THE SITE PREPARATION – TRIAL REVIVAL PROJECT: GOLDEN DOWNS SITE

SOIL PHYSICAL PROPERTIES and TREE ROOTING PATTERNS

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Craig Ross[1], John Dando[1], Robyn Simcock[2], Doug Graham[3] and Mark Forward[4]

[1]Landcare Research
Private Bag 11 052
Palmerston North

[2]Landcare Research
Private Bag 92170
Auckland

[3]Forest Research
Private Bag 3020
Rotorua

[4]Weyerhaeuser NZ, Inc.
Private Bag 5
Richmond
Nelson

Landcare Research Contract Report: LC0405/115

PREPARED FOR:
Forest Research
PO Box 29 237
CHRISTCHURCH
for the New Zealand Forest Site Management Cooperative

DATE: May 2005

Reviewed by:

Dr. Roger Parfitt
Senior Scientist

Approved for release by:

Dr. Margaret Lawton
Science Manager

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Project and client

The effects of cultivation (ripping) on forest soil physical conditions, tree rooting patterns, wood production, and windthrow were assessed at rotation end, through Forest Research for the New Zealand Forest Site Management Cooperative. The work was carried out on a trial site established in 1974 in Golden Downs Forest, Christies' Block, Nelson, in May 2005.

Objectives

- To measure soil physical properties across site cultivation treatments on a subset of trials, covering a range of textural classes
- To assess plant rooting patterns
- To correlate soil physical conditions and rooting patterns with changes in tree productivity resulting from the cultivation treatments.

Methods

The effects of cultivation (one-way ripping with a bulldozer) were compared with unripped sites:

- Soil strength profiles and soil physical properties were measured at two depths in cultivated and uncultivated plots
- Surface relief and general tree rooting patterns were assessed
- Soil and root assessments were interpreted for the effects of ripping on wood production and tree windthrow.

Results

- Cultivation by one-way ripping resulted in a U-shaped zone of loosened subsoil down to 65–70 cm depth (cross-sectional area of about 1800 cm^2), still evident after 31 years. The ripping zone of subsoil had significantly lower soil strengths (penetration resistances) and bulk densities but higher macroporosities compared with unripped subsoil. The total available water-holding capacities of subsoil and physical properties of topsoil were not significantly affected by ripping after 31 years.
- Ripping improved root development into the loosened subsoil, particularly medium and large roots. Subsoil loosened by ripping had significantly more roots than unripped subsoil.
- Ripping resulted in a 55 m^3/ha (9%) increase in wood production but this difference was not statistically significant. Ripped blocks also had more uniform wood production compared with higher variability (standard errors) in unripped blocks.
- Ripping improved tree stability against windthrow. This was attributed to better root penetration into the subsoil and the good anchorage provided by the clayey matrix in the Moutere Gravels.

Conclusions

1. Ripping was beneficial and is recommended for Korere hill soils and other similar soils developed on weathered gravels with clayey matrices because:
    - Wood production was increased by ripping.
    - Subsoil loosening and improved root development in the subsoil was still evident after 31 years of forest growth.
    - Trees growing on ripped plots were less susceptible to windthrow than unripped plots. The extra root penetration into the loosened clayey matrix of the Moutere Gravels subsoil improved tree stability to windthrow by providing better anchorage for the trees.

2. The stabilizing effect of ripping the clay-rich subsoil gravels of the Korere hill soils would probably not be achieved by ripping gravels with a sandy matrix. Thus these conclusions are probably not applicable to gravelly soils that have sandy matrices.

1. Introduction

A series of cultivation trials was established in the 1970s and early 1980s by the Forest Research Institute (FRI) on a variety of soils throughout New Zealand to examine the effects of cultivation and fertiliser at time-of-planting. The cultivation/fertiliser experiments were installed as split-plot factorials, with the main plots as the cultivation treatments (either ripping, or ripping and bedding) and fertiliser as sub-plots. Descriptions and early results from the North Island trials were presented in Williamson (1985), Hunter and Skinner (1986), Mason and Cullen (1986), and Mason et al. (1988). More recent reviews of site preparation (Hunter-Smith et al. 1996 and Smith et al. 1996) summarized techniques in New Zealand and overseas, and research on soil compaction during forest harvest and its amelioration by ripping are reported in McQueen et al. (1994), Simcock et al. (1996) and Simcock et al. (1997).

Data on long-term effects of cultivation on wood production (tree productivity) from the FRI trials were collected in the main plots near rotation end, i.e. just before harvest (Skinner et al. 2001a & b). The second component of the project examined soil physical conditions on a subset of the trials, covering a range of textural classes. Comparisons of soil physical conditions and rooting patterns between cultivated and uncultivated plots aimed to help explain the tree production results.

Soil physical conditions and general tree rooting patterns for 6 trial sites in the North Island (Northland and Central Plateau) were reported in Ross et al. (2002a & b, 2004a & b). This report presents the results of examinations of soil physical and root characteristics for a trial site (NN373/1–4) in Golden Downs Forest, Christies' Block in the Nelson area. This forest was formerly within Big Bush State Forest and is currently part of the Weyerhaeuser New Zealand Inc. Golden Downs Forest estate. The stand age was 27 years when wood production was measured and 31 years when the soil and root studies were conducted.

2. Objectives

- To measure soil physical properties across site cultivation treatments on a subset of trials, covering a range of textural classes.
- To assess plant rooting patterns.
- To correlate soil physical conditions and rooting patterns with changes in tree productivity resulting from the cultivation treatments.

3. Methods

The trial was established in 1974. The cultivation treatment was one-way ripping with a bulldozer. The type of ripper used was not recorded.

A control and two representative cultivated sites were selected from Block 4 of this trial. Block 4 was chosen because it was gently sloping and was free of recent wind-throw (unlike Blocks 1 to 3 that were on more sloping, hilly land and had recent wind-thrown trees). The trial is on Korere hill soils, classified as Typic Firm Brown Soils (formerly Yellow-brown Earths).

Penetration resistance (soil strength) profiles were measured to a maximum depth of 0.7 m, along a 3 m transect at right angles to the direction of cultivation (tree rows), using an Eijkelkamp recording penetrometer (*Penetrologger*® model 06.15.01, 30°, 1.6 cm diameter cone at 2 cm/sec). The transects were located about 1 m from trees and were centred on the middle of a row of tree trunks. Soil samples at 10 cm increments down to 70 cm were collected for moisture content profiles, to assess the effect of water contents on penetration resistances (data not presented here).

Microtopography of the ground surface along the same transect was measured from a horizontal (using an Abney level) string mounted on stakes above the highest point of the transect.

A trench was dug to a maximum depth of about 1.5 m using a small hydraulic excavator. A general profile description was made, photographs taken, and a general appraisal of tree rooting patterns made, along with depths to mottling or an impenetrable layer.

Soil cores (about 600 cm^3) from 2 depths (in topsoil and subsoil horizons) were sampled within the loosened ripped zone according to the penetrometer profile or in a similar location relative to the tree row in the control plot. Moisture release, using the methods described in Gradwell (1972), was used to assess macroporosity and total available water-holding capacity. Bulk density was measured from the cores. The data presented are the average of four replicates; all results are given Appendix 1.

The number of wind-blown trees from several recent storm events (in spring 2004 through the summer to the end of March 2005) in blocks 1, 2, and 3 (on hill slopes) was assessed from the first 5 trees in every row (15 rows per treatment) within ripped and unripped plots. There were only two plots (ripped and unripped) for each block. A total of 450 trees were assessed for windthrow.

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4. Results and Discussion

4.1 Soil strength and surface relief

Soil strength[1] profile isopleths for the two ripped plots and one control plot are presented in Figure 1.

Trenches across these profiles (Fig.2–7) showed subsoil differences between the sites, particularly the depth to tight gravels which limit root development. These morphological differences were reflected in the soil strength isopleths. Both ripped sites had tight, somewhat cemented gravels at about 40 cm depth; these gravels were impenetrable to the penetrometer. Impenetrable stones occurred at 15 cm depth at one end of the ripped 1 site transect. In contrast, the control unripped soil profile generally had lower strengths across the transect because there were fewer stones in the subsoil, except for a stony patch around 2–2.5 m across the transect (Fig.1 & 3).

The ripped zones were prominent as U-shaped zones of low soil strength (0–2 MPa) down to about 65–70 cm (Fig.1). The width of loosened soil was about 40–50 cm at 40 cm depth. The cross-sectional area of loosened subsoil was about 1800 cm^2 (0.18 m^2). Loosened subsoil, a consequence of ripping, is evident in the photographs of ripped soil profiles in the trenches (Fig. 4–7).

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[1] Soil strength, as used in this report, is the same as penetration resistance

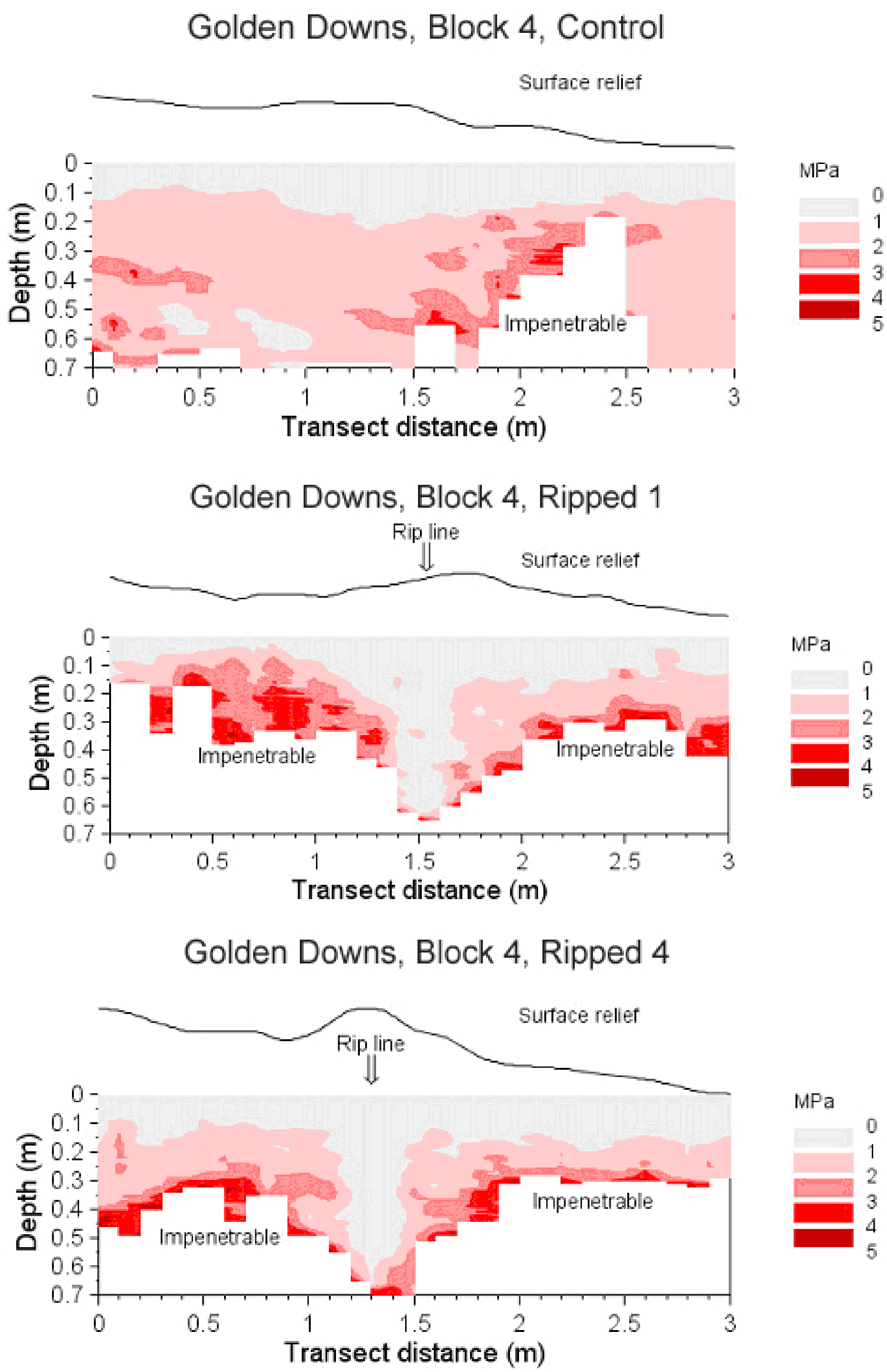

Fig. 1 Soil strength profile isopleths for the Golden Downs cultivation trial NN373.

Ripping left small surface mounds still evident after 31 years, in one case centred on the ripped zone and in the other, offset from it.

4.2 Soil profiles

Fig. 2 Excavating a 3.5 m long by about 1.5m deep trench at right angles to the ripping direction.

Fig. 3 Trench soil profile for the unripped Control plot showing large roots confined to the Ah horizon. The pale zone with iron-pan at base (at 1–1.2m depth, arrowed) is a localized, saucer-shaped gleyed zone. Scale marker is in 10-cm increments in all photographs and the small white flag stems mark the ends of the 3-m transect.

Fig. 4 Trench soil profile for ripped 1 site. Note roots in the U-shaped loosened ripped zone (to about 65 cm, outlined by the dotted line) to the right of the scale marker.

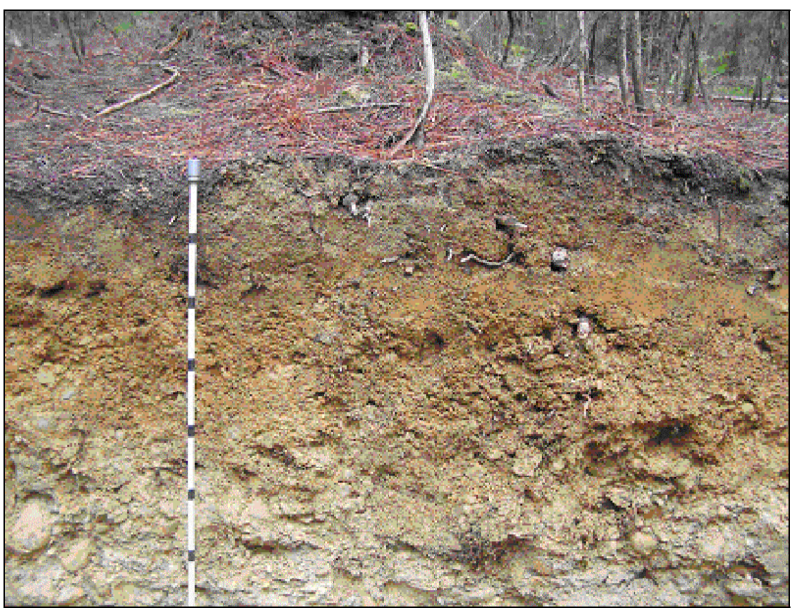

Fig. 5 Close-up of ripped zone for ripped 1 site. Note the roots in the U-shaped loosened zone extending down to about 65 cm to the right of the scale marker.

Fig. 6 Trench soil profile for ripped 2 site. Note roots in the U-shaped loosened ripped zone (to about 70 cm, dotted line) to the right of the scale marker. The blue pen tip points to the bottom of the loosened zone. The white flag stems mark each end of the transect.

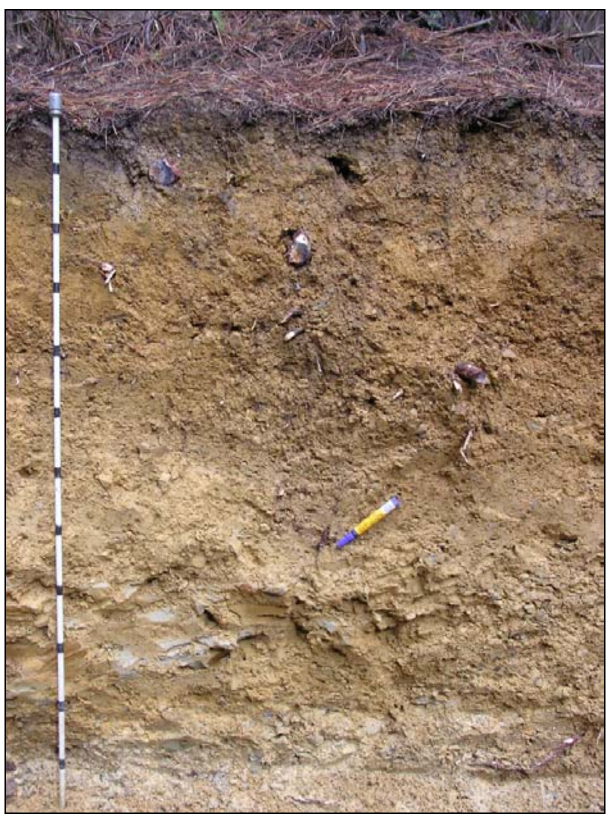

Fig. 7 Close-up showing roots in a U-shaped loosened zone down to about 70 cm (marked by the pen) for ripped 2 site. Scale marked in 10-cm increments.

4.3 Bulk density, macroporosity and total available water-holding

Soil physical properties are presented in detail in the Appendix1. There were no significant differences in bulk densities, macroporosities and total available water-holding capacities in the 1–10 cm topsoil layer (Fig. 9, Appendix 1). However, in the subsoil (20–44 cm zone) the ripped, loosened zones had significantly lower bulk densities (average 1.03 g/cm^3) and higher macroporosities (average 29.6%) compared with the unripped control (1.35 $g/cm^3$and 7.4% respectively). These soil physical changes from ripping, combined with much lower soil strengths, allowed roots to readily penetrate the clayey matrix of the stoney (Moutere Gravels) subsoil. Root penetration into unripped subsoil was very restricted, comprising occasional fine and very fine roots down to about 1m depth. In contrast, ripping did not alter total available water-holding capacities of the susboils (8.2% ripped cf 8.9% unripped at 20–44 cm.).

Fig. 8 Sampling cores in the ripping zone for soil physical analyses.

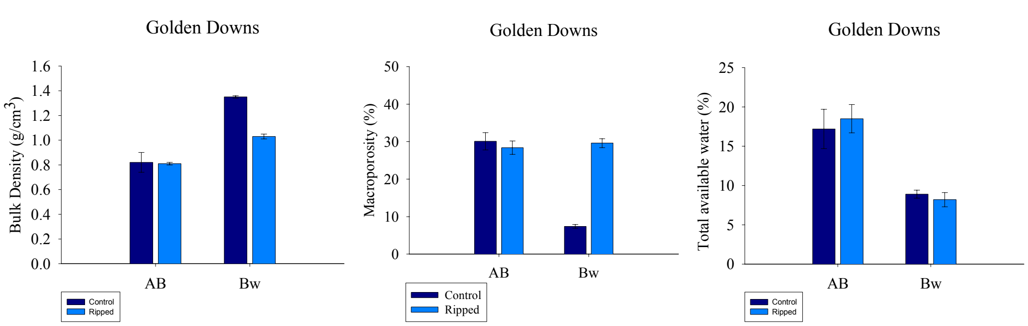

Fig. 9 Bulk density, macroporosity and total available water at two depths (Topsoil Ah 0–10 cm horizon and within the subsoil Bw horizon in the 20–44 cm zone), ± sem.

4.4 Rooting patterns
Rooting patterns are shown in Figs 3–7. Thirty-one years after cultivation, there were significantly more roots in the ripper-loosened subsoil than the unripped subsoil. Particularly noticeable were the much more abundant medium to large roots in the loosened zone than in the uncultivated subsoil. Outside the ripped zone and in the unripped control site, larger roots were essentially confined to the topsoil (Ah) and mixed topsoil/subsoil (AB) layers. Fine and very fine roots were also much more numerous in the ripped zone of subsoil compared with the unripped subsoil, although occasional, mostly fine and very fine roots were scattered through the gravel matrix of the unripped subsoil down to about 1 m.

Ripping may enhance juvenile tree growth on these soils by improving the volume of subsoil occupied by roots. A risk of periodic summer droughts in Golden Downs Forest suggests that more extensive rooting in the subsoil would improve water supply to trees under droughty conditions, given that total available water-holding capacity was not affected by ripping.

4.5 Wood production and windthrow
Tree performance, as measured by wood production, is presented for the Golden Downs cultivation trial in Fig. 10. Wood production increased by about 55 m^3/ha or 9% after ripping but this was not statistically significant. It is interesting to note that wood production varied much less between different blocks in ripped treatments (se 31 m^3/ha) compared with unripped controls (se 74 m^3/ha).

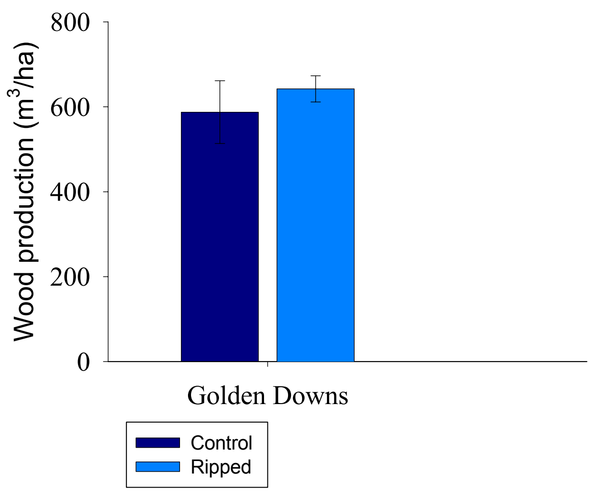

Fig. 10 Effect of ripping cultivation on harvest wood volume (± sem) at the Golden Downs cultivation trial site NN373 (from Skinner et al. 2001b).

Windthrow data from the subsample assessments for all 3 blocks (Table 1) show 28 windthrown trees (28%) for controls compared with 5 for ripped (2%). This suggests that ripping helped tree stability, perhaps by allowing deeper rooting into the subsoil. This finding is contrary to what might be expected from long-term soil loosening by ripping. The key factor is thought to be the clayey matrix of the Moutere Gravels in the Korere hill soils. Despite being loosened by ripping, the soil is still strong enough to withstand the forces of tree movement during gale-force winds. Thus, ripping, by promoting extra rooting into the subsoil, enhances tree stability through better anchorage. However, this benefit would probably not be achieved by ripping gravels with a sandy matrix since soil strength in such subsoils would be insufficient to withstand the wrenching effect of tree and root movement under gale-force winds.

Table 1. Effect of ripping on tree windthrow. Numbers and percentage of windthrown trees in subsamples of trial blocks 1–3 on hilly slopes.

Block	Control	Ripped
1	11	5
2	8	0
3	9	0
Total	28(12%)	5(2%)

5. Conclusions

1. Ripping was beneficial and is recommended for Korere hill soils and other similar soils developed on weathered gravels with clayey matrices because:
   - Wood production was increased by ripping.
   - Subsoil loosening and improved root development in the subsoil was still evident after 31 years of forest growth.
   - Trees growing on ripped plots were less susceptible to windthrow than unripped plots. The extra root penetration into the loosened clayey matrix of the Moutere Gravels subsoil improved tree stability to windthrow by providing better anchorage for the trees.
2. The stabilizing effect of ripping the clay-rich subsoil gravels of the Korere hill soils would probably not be achieved by ripping gravels with a sandy matrix. Thus these conclusions are probably not applicable to gravelly soils that have sandy matrices.

6. Acknowledgements

The authors thank Weyhaeuser staff in Nelson who cooperated with us on this project. Peter Clinton, Forest Research is thanked for her help with administering the project. We appreciated Roger Parfitt's helpful review of the report and Peter McGregor's editing.

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