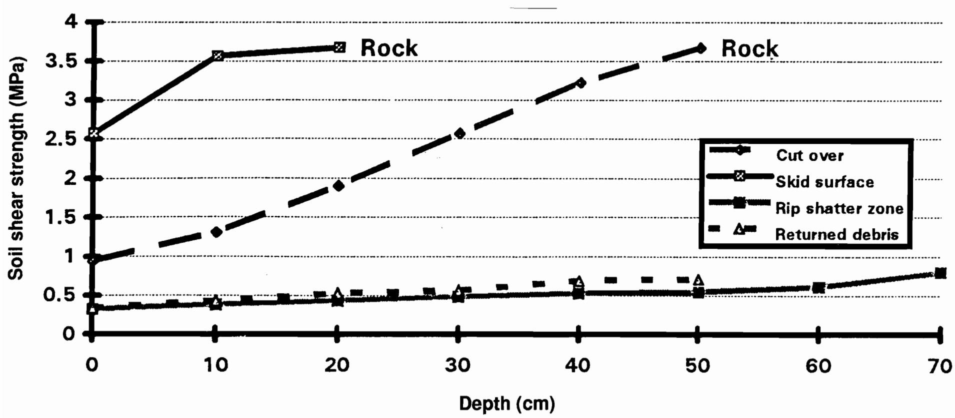

FIG. 6–Soil shear strengths by depth in the skid sites, cutover, and rip shatter zones, Berwick.

The depth of soil and woody material returned to the skid over the original surface averaged 45 cm. The returned material comprised mostly soil. The waste wood around the skid edge was swept away from the skid by the excavator in order to access the soil underneath.

The nutritional status of the skid surface was improved by returning the soil removed from the skid during construction (Table 3).

TABLE 3–Soil chemistry, Berwick.

	pH	N (g/kg)	C (g/kg)	P Bray 2 (mg/kg)	Ca	Mg	K
					Bray cations (Cmole$_c$/kg)		
Cutover	4.67	2.6	54.3	3.19	0.231	0.121	0.027
Skid surface	5.08	0.7	21.5	4.72	0.131	0.070	0.024
Returned soil	4.91	1.6	31.1	5.02	0.181	0.064	0.028

Growth Results

Kaingaroa

In June 1993 and 1994, 1 and 2 years after the trial was planted, the trees were measured for height and for stem diameter at ground level. Subjective assessments of the health and form of each tree were carried out at the same time.

At the initial measurement immediately after planting the trees showed no differences, but at the 1993 measurements the cutover plots were performing best. Rip + return soil plots were next (mean height 85% of that for trees on cutover and mean diameter 87%). The rip only were the worst (height and diameter 71% of those for trees on cutover) (Fig. 7). Diameter trends followed those for height (Fig. 7).

At age 2 the rip + return soil treatment was giving growth that was less than the cutover plots but not significantly so (height 90% and diameter 92% of those on the cutover). The rip only treatment had fallen further behind and those trees were significantly smaller than for both the cutover and the rip + return soil treatment (height 61% and diameter 62% of height and diameter of trees on the cutover).

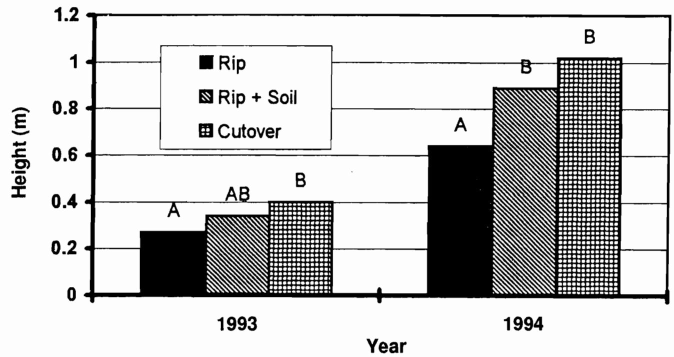

FIG. 7–Height growth data for 1993 and 1994, Kaingaroa.
Note: Columns in an annual series headed by a different letter differ significantly (p=0.05).

The results of the health assessment are given in Table 4, and the form assessment followed the same pattern. There was a heavy infestation of *Dothistroma pini* Hulbary in the whole of the trial area. However, the effects were most evident in the cutover plots. There was also some evidence of *Diplodia pinea* (Desm.) Kickx (tip dieback) in the cutover plots. This resulted in the cutover trees, despite having the best height and diameter growth, having the worst health and tree form. There appeared to be an interaction between the oversowing and the level of *Dothistroma* infestation. The trees on the bare skid had little *Dothistroma* whilst the trees in the cutover were generally badly affected. The trees on the skid, where the soil was pushed back and the grass growth had been slower and less dense than on the cutover, were in between.

Survivals were 98% for the rip only, 97% for the rip + return soil, and 86% for the cutover.

TABLE 4–Tree health, Kaingaroa.

	Rip	Rip + Soil	Cutover
1992	1.1	1.1	1.1
1993	1.1 a	1.2 b	1.2 b
1994	2.0 a	2.0 b	2.4 b

Golden Downs

After 1 year of growth, there were some significant differences between the treatments on the skid as well as between trees on the skid and the cutover (Fig. 8). The trees on the cutover were doing better than any of the rehabilitation treatments, which was to be expected. The rip only treatment was performing poorly, with the addition of slash or fertiliser making a small but significant improvement. The rip + fertiliser + slash treatment was giving the best height growth, at about 78% of that on the cutover. Growth may improve over the next 2 years as the slash rots and provides some organic matter for the trees.

There were also significant differences in diameter growth, which followed the same pattern as height growth, with the cutover performing the best and the R+S+F treatment next at 82% of the cutover. The R+S+F treatment was significantly better than either R or R+S but not R+F. This suggests that the fertiliser was providing the improvement at this stage.

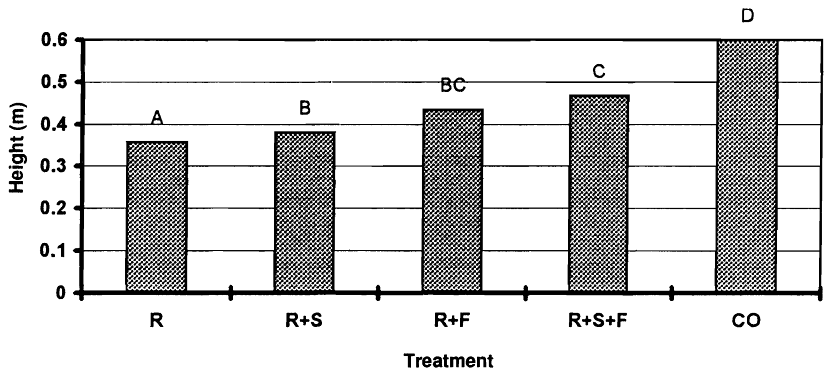

FIG. 8–Height growth data for 1994, Golden Downs.
Note: Columns headed by a different letter differ significantly (p=0.05).

Significant differences were evident in the health of the trees, with the trees without fertiliser showing a high degree of yellowing, along with their poor growth. The fertiliser helped but did not entirely alleviate the nitrogen deficiency (Table 5). There were no differences in tree form at the 1994 measurement.

TABLE 5–Tree health, Golden Downs.

	Cutover	Rip	Rip+Slash	Rip+Fert	Rip+Fert+Slash
1993	1.1	1.1	1.1	1.1	1.1
1994	1.4 a	3.0 b	2.7 b	2.3 c	2.2 c

Berwick

At this point there are no growth data for the Berwick trial as when the measurements were carried out it was not yet 1 year old.

Production Rates and Costs

Kaingaroa

The area logged in Compartments 1057 and 1058 was 162.5 ha, and 17 skid sites totalling 9.6 ha (5.9% of the land area in the compartments) were used. The 10 skids selected for the trial had an average size of 0.45 ha (0.33 to 0.64 ha), including the heaps of soil and debris surrounding the working surface.

The production rate of the ripping operation was 0.42 productive machine hours (PMH) per skid, including time to travel from skid to skid—a cost of $56/skid. The production rate of the soil debris spreading operation was 3.4 PMH/skid, including travel time—a cost of $340/skid. Total cost per skid to rip and spread the soil and organic debris back over the site was $396. At an average skid size of 0.45 ha, this is a cost per hectare of approximately $880.

Costs were derived from the time study data using a costing method developed for logging contractors (Riddle 1994). The cost of the standard cutover site preparation treatment in this area was approximately $350/ha.

Golden Downs

The area logged in Golden Downs was approximately 45 ha and nine skid sites were used. The skid sites covered 2.4 ha in total, or 5.3% of the area, at an average of 0.3 ha/skid. The skids ranged in size from 0.17 to 0.58 ha and included the "bird's nest" of wood waste around the skid edge.

The production rate of the skid ripping operation was 1.5 PMH/skid, including the machine time for travelling from skid to skid—a cost of $145/skid.

The ripping was carried out with an excavator fitted with a ripper tine. Each rip line was a double rip at spacing of 1 m, and the space between each set of double rips was 4 m. Ripping with a large tractor (≥150 kW) would have been faster and cheaper. However, there was no such machine available at the time of the trial and the excavator was on site to do the soil and slash retrieval.

The retrieval and spreading of the slash was achieved at a rate of 2.3 PMH/skid. The time to rip and retrieve the soil and debris was 3.85 PMH/skid, which equates to a cost of $365/skid or $1215/ha.

Berwick

All the preparation of the sites was carried out with an excavator. Because of the rolling nature of the site, the soil pushed off the skid during construction had to be retrieved uphill and excavators were more efficient at this than bulldozers.

The area logged to the eight skids totalled 65.5 ha. The area of the skids totalled 2.48 ha for an average of 0.31 ha/skid, with a range of 0.23 to 0.45 ha. This equates to 3.8% of the area logged.

The production rate of the ripping operation (a double parallel rip at 4-m spacings as at Golden Downs) was 0.8 PMH/skid at a cost of $76/skid. The production rate for returning soil and debris, including moving from skid to skid, was 2.9 PMH/skid at a cost of $275/skid.

The total cost to rip and return the soil and woody debris was $380/skid (4.0 PMH). This equates to a cost of $1230/ha.

DISCUSSION AND CONCLUSIONS

Kaingaroa

Based on these preliminary results, and assuming that the rehabilitated skid site growth trend continues at 80 to 90% of the cutover growth, then the extra costs involved in rehabilitating skids can be assessed using the Internal Rate of Return (IRR).

Assuming similar silvicultural regimes and costs for the cutover and the skids, with a lower final return from the skids because of slower growth, it is assumed that the cutover will return $35,000/ha net at an IRR of 14%, and the rehabilitated (rip + returned soil/debris) skid site $29,750/ha net at an IRR of 12%. The ripped skid will return at best $15,000/ha at an IRR of 9%. This would indicate that the rehabilitation of the skid sites is worthwhile, given that the skids in question have not been surfaced with large amounts of rock or gravel. However, this trial was only 2 years old and any analysis of costs and benefits is indicative only.

It should also be noted that the skids will need close monitoring to determine any fertiliser requirements as the soil nutrition analyses indicate that deficiencies may be a problem in the long term. A programme of foliage sampling is planned to monitor the nutrient status of the trees.

Golden Downs

The results after 1 year suggested that rehabilitating these skids is physically possible, but more expensive than in Kaingaroa. At the same time, significant treatment differences could already be shown. However, it was too early to make any prediction on the continuation of the growth trends as the organic material returned to the skid had yet to decay and the effect of this will not be apparent for another 2 years at least.

Berwick

The cost per skid was similar to that at Golden Downs. However, a lot more soil was returned to the skid than at either Kaingaroa or Golden Downs and this should provide a good growing site for the trees.

All Trials

The costs of the rehabilitation treatments ranged from $880 to $1250/ha of skid surface. This is three to five times the normal mechanical site-preparation cost for most forest cutover in New Zealand. However, given that significant growth responses can be gained, it would appear that it is possible that unsurfaced skid sites can be successfully returned to a level of production that is 80 to 90% of the surrounding cutover.

The area of land occupied by skid sites ranged from 4 to 6% of the area logged. If this land is left unplanted, it represents a significant loss in overall forest productivity.

The rehabilitation methods used here are not necessarily the best for all situations and some customising of equipment, methods, and regimes may be necessary. They do, however, represent the basic requirements for re-establishment of skid sites—cultivation of a very compact soil and returning nutrients and organic matter to a very nutrient deficient site.

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