THINNING OF RADIATA PINE BY CRAWLER TRACTOR ON STEEP SLOPES IN NORTH-EASTERN VICTORIA: A PRELIMINARY STUDY

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(Received for publication 3 December 1981; revision 29 March 1982)

ABSTRACT

Machine productivity, damage to the retained trees, and degree of site disturbance in a delayed first-thinning operation were measured in a preliminary study during 5 working days in August 1980, in a stand of 18-year-old radiata pine (**Pinus radiata** D. Don) in the Merriang Plantation on slopes in excess of 50% (26.5°). The average daily productivity measured during this short study was compared with records from operations on a range of slopes in the locality. Skid tracks constructed prior to the study were not included in productivity calculations, though the cost of these tracks was only 4% of the total cost of the operation. There was no evidence that slope had a substantial effect on productivity but further detailed studies, over a comprehensive range of slope classes and sites, are necessary. During the steep terrain thinning study 17% of retained trees were damaged, though for radiata pine this is likely to cause only a minor loss in value of the final crop. In the study area 25% of the soil surface was disturbed; however, the combination of stable soils and frequent cross-drainage of skid tracks should minimise the likelihood of significant soil erosion.

INTRODUCTION

Background

A total of approximately 18 273 ha of softwood plantations have been established in north-eastern Victoria in the Ovens Plantation Zone which comprises Beechworth, Bright, and Myrtleford Forest Districts. Planting of radiata pine in the zone began in 1916 at Bright on land heavily disturbed by gold dredging. Plantations on steep foothills cleared of indigenous forest were first established on a substantial scale at Myrtleford in 1927. During the following decade, large areas of such land at Myrtleford, Bright, and Stanley (near Beechworth) were cleared by hand and planted, to provide employment for men on Government sustenance during the Depression. The rate of plantation establishment declined during World War II (Fig. 1) and did not markedly increase until 1962. The average area planted between 1962 and 1980 has been 630 ha/year.

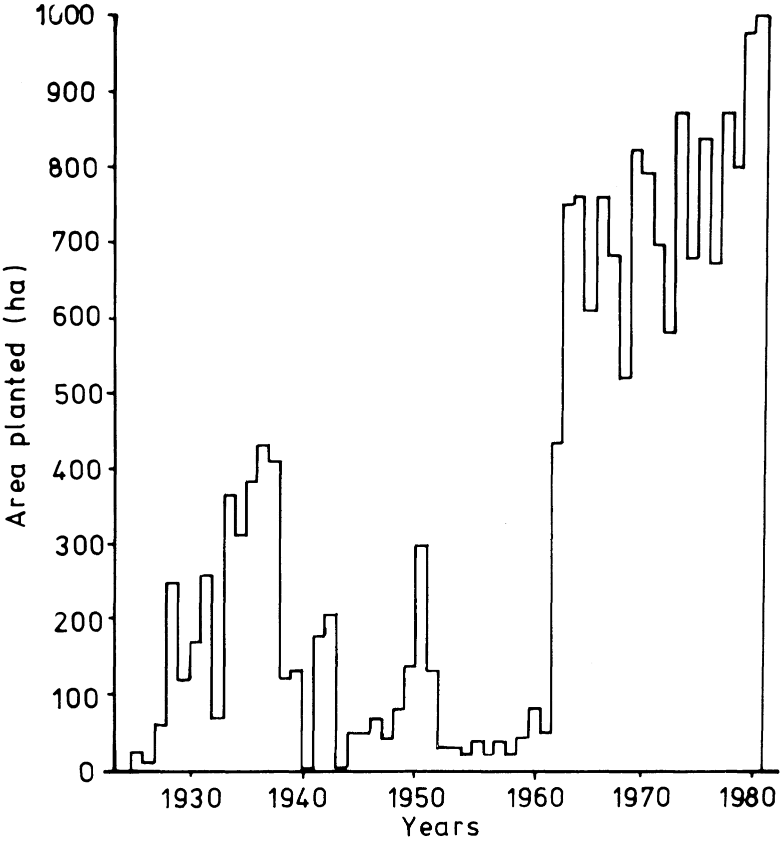


FIG. 1—Annual planted area of conifers in the Ovens Plantation Zone between 1925 and 1981.

Plantation establishment is currently confined to land with slopes of generally less than 36%, though there are large areas of steeper terrain in the older plantations. The proportions of the Bright, Beechworth, and Myrtleford plantations in moderate (0–30%), steep (30–50%), and very steep (> 50%) slope classes are given in Table 1. More than half of the Bright and Myrtleford plantations are located on slopes steeper than 30%, which approximates the operational limit of skidders and mechanised harvesting systems.

A high proportion of the plantations in all slope classes have been planted at an espacement of 2.4 × 2.4 m (1680 stems/ha) and progressive thinning of these stands is required to maintain health and stability to wind and to enhance sawlog production.

The area of plantation that will fall due annually for first thinning will vary from 500 to 900 ha during the next decade.

TABLE 1—Proportions of Beechworth, Bright, and Myrtleford Plantations in three slope classes

District	Plantation area (ha)	Proportions in three slope classes*		
		0–30%	30–50%	>50%
Beechworth	3956	0.83	0.15	0.02
Bright	5133	0.43	0.31	0.26
Myrtleford	9184	0.42	0.44	0.14

* 30% = 17.5°; 50% = 26.5°

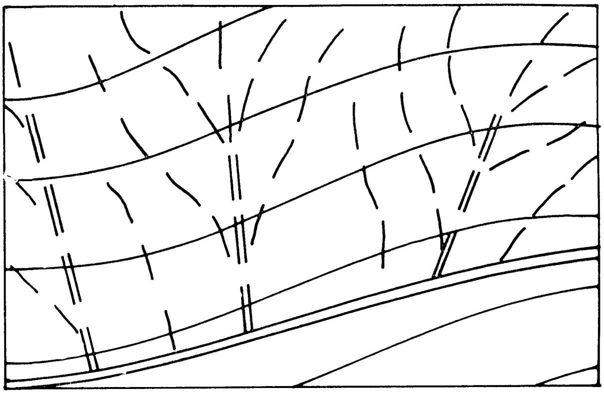
Methods of Thinning in the Ovens Plantation Zone

Small crawler tractors are the most common machines used for both thinning and clearfelling in the Ovens Plantation Zone. Skidders are used less frequently, and mechanised harvesting systems have only recently been introduced. Mechanised systems and skidders are generally restricted to slopes of less than 36% for thinning operations, whereas crawler tractors are used on all slopes. Trials of cable systems in the zone have shown them to be suitable for thinning, though they have never been used on a permanent basis (Lembke 1979); this is because the cost of cable thinning of steep terrain is 50–100% higher than the cost of thinning similar-sized stems on flat-to-undulating ground using conventional ground-skidding systems (Galbraith & Sewell 1979; Aulerich *et al.* 1976).

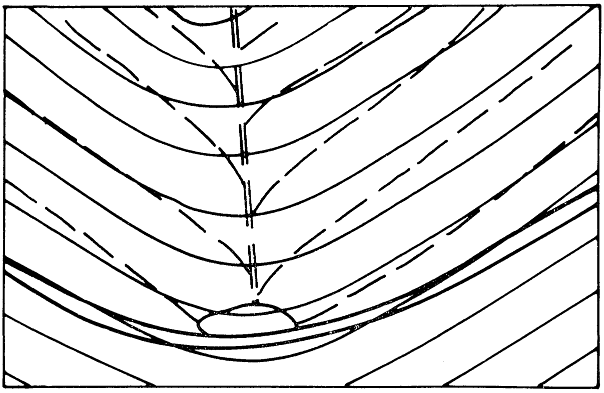
Various techniques are used for thinning steep terrain by crawler tractor, depending on the slope and topography of the logging coupes. For slopes between 30 and 50%, primary and secondary skid tracks generally do not require excavation and are merely conveniently located pathways leading downhill to a roadside landing (Fig. 2a). For slopes greater than 50%, skid tracks are constructed throughout the area to be thinned. Where they exist, spurs are generally used for both landings and primary skid tracks since minimal earthwork is required. Secondary skid tracks are of bench-type construction, approximately 25–30 m apart, and are parallel and gently sloping (Fig. 2b). When the distance between spurs exceeds about 500 m, the layout consists of a set of parallel skid tracks running diagonally across the face of the logging coupe at an angle of approximately 45° to the direction of maximum slope (Fig. 2c). The spacing of these skid tracks is generally 30–40 m and their slopes are 30–40%.

Trees are felled towards skid tracks at an acute angle, to minimise damage to the felled stems and standing trees when the stems are winched to the tractor. Currently, directional felling aids are not used in this zone.

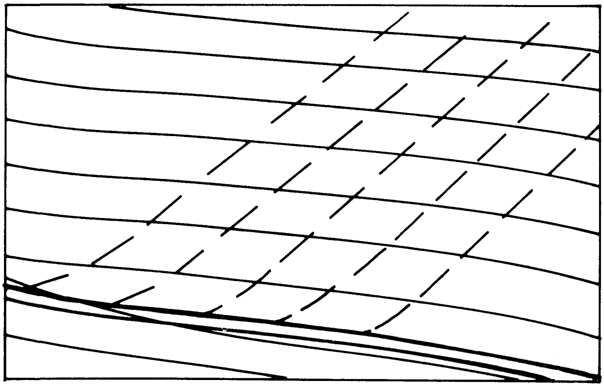
In recent years, thinning in the Ovens Plantation Zone has been confined to areas of moderate slopes, steep terrain being thinned only when it has formed part of an otherwise moderately sloping coupe. The productivity, site disturbance, and stand damage were recorded in a preliminary study of thinning on slopes predominantly in excess of 50%. The average daily productivity measured in this study was compared with that calculated for a steep terrain thinning trial and for three routine thinning operations on moderate slopes in the Ovens Plantation Zone.



a. for coupes with slopes between 30 and 50%.



b. for coupes intersected by a spur and with slopes greater than 50%. A landing is shown.



c. for coupes with uniform slopes greater than 50%.

FIG. 2—Common layouts of skid tracks for steep terrain thinning (solid lines are contour lines).

PRODUCTIVITY OF THINNING OPERATIONS

Thinning Operation on Steep Terrain

A study of a delayed first-thinning operation was carried out in an 18-year-old stand of radiata pine in the Merriang Plantation near Myrtleford, during 5 working days in August 1980. A three-man logging crew used a John Deere 450C crawler tractor to thin a 0.94-ha area of plantation bounded by a spur, a gully, and two roads (Fig. 3). Slopes varied from an average of 30% along the spur to a maximum of 55% near the gully. The mean annual rainfall of this locality is approximately 1200 mm and the elevation ranges from 270 to 660 m. Stand parameters before and after thinning are listed in Table 2. The average stem volume for this delayed thinning was larger than would be expected for an on-schedule first thinning. Assessments in this locality have shown that on-schedule first thinnings will yield an average stem volume of around 0.13 m^3 (R. J. Steiner, formerly Forests Commission Victoria, pers. comm.), compared with 0.25 m^3 in this study (Table 3).

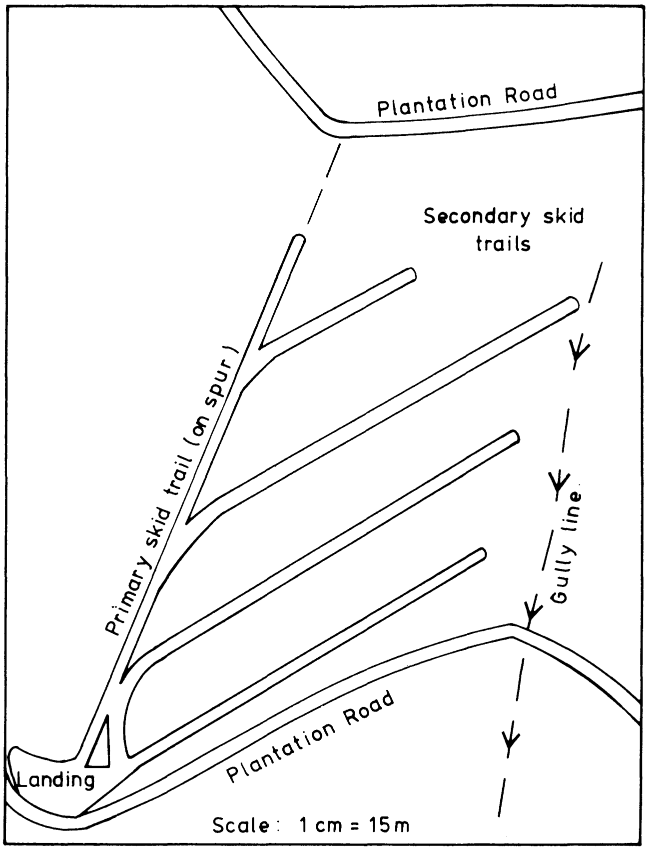


FIG. 3—Layout of skid tracks in study area.

TABLE 2—Characteristics of the stand before and after thinning

Stand parameters	Before thinning	After thinning
Stocking (stems/ha)	1495	466
Basal area (m^2/ha)	48.6	23.1
Mean d.b.h.o.b.* (cm)	19.8	23.4
Top height† (m)	26.6	26.6
Site Index‡	28.7	28.7

* Diameter at breast height over bark.

† Mean height of the three tallest trees in each of four 0.03-ha plots.

‡ Site Index is defined as the estimated stand height (m) at age 20 years.

TABLE 3—Crew productivity data for three men and a John Deere 450C crawler tractor, thinning on steep terrain

Production in 5 days (t)	150.4
Productive machine hours*	33.0
Crew productivity (t/h)	4.6
Average stem volume removed (m^3)	0.25
Average number of pieces per skid	5.7
Average volume per skid (m^3)	1.4
Average skid distance (m)	89.0
Average number of skids per day	26.4

* Not including construction time (4 hours) for 430 m of tracks prior to commencement of thinning operation.

Before felling began, four secondary skid tracks were constructed approximately 30 m apart, using the crawler tractor. These tracks totalled 430 m in length and were constructed in 4 hours. No trees were extracted during this operation. An additional 110 m of secondary tracks were constructed during the thinning operation. The primary skid track was located on a spur and the only requirement for its formation was the extraction of a row of trees.

The logging crew comprised two fellers and a crawler tractor operator. The crew productivity and factors associated with it are given in Table 3. As well as felling and delimbing trees, the fellers helped with attaching chokers and, occasionally, with bucking at the landing. The tractor operator performed all operations associated with extraction of the stems and, generally, also bucked the stems at the landing.

The activities of the tractor operator were divided into elements and the time spent on each was measured (Table 4). Skid distance and the number and volume of stems in each skid were also measured. Each load of timber hauled from the operation was weighed, thus providing the total weight of timber extracted during the study.

TABLE 4—Percentage of productive machine hours for crawler tractor operator by elements of operation

Activity of tractor operator	Percentage of productive machine hours
Track construction*	7.2
Travel to felled stems	8.6
Position and clear	6.8
Choke stems	21.6
Winch stems to tractor	4.9
Travel to landing	9.5
Unchoke stems	10.9
Buck stems	12.5
Heap logs	7.9
Delays	10.1

* Not including construction of 430 m of tracks prior to commencement of thinning operation.

The 33.0 productive machine hours (Table 3) in 5 working days represents a machine utilisation of 82.5%, using the Canadian Pulp and Paper Association definition (McMorland 1980):

$$\text{Machine utilisation} = \frac{\text{Productive machine hours} \times 100}{\text{Scheduled machine hours (8 hr/day)}}$$

Utilisation in this short-duration study is similar to an average machine utilisation of 79% recorded by McMorland (1980) in a study of 1110 shifts of logging crews working with small crawler tractors.

Not all of the time spent constructing tracks was included in the productive machine hours of Tables 3 and 4. It is normal practice for the contractors who carried out the thinning to construct benched tracks before steep terrain logging commences, and approximately 85% of the required tracks were constructed 3 weeks prior to the commencement of this study; this track construction was not included in productivity calculations because it did not directly affect the productivity of the three-man thinning operation but, rather, was a cost of the operation (4% of total cost). The 4 hours of preliminary track construction required for this 0.94-ha study area is representative of the average time of construction required per week of operation on steep terrain in this locality, where rock outcrops are infrequent, though it may be different for other localities in the zone. The track construction during the logging operation was less efficient than the construction before logging commenced (an average construction rate of 45 m/hour compared with 110 m/hour) because different operators were used, one being less experienced in constructing narrow tracks on steep slopes.

The average skid distance in the study (89 m) is probably less than usual for this type of thinning, and the long-term average skid distance may be as high as, say, 150 m in routine operations on steep terrain. If the average skid distance was 150 m instead of 89 m, the proportion of productive machine hours involved in travelling (Table 4) would increase from 18.1% to 27.2%, the average number of skids per day would drop from 26.4 to 23.4 and productivity would decline by 11%. This illustrates the influence of skid distance on productivity.

The fellers had considerable difficulty with felling trees in the desired direction during the study and, when the felled trees were scattered, it was necessary to winch individual stems or small groups of stems to the tractor separately, rather than in a bunch. The lack of precision in felling also necessitated delays whilst hanging trees were freed. The length of time during which the tractor operator was involved in choking or delays could possibly be reduced if directional felling techniques were used by the fellers. Additionally, if a better felling pattern could be achieved, it would then be feasible to attach extra chokers to the winch rope so that more stems could be choked per skid.

Comparisons between Productivities of Trial and Routine Operations

In Table 5, the average daily productivity for the present study is compared with that for a steep terrain thinning trial and for three routine thinning operations on moderate slopes (the time taken to construct skid tracks by crawler tractors prior to commencement of steep terrain thinning is not included in the calculations of productivity). The data for operations 2 to 5 were obtained from Australian Forest Industries records of the location of each logging crew and weighbridge dockets of loads hauled. Records of daily attendance of individuals and of major delays due to mechanical breakdowns were not available.

The data from operations 2 to 5 were not sufficiently detailed to allow definitive comparisons between the productivities of the steep terrain study and these operations as neither stem volumes nor skid distances were measured. To isolate the influence of slope on productivity, reliable data on average stem volume, skid distance, crew attendance, and major mechanical breakdowns would be required. Nevertheless, the average daily productivities of both the study and the trial on steep terrain were within the range of those of the three routine operations on moderate slopes. This indicates that, under the conditions of the five operations considered, slope may not have substantially affected productivity; variations in crew efficiency, average stem volume, and average skid distances are possible confounding factors.

Machine productivity would be expected to be highly dependent on stem volume because the volume of each skid is determined by the number of stems that can be choked rather than by the capacity of the crawler tractor to skid the load. This probably accounts for the low productivity of operation 5, which was undertaken in a low site-quality stand, where average stem volume was estimated by the Australian Forest Industries Logging Supervisor to be 0.15 m^3 compared with 0.25 m^3 measured in operation 1. Likewise, the relatively high productivity measured in operation 2 on steep terrain may have been partly due to a large average stem volume from this 29-year-old stand.

TABLE 5—Productivity of trial and routine thinning operations

Operation	Type of thinning	Location and compartment	Plantation age (years)	Slope (%)	Machine	No. of days of operation*	Average daily productivity (t/day)
1	Delayed first (present study)	Myrtleford, Merriang 109	18	> 50	JD450†	5	30
2	Delayed first (trial)‡	Myrtleford, Merriang 112	29	> 50	JD450	9	33
3	Delayed first	Myrtleford, Merriang 116	17	< 30	JD450	48	28
4	Delayed first	Myrtleford, Merriang 116	17	< 30	JD450 Skidder	24§	34
5	On-schedule first‖	Beechworth, Stanley 001	17	< 30	Skidder	66	17

* Wet days not included. For operations 1 and 2 most tracks were constructed before the commencement of the logging operation.

† John Deere 450C crawler tractor

‡ Small part of stand was thinned 6 years previously

§ Two crews operated to the same landing on 3 of the 24 days

‖ On a markedly lower site quality than were operations 1 to 4

STAND DAMAGE ON STEEP TERRAIN

On the 0.94-ha study area of the steep terrain thinning, all standing trees were assessed for damage after the operation. A total of 17.4% of the residual trees were damaged during the thinning; 8.0% had scars less than 50 cm^2 and the other 9.4% had larger scars. Damage was mainly confined to the butt and is likely to cause only minor loss in value of the final crop of radiata pine, assuming that the crop will be harvested mainly for sawlogs rather than peelers.

The main causes of damage observed were track construction, skidding around trees, and winching stems to the tractor. The tractor operator was careful in constructing tracks and in skidding, but could not avoid damaging standing trees where felled stems were not aligned towards the track. It is estimated that half of the damage occurred whilst stems were being winched to the tractor and this could have been substantially reduced if directional felling techniques had been used.

SOIL DISTURBANCE ON STEEP TERRAIN

The degree of soil disturbance on the study area was assessed by measuring the width of exposed soil and the depth of cut every 20 m along all skid tracks. The average width of skid tracks was 4 m and they occupied approximately 25% of the coupe area; this is similar to the findings of Smith & Wass (1976) in a study of soil disturbance on clearfelled sites in Canada. They found that 30% of the ground in logging areas with slopes ranging from 30 to 60% was disturbed by skid tracks. No measurements of soil disturbance were made on the moderately sloping sites of operations 3 to 5 but observations indicated that, although the incidence of soil disturbance was similar to if not higher than that on the steep terrain, the severity of disturbance was considerably lower because fewer side-cuts were required.

In constructing the secondary tracks, 405 m^3 soil/ha was displaced. This disturbance is unlikely to be associated with significant erosion because most tracks were either on the contour or gently sloping, so that it was relatively simple to construct cross-drains at frequent intervals to divert runoff into undisturbed ground litter. But the primary skid trail was steeper (up to 40%) and it was therefore more difficult to construct cross-drains without damaging standing trees. This track will possibly produce substantial runoff during heavy storms, though it is unlikely that serious erosion will occur because the red clay loams in this locality are extremely stable (senior author, unpubl. data).

CONCLUSIONS

It is feasible to thin steep terrain by crawler tractor, and comparisons using limited data from routine operations revealed no evidence that slope had a substantial effect on productivity. Skid tracks constructed prior to the study were not included in productivity calculations, though the cost of these was only 4% of the total cost of the operation. However, further detailed studies over a range of slope classes and sites are necessary in order to determine the effect of slope on productivity.

During the steep terrain thinning study 17% of retained trees were damaged; however, for radiata pine this is likely to cause only a minor loss in value of the final crop.

In the steep terrain study area 25% of the soil surface was disturbed, primarily by construction of skid tracks. Soil erosion is not expected to be a problem, because the soils in this locality are extremely stable and most tracks were cross-drained at frequent intervals so that track runoff flowed into undisturbed ground litter.

ACKNOWLEDGMENTS

The productivity study of steep terrain thinning was a joint project between the CSIRO Harvesting Research Group and the Forests Commission Victoria, and John Ward of Queensland Department of Forestry is thanked for initiating and carrying out the productivity study, whilst on secondment to CSIRO. The study would not have been possible without the co-operation of Ted Fenn's logging crew; the logging contractors, Cunneen Bros.; and the mill, Australian Forest Industries. In the particular, our thanks go to Wally Cunneen and Ron Cherry. We are grateful to the Myrtleford staff of the Forests Commission Victoria, under Bernie Evans, for assisting with the project. Richard Steiner was particularly helpful in this regard.

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