REPORT

ISSN 1174 - 1406

Volume 24 No. 6 1999

Rehabilitation of Logging Extraction Tracks

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Figure 1 - Left extraction track post harvest, Upper right - tree growth on untreated track (age 5), Lower right - tree growth on ripped and fertilised track (age 5)

Abstract

Logging extraction tracks can occupy up to 15% of the potentially productive land area of a forest. Returning this land to a level of productivity similar to the surrounding cutover is desirable if it is economically viable and cannot be reduced by other means.

The results from the three growth trials, with trees up to five years old were:

Omataroa Forest (age 5) - Cutover plots were generally giving better growth than the track, regardless of treatment.

Golden Downs Forest (age 5) - Ripping and fertilising the tracks has given good tree growth, better than the surrounding cutover. On contour tracks, trees planted on the outer edge of the tracks performed better than those on the inner edge in all treatments.

Berwick Forest (age 4) - Ripping and fertilising gave tree growth similar to the cutover, and significantly better than the untreated track.

Simple analysis of the costs and benefits, (net present value) based on the tree growth rates and survivals showed that for Golden

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Downs and Berwick, the cost of ripping and fertilising the tracks was justified in terms of tree growth. The planting of untreated tracks was less attractive financially than carrying out the rehabilitation as even though they had a low initial cost, they had very poor growth.

Introduction

Extraction tracks created by ground-based logging operations can occupy from 5% to 15% of the potentially productive land area of a forest. This is in addition to the area taken up by access roads and log processing landings, which can be a further 5% to 8% of the total land area available (Hall, 1993a).

A loss of revenue from poor tree growth on tracks of between $1400 and $4200 per hectare can be calculated. This range is dependent on the percentage of tracks (5% to 15%), (given the average growth rates of trees planted on untreated tracks in these trials) and a loss of harvest volume based on these, and if an assumed revenue of $45,000 per hectare is used.

The amount of land occupied by tracks is dependent on; ground slope, evenness of the contours, roading and landing density, logging system, harvest planning and machine operators.

There are three main types of ground-based tracking:

- random access (operator choice)
- designated tracks (planner defined)
- contour tracks (operator or planner defined)

Random access is generally used on flat to rolling terrain with few operating constraints, that is the machine operator can drive where he wants, to optimise loads and extraction distance.

On rolling terrain or in areas with sensitive soils, the logging planner may dictate where all extraction tracks are to go, and the machines are not allowed to travel at random off these tracks.

On steep terrain which is close to the limits of the capabilities of the extraction machine, it is not uncommon to find that tracks are cut (benched) into the hillside to create a flat running surface.

In all cases, the density of the tracking becomes higher the closer you get to the landing.

It is well documented that trees planted on extraction tracks do not grow as well as those planted on the adjacent cutover (Murphy, 1984). Given the amount of land that can be affected by extraction tracks, it is desirable that these tracks be rehabilitated to a level of productivity similar to that of the surrounding cutover in a cost effective way (Schuster, 1979).

Soil damage created by tracking is usually topsoil removal, compaction and rutting. Tracks can also impact on soil permeability, and alter water flow across the site.

In order to determine the effectiveness and cost - benefits of some rehabilitation treatments aimed at ameliorating the compaction and soil loss (with its associated nutrient loss) caused by tracking, three growth trials were established.

Acknowledgments

Liro acknowledges the assistance of P. F. Olsen and Company Limited, Carter Holt Harvey Forests Limited, Fletcher Challenge Forests Limited, Weyerhauser New Zealand Incorporated and Wenita Forest Products Limited in the installation and maintenance of these trials.

Methods

The three trials were established in different regions of New Zealand, on different soil types.

1. Omataroa Forest, Bay of Plenty, which has a layer of scoria over pumice sub-soil, both of volcanic origin. Terrain is broken with short steep slopes. Harvested by hauler with two-staging along skidder tracks to a central skid.

2. Golden Downs Forest, Nelson, clay loam soil over Moutere gravel (glacial origin). Rolling to steep terrain with long slopes. Ground-based logged using contour tracks.

3. Berwick Forest, Otago, yellow brown earth over sedimentary rock. Rolling terrain with long slopes. Ground-based logged using random tracks.

The trial design was the same for all sites, with six treatments, replicated randomly along the tracks radiating out from skid sites. The trials in Omataroa and Golden Downs have nine replications, the Berwick trial has ten.

The treatments were:

1. Untreated track (U)
2. Rip track (R)
3. Rip track and fertilise (RF)
4. Rip track and return soil (RS)
5. Cutover (CO)
6. Cutover no weed control (Cnwc)

Plots for each treatment were 30 m long, along tracks of approximately 4 m width. Two rows of trees were planted along the track in each plot. The cutover plots were laid out in a similar shape parallel, and adjacent, to the tracks. The ripping treatment consisted of a double rip for each row, running along the track. The rips being placed 500 mm apart, all ripping operations were carried out with excavators. The returning of the soil was also done with the excavators, which had both ripper and bucket attachments and quick release fittings for changing attachments.

Fertilisation treatments consisted of 50g per tree by hand application immediately after planting with repeat applications applied every second year. Fertiliser used varied with the sites; Omataroa - Magamp+K, Golden Downs - NitroPhosKa, Berwick - DAP.

During the establishment of the trials, productivity data was collected so cost estimates could be made for the treatments. Soil strength data were also collected. The amount of tracking in relation to the area logged was also measured.

Spot releasing was carried out on treatment 5 as necessary, with the track plots receiving no releasing treatments (none were necessary).

The trials have been measured annually since establishment, with height and diameter (root collar moving to DBH) data being collected, along with a health and form assessment of each tree.

Table 1 - Proportion of harvested area occupied by tracks

Omataroa	7.2%
Golden Downs	9.7%
Berwick	8.3%
Average	*8.4 %*

There was a substantial proportion of the harvested area occupied by extraction tracks at all sites (Table 1).

The objective of ripping of the tracks was to ameliorate the compaction in the tracked areas to a level where tree root growth was not restricted. Previous research has found that root growth in radiata pine is impeded where the soil has a soil resistance to penetration of over 3 megapascals (Mason and Cullen, 1986). The ripping of the soil reduced the resistance to penetration substantially (Hall 1993b).

The second major soil issue identified with the tracks was topsoil removal. Its assumed effect on nutrient levels was addressed in one treatment by returning soil adjacent to the track, to the track surface. Commonly, this was topsoil side-cast during creation of the extraction tracks. Soil samples were collected and analysed to see if there were differences in nutrient levels (Table 2). Samples were collected from a depth of 10 to 20 cm below the soil surface.

Table 2 - Soil nutrient analysis results

	Omataroa Forest			Golden Downs Forest			Berwick Forest		
	N%	P mg/kg	K cmolc/kg	N%	P mg/kg	K cmolc/kg	N%	P mg/kg	K cmolc/kg
Cutover	0.180	9.48	0.256	0.289	7.34	0.240	0.296	5.34	0.373
Track surface	0.082	4.65	0.213	0.077	4.53	0.190	0.137	2.34	0.195
Returned soil	0.117	5.31	0.225	0.102	6.52	0.169	0.202	3.40	0.305

For three key elements, Nitrogen (N), Phosphorous (P) and Potassium (K) there was a distinct pattern to the results at all sites, with the cutover having the highest levels and the track surface the worst. The soil returned to the track from the side-cast material was generally in between the two extremes. The returning of the soil was partially effective in rectifying nutrient loss from tracking.

Growth Results

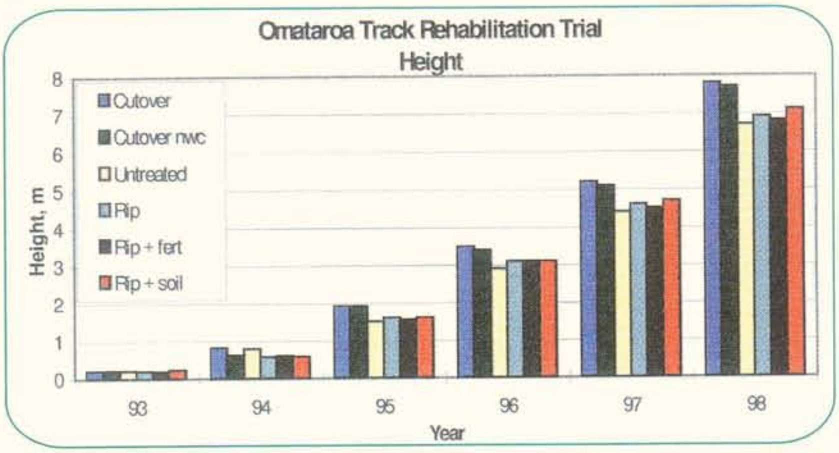

Figure 2 - Height growth 1994 to 1998

The results for height growth in the Omataroa trial are shown in Figure 2. The two cutover treatments are outperforming the track plots, with the rip and returned soil treatment (RS) giving the next best height growth.

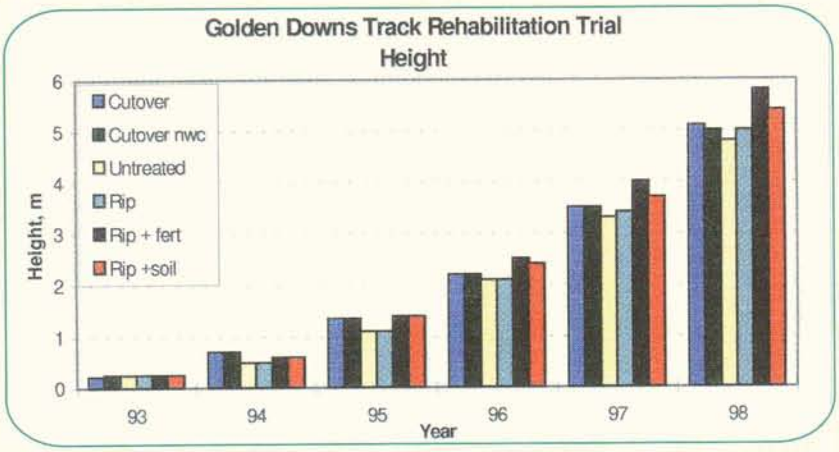

Figure 3 - Height growth 1993 to 1998

Figure 3 shows height growth results over time for the Golden Downs trial, with the rip and fertilise (RF) treatment giving the best results, with better growth than on the cutover.

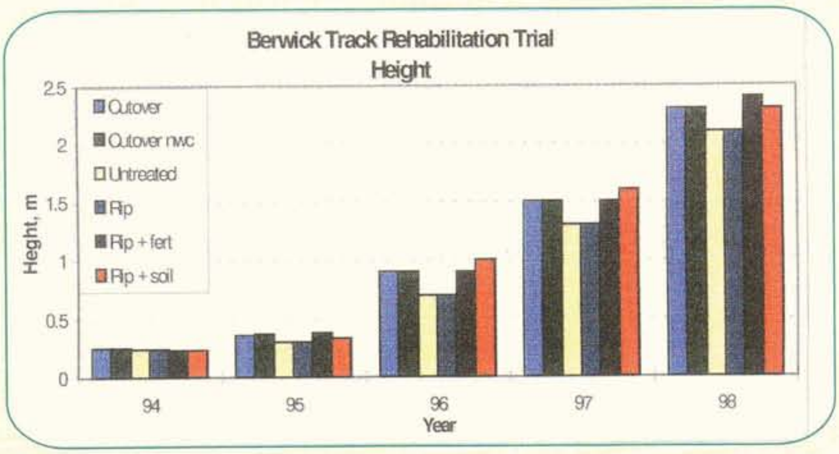

Figure 4 - Height growth 1993 to 1998

Figure 4 presents results for height growth in the Berwick trial. The RF treatment is giving the best growth, with the RS treatment giving results similar to the cutover.

Table 3 - Omataroa, 1998 annual measurement results

	DBH, mm	DBH Inc, mm	Height, m	Height Inc, m	Health	Form	Survival %
Cutover - wc	125 a	32 a	7.8 a	2.4 a	1.1 a	1.2 a	87 a
Cutover - nwc	119 ab	30 a	7.7 a	2.4 a	1.1 a	1.2 a	83 ab
Untreated	104 bc	30 a	6.7 b	2.3 a	1.3 ab	1.3 a	79 ab
Rip	104 bc	31 a	6.9 b	2.4 a	1.3 ab	1.3 a	84 ab
Rip + fert	101 c	28 a	6.8 b	2.2 a	1.4 b	1.4 a	73 b
Rip + soil	106 bc	31 a	7.1 ab	2.5 a	1.2 ab	1.2 a	89 a

Note: data in a column followed by the same letter **are not** significantly different (P < 0.05). Data followed by different letters **are** significantly different. For Health and Form, a lower score indicates superior performance.

The full results for the 1998 measurement are given for the Omataroa trial in Table 3. CO has the largest diameter, significantly larger than all other treatments except Cnwc. RS, U and R all have similar diameters. RF had the smallest diameter, significantly less than both the cutover treatments. There were no treatment differences in DBH increment.

The CO treatment was significantly taller than the other treatments except RS, which was not significantly different to either the cutover plots or the other track rehabilitation treatments. There were no differences between treatments for height increment.

There were no treatment differences for tree form. The cutover treatments had a significantly better health score than the RF. The trees planted on the tracks were generally slightly chlorotic, leading to slightly inferior health scores.

The RF treatment had the lowest survival, significantly less than the cutover treatments. When basal areas (DBH/survival) were calculated, the CO plots had significantly greater basal area than the U and RF plots, but were not significantly larger than the RS plots.

The results show that, at this site, trees planted on the untreated track have grown significantly less than the trees on the cutover, but not less than the trees in the rehabilitation treatment. The fertilisation has had a slight negative effect.

Table 4 - Golden Downs, 1998 annual measurement results

	DBH, mm	DBH Inc, mm	Height, m	Height Inc, m	Health	Form	Survival, %
Cutover wc	79 ab	31 a	5.1 b	1.6 ab	1.1 a	1.3 a	80 b
Cutover nwc	75 b	29 abc	5.0 b	1.6 ab	1.2 a	1.2 a	91 a
Untreated	72 b	26 c	4.8 b	1.5 b	1.4 b	1.4 b	86 ab
Rip	72 b	27 c	5.0 b	1.6 ab	1.4 b	1.3 a	96 a
Rip + fert	87 a	30 ab	5.8 a	1.7 a	1.1 a	1.2 a	87 ab
Rip + soil	81 ab	27 bc	5.4 ab	1.6 ab	1.2 a	1.2 a	94 a

Note: Data in a column followed by the same letter **are not** significantly different (P < 0.05). Data followed by different letters **are** significantly different. For Health and Form, a lower score indicates superior performance.

In the Golden Downs trial, trees in the RF treatment had the largest DBH (Table 4). They were not significantly larger than CO or the RS treatments, but were significantly larger than Cnwc, U and R. The RS treatment has the second largest DBH, but is not significantly larger than the other treatments.

For DBH increment CO has the best result, significantly larger than RS, R or U, but not larger than Cnwc or RF. This suggests that although the RF and RS treatments currently have slightly larger diameters, they are growing at about the same rate as the cutover plots.

Trees in the RF treatment have the greatest height and are significantly taller than all treatments except RS. RF also has the greatest height increment, significantly greater than the untreated track, but not significantly different to the other treatments.

There are no major trends apparent for height growth, except that the rehabilitation treatments, RF and RS are performing as well as the cutover treatments.

The trees in the U and R treatments have significantly poorer health than the other treatments. The untreated treatment has poorer form than the other treatments.

The CO plots have the lowest survival, significantly lower than Cnwc, R and RS treatments but not significantly worse than U and RF. This poor survival is attributable to a number of deaths in the first year of the trial when the cutover plots were subjected to attack from Hylastes ater bark beetle. There have been few deaths in any treatment since the first year.

The RF and RS plots have significantly greater basal area than the U, CO and Cnwc plots.

For all variables except health and form, the outer rows of the plots are giving significantly better performance across all treatments.

The tracks in this trial were all contour tracks, that is, they are benched into the hillside, with a cut bank on one edge and a fill slope on the other. The tracks had two rows of trees planted on them - one row of trees along the inner (cutbank) edge and one along the outer (fill slope) edge. The trees in the outer rows are consistently performing better than those on the inner row (Table 5). The trees in the outer rows of the rip and fertilise and rip and return soil treatments are performing as well as the trees in the cutover plots. This would suggest that in re-establishing trees on contour extraction tracks, only one row of trees should be planted, towards the outer edge of the track.

Table 5 - Effect of inner and outer rows, Golden Downs

	DBH, mm	DBH Inc, mm	Height, m	Height Inc, m	Health	Form	Survival, %
Outer row	86 a	32 a	5.5 a	1.7 a	1.2 a	1.3 a	91 a
Inner row	69 b	25 b	4.9 b	1.5 b	1.3 a	1.3 a	87 b

Table 6 - Berwick, 1998 annual measurement results

	RC Diam, mm	RC Diam Inc, mm	DBH, mm	Height, m	Height Inc, m	Health	Form	Survival %
Cutover	68 a	27 a	24 a	2.3 a	0.8 a	1.3 b	1.4 a	92 a
Cutover + wc	68 a	27 a	25 a	2.3 a	0.8 a	1.3 b	1.4 a	93 a
Untreated	57 b	23 b	19 b	2.1 b	0.7 a	1.5 a	1.5 a	87 ab
Rip	57 b	24 b	19 b	2.1 b	0.7 a	1.4 ab	1.5 a	93 a
Rip + fert	72 a	28 a	28 a	2.4 a	0.8 a	1.3 b	1.5 a	84 b
Rip + soil	66 a	27 a	23 ab	2.3 a	0.7 a	1.3 b	1.4 a	91 a

Note: Data in a column followed by the same letter **are not** significantly different ($P < 0.05$). Data followed by a different letter **are** significantly different. For Health and Form a lower score indicates superior performance.

In the Berwick trial (Table 6), for root collar diameter (RCD) and root collar diameter increment (RCDI), the U and R treatments were giving significantly less growth than the CO, RF and RS treatments. For DBH that trend was similar but the difference between the RS treatment and the R and U treatments was not significant.

The CO, RF and RS heights were significantly greater than those for R and U. There were no differences in height increment.

There were no differences in form by treatment. Trees in the U treatment were significantly less healthy than those in the other treatments.

The RF treatment had significantly lower survivals than the other treatments.

The basal areas in the RS, RF and CO plots were not significantly different, but these three treatments had significantly larger basal area than the U and R treatments.

Production Rates and Treatment Costs

Based on the results of the trials, it is suggested that only one row of trees be planted along the tracks, instead of the two rows planted in the trials. Time and cost of this suggested practice is presented in Table 7.

Table 7 - Production rates and costs of treatments

	Production	Cost
Rip	3.3 PMH/km	$330/km
Rip + Return soil	8.8 PMH/km	$880/km
Fertilise	1.0 man hr /km	$50/km
Rip + fertilise	-	$380/km

Discussion

The area of potentially productive land occupied by ground-based logging extraction tracks was found to be substantial, averaging over 8%. In an environment where forestry practices are under increasing scrutiny to see if they are sustainable, rehabilitation of these tracks may be desirable.

The soils within the area affected by the tracks have been compacted to a degree that inhibits tree growth. The key nutrients of N, P, and K are present in lower levels in the untreated tracks.

The rehabilitation treatments of ripping, fertilising and returning soil address the issues of compaction and nutrient deficiencies. In the case of fertilising, repeated fertilisations are likely to be necessary.

The costs of the treatments vary considerably. The benefits of the treatments have to be assessed in terms of growth benefit in relation to cost.

The effectiveness of the rehabilitation treatments varied with trial site. In Omataroa (Bay of Plenty, volcanic soil) the cutover treatments are outperforming the rehabilitation treatments, with little difference between treatments. The R and RS treatments gave the best growth on the tracks.

In Golden Downs, the RF and RS treatments outperformed the cutover in terms of DBH, height and survival. Trees planted on the outer (downhill side) edge of the track performed better than trees on the inner (uphill side) edge. This is consistent with findings on track rehabilitation in Canada (Wass and Smith 1997)

In the Berwick trial, the RF treatment is outperforming the cutover, with the RS slightly behind the cutover.

The figures for DBH and survival were converted into basal area and then into standing volumes using the treatment mean heights. These figures were extrapolated over time to give a percentage difference in volume available at clearfelling. A simple analysis of costs and benefits was then carried out (Net Present Value, NPV).

Table 8 - $NPV of treatments by trial

	CO	U	R	RF	RS
Omataroa	$6,700	$3,400	$1,900	$ 2,600	**$5,200**
Golden Downs	$6,800	$5,800	$6,100	**$10,000**	$8,000
Berwick	$6,600	$2,700	$2,600	**$ 6,400**	$4,400

Note: These figures are for comparative purposes, and **do not** represent expected real returns.

From Table 8, it can be seen that for Omataroa the best treatment option was RS, but it was returning substantially less than the cutover. In Golden Downs, both the RF and RS treatments were giving better returns than the cutover, with RF being the better option. In Berwick, the RF treatment was the best option, giving better growth than the cutover.

A factor needing further consideration is the intensity of the tracking. The further the track extends from the landing, the greater the distance there is between tracks and the less intensive the soil damage is due to fewer machine passes. It may be worthwhile to concentrate on the rehabilitation of tracks in the area close to the landing where tracks merge and converge and soil damage and disturbance is most concentrated. It is likely that the benefits from rehabilitating tracks at the extreme ends away from the landing will be less than that gained close to the landing. The exception to this, is the case of contour tracks where the impact of constructing the track is similar at both ends.

Conclusions

The loss of land from tracks can be significant.

The main issues for tree growth on tracks are compaction and nutrient deficiency.

Ripping and fertilising or ripping and returning soil to the tracks are both effective in mitigating the compaction and nutrient deficiencies.

The ripping and fertilising treatment was cheaper than the ripping and returning soil.

At two of the three trials, the ripping and fertilising has given tree growth rates equal to, or greater than, that of the cutover. At one trial, the fertilising had a slight negative effect on growth.

For the Golden Downs and Berwick trials, the expense of the rehabilitation treatments can be justified by the subsequent tree growth.

When contour tracks are being replanted, trees should be planted on the outer edge of the track.

References

Hall P. (1993a): Skid site rehabilitation. Logging Industry Research Organisation Report Vol. 18 No. 8.

Hall P. (1993b): Logging extraction track rehabilitation. Logging Industry Research Organisation Report Vol. 18 No. 21.

Mason E. G. and Cullen A. W. J. (1986): "Growth of Pinus radiata on ripped and unripped Taupo pumice soil" N. Z. Journal of Forestry Science. Vol. 28 (2)

Murphy G. (1984): "Pinus Radiata survival, growth and form four years after planting off and on skid trails". N. Z. Journal of Forestry Science. Vol 28 (2).

Schuster C. J. (1979): "Rehabilitation of soils damaged by logging in South-west Western Australia". Forest Department of Western Australia - Research Paper No. 54.

Wass E. F., and Smith R. B. (1997): Impacts of cross contour skid roads on properties of a gravelly loam soil and on planted seedling performance. Canadian Forest Service. Information Report BC-X-369 Pacific Forestry Centre, Victoria, British Columbia, Canada.