Benefits, Problems and Costs of Excavators and Bulldozers used for Clearing Operations in Southern Tasmania

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Abstract

Benefits, problems and costs of operation of large, tracked excavators with and without bulldozers for clearing clearfelled coupes prior to establishment of eucalypt plantations are considered for four sites in southern Tasmania. Clearing occurred in 1989, 1990 or 1991. Average cost for bulldozers to push and pile was $883/ha compared with $1186/ha when used with an excavator to rake and pile and $1222/ha when excavators were used alone. Greater cost incurred by using an excavator was offset by reduced site disturbance and loss of topsoil, and increased land for planting through a reduction of area lost under windrows.

Introduction

The satisfactory establishment of eucalypt plantations on clearfelled coupes and at other sites which have previously supported forest demands the formation of planting areas which are free of slash and, if practicable, stumps. Clearing should aim to minimise site disturbance and loss of topsoil and to maximise the area available for planting. While this may involve additional cost prior to planting, major benefits can be obtained subsequently. For example, post-planting management is greatly facilitated as fertilizers and herbicides can be applied manually or from tractor-mounted devices, more uniform growth rates are obtained throughout the plantation within the genetic constraints of the planting stock, and costs of thinning, harvesting and the establishment of subsequent rotations are reduced.

Until recently, clearing operations in southern Tasmania have been done by bulldozer. A major disadvantage of these machines is the potential to remove large quantities of soil with the slash and stumps. Use of raker blades reduces this problem but they are no better than conventional blades for either stump removal or placement of woody material into windrows and piles. Large tracked excavators are now available that can rake and stack debris without incurring soil loss as well as being able to remove stumps. If necessary, they can be used in conjunction with one or more bulldozers.

This paper considers the problems, benefits and costs associated with using an excavator assisted by bulldozers, and alone, for clearing after clearfelling at four sites in the Geeveston District of the Forestry Commission, Tasmania.

Methods

The excavator

The machine was a Caterpillar E300 (Hazell Brothers, contractor) with a working arm of 13 m radius (Table 1). The prime mover

Table 1. Specifications of clearing machinery.

Specifications	Bulldozer Caterpillar D6H	Bulldozer Caterpillar D7H	Excavator Caterpillar E300
Flywheel power (kW)	123	160	135
Operating weight (t)	17.8	24.2	30.1
Standard track-shoe width (mm)	560	560	800
Length of track on ground (m)	2.62	2.90	4.82
Ground contact area (m^2)*	2.94	3.24	7.71
Ground pressure (kPa)†	59.0	73.0	43.1

* Ground contact area = width of track shoe x length of track on ground x 2

† Ground pressure = $\frac{\text{operating weight}}{\text{ground contact area}}$

carried either a six-pronged finger raker incorporating a thumb grab, or a 1.2 or 2.0 m width excavating bucket. Each piece of equipment could be disconnected or connected by a hydraulically operated quick-release mechanism of proprietary manufacture. The finger raker was designed and built by Hazell Brothers in conjunction with Australian Newsprint Mills Forest Management (ANM/FM) and the thumb grab was modified from equipment of standard manufacture (Photo 1).

Clearing and site description

Creekton Road (Hastings coupes H4b, c). An 83-hectare block of clearfelled eucalypt regrowth was cleared and windrowed between January and March 1989 (Raminea Topographic Sheet 4820: 929005) at Creekton Road preparatory to eucalypt plantation establishment (Fig. 1). The regrowth originated from a wildfire in 1914. Based on data from regrowth management assessment plots, Site Index (Lawrence 1981) of the *Eucalyptus obliqua* stand was 37.0 m.

In addition to the stumps and slash left after clearfelling, further difficulties were caused by residual pulpwood and fuelwood (> 200 t/ha). This had not been removed due to mill closure and the non-availability of an on-site chipper prior to clearing. A chipper became available after clearing commenced and 4255 t of fuelwood were removed from an unmeasured area of the coupe. During clearfelling, pulpwood and sawlog were removed at 270 and 57 t/ha respectively.

The block was divided into four compartments (A, B, C, D) of approximately 20.5 ha each (Fig. 1). Two compartments (A, B) comprising Creekton B (where B = bulldozer treatment, X = excavator and BX = combination) were cleared with partial stump removal using a Caterpillar D6 bulldozer and a machine equivalent to a Caterpillar D7. The remaining compartments (C, D) comprising Creekton BX were cleared with total stump removal using a D7 bulldozer working in conjunction with the E300 excavator. The bulldozers were fitted with standard blades. On Creekton B, the bulldozers (G. H. Norris, contractor) were able to push 80% of stumps within an operational time limit of three minutes per stump. This time limit was imposed at all sites with all machines. Stumps that did not break out in that time were left in place. All stumps and ground debris were then pushed, as far as topographical constraints allowed, into windrows aligned at 50 m intervals. Windrows were formed along and across contours within the prescribed limits of the Forest Practices Code (Forestry Commission 1989). The excavator broke up and removed all stumps on Creekton BX, and was used to stack these and the debris pushed by the bulldozer into windrows aligned as per Creekton B.

Creekton Road (Hastings coupe H3d). A second area of 20.9 ha, Hastings B, at Creekton Road (FCT in Fig. 1) was cleared in 1989. The block was contiguous with and of similar history and Site Index (37.0 m) to coupes that comprised Creekton B and Creekton BX (Fig. 1). The pulpwood and sawlog cuts were removed at 262 and 51 t/ha respectively. Logging residue was considerably less than that on Creekton B and BX. This block was cleared and windrowed with the same D7 and D6 bulldozers as above.

Esperance Road. Nine hectares of depauperate forest, Esperance BX, adjacent to the junction of Peak Rivulet and Esperance Roads (Raminea Topographic Sheet 4820: 913063) were cleared in 1990. Site Index was estimated as 28.0 m.

Aerial photographs illustrated a mosaic of scattered *Eucalyptus obliqua* oldgrowth of average height 34-41 m, with patchy stands of *E. obliqua* and *E. nitida* regrowth of average height 15-27 m and dense stands of *Melaleuca*

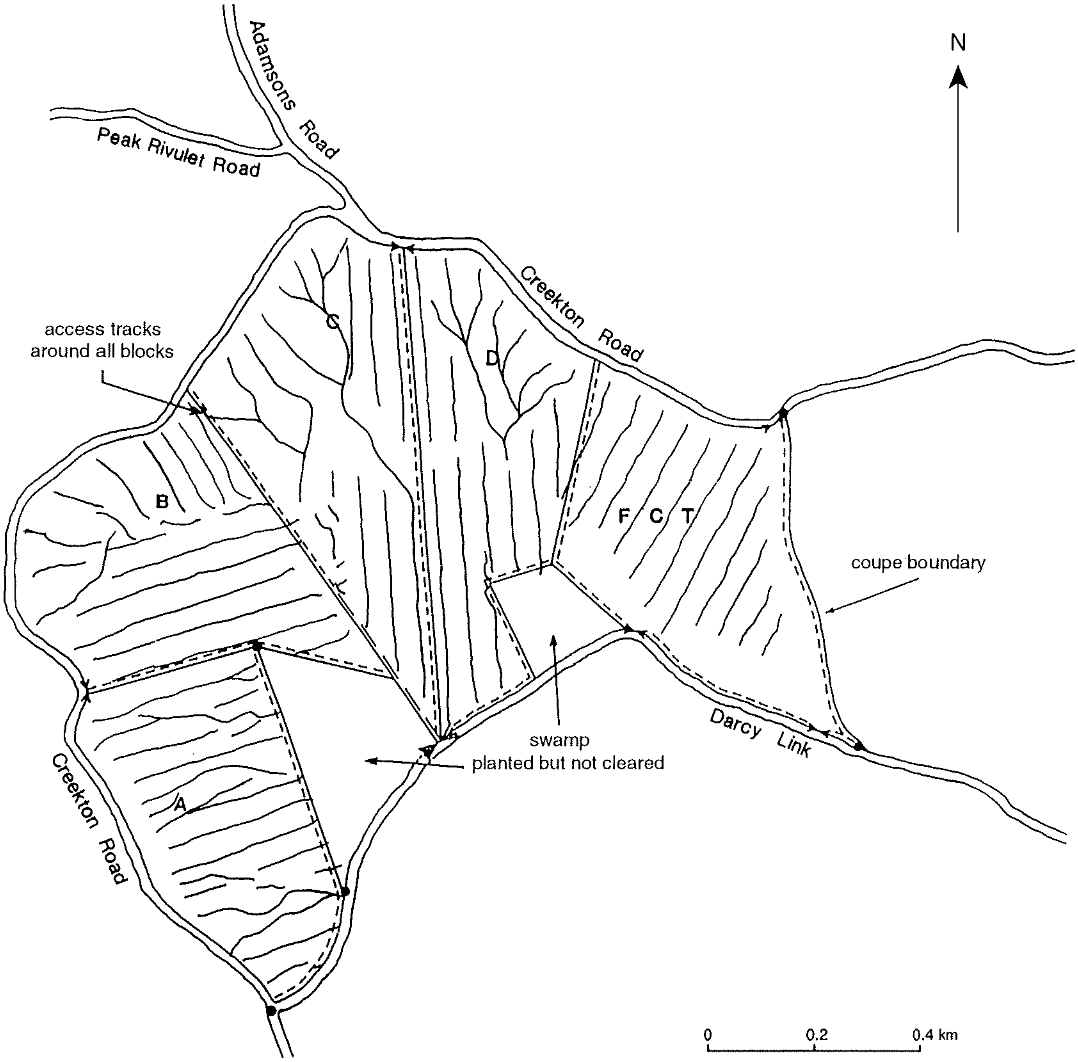

Figure 1. The two plantations at Creekton Road. Compartments labelled A and B coincide with Creekton B, compartments C and D coincide with Creekton BX; the area labelled FCT coincides with Hastings B. Lines inside compartments represent windrows. (For further information see text.)

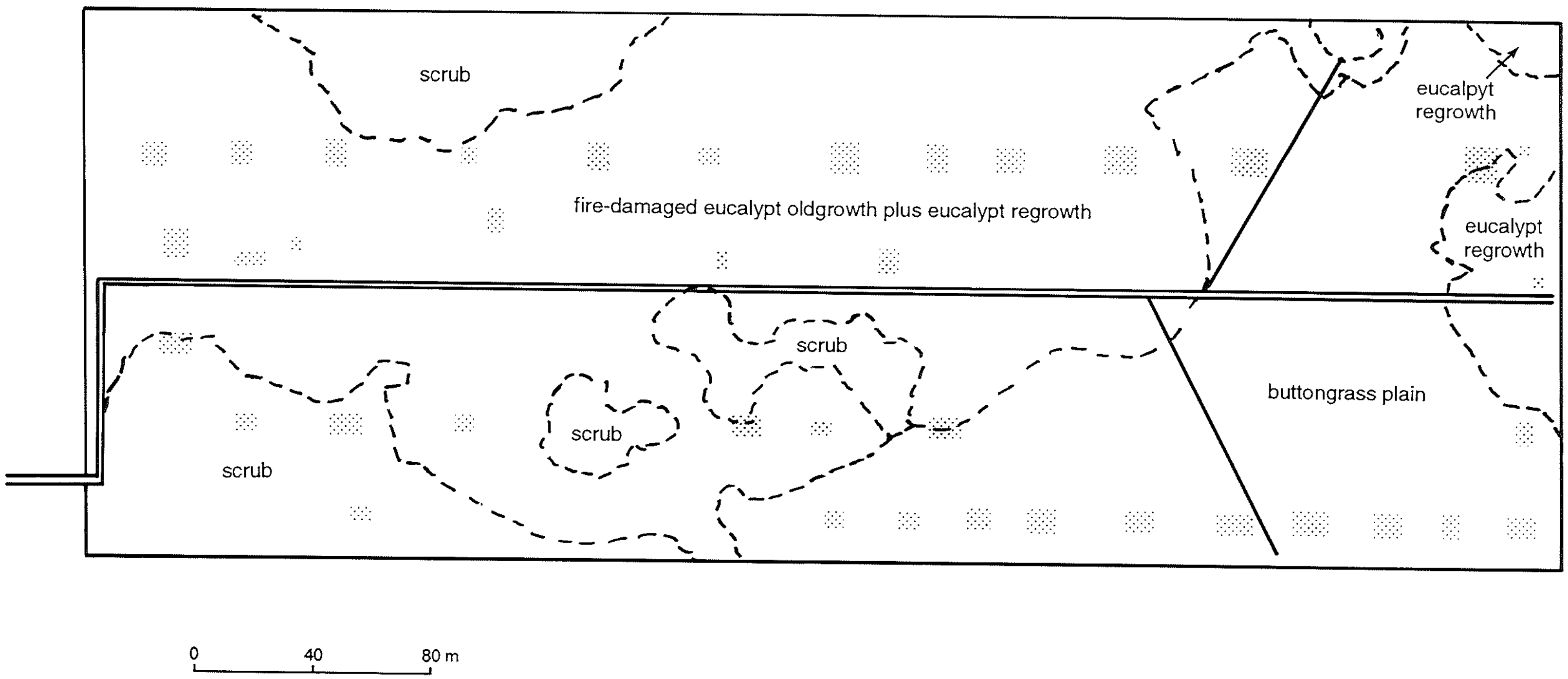

Figure 2. Distribution of existing vegetation at Esperance BX before clearing. The continuous lines within the plantation boundary mark the 2.0 m (double line) and 1.2 m (single line) drains. The stippled rectangles are the residual piles of unburnt slash at completion of clearing.

squarrosa and *Leptospermum lanigerum* interspersed with dense *Gahnia grandis* (Fig. 2). The area included approximately 1 ha of buttongrass *(Gymnoschoenus sphaerocephalus)* plain with *Pteridium esculentum* (bracken), and overall was unsuitable for a merchantable cut of sawlog or pulpwood.

A D7 and a D6 bulldozer (T.A. Field, contractor) were used to push all standing trees and roll down the scrub. A planned approach to raking and piling was devised for an E300 excavator, which aimed at maximising the ultimate area of ground available for planting whilst minimising machine movement.

The excavator was fitted with the finger raker previously described. This was used initially to rake the dense tangle of rolled-down scrub and overstorey heads into rows of piled material along pegged lines parallel to the long axis (500 m) of the level planting block. As the block was bisected by a central drain (see Fig. 2), the pegged lines were positioned at 15, 45 and 75 m from each side (block width was 180 m). Given the working radius of 13 m, the excavator was able to rake and pile with minimum movement over three zones, *viz.* 0-15-30, 30-45-60 and 60-75-90 m. The excavator then constructed discrete piles along these lines from the wall of raked material. Two ground crew were employed in cross-cutting material either too large or too long for manipulation by the excavator, and larger logs and stumps were stacked on top and the piles set alight.

At the beginning of each day, the excavator restacked partially burnt piles, and where possible, combined remnants of burnt piles with larger piles to reduce the area of unavailable ground. New piles were rekindled or set alight by the ground crew.

Arve (Arve coupe AR 22b). A 73-hectare block of clearfelled eucalypt regrowth and oldgrowth was cleared and windrowed by the Forestry Commission in March and April 1991 at Conways Road adjacent to the junction of the Arve and Lidgerwood Roads (Huon Topographic Sheet 8211: 868225) preparatory to eucalypt and blackwood plantation establishment.

The regrowth component of the stand originated from fires in 1926 and 1934, and the coupe consisted of a mosaic of forest types ranging through regrowth of average height 44-50 m to oldgrowth of 55-76 m. Approximately one-third of the coupe was logged prior to a wildfire in 1990 after which the remainder was salvage logged. Yield consisted of 281 and 198 t/ha respectively of oldgrowth and regrowth pulpwood, 8.5 and 52.7 t/ha of oldgrowth and regrowth sawlog, 5.3 t/ha of veneer logs and 2.2 t/ha of minor species logs. Residue was assessed at 2.6 t/ha of pulpwood quality material.

After clearfelling, the coupe was divided into two compartments. One compartment of 30 ha, Arve X, was cleared and windrowed by the E300 excavator (Hazell Brothers, contractor). The second compartment of 43 ha, Arve B, was cleared and windrows pushed with D7 bulldozers fitted with standard blades (Forestry Commission). Approximately 90% of stumps were removed on each compartment.

Windrow area and soil inclusion

Windrow areas formed by bulldozer and excavator were compared at Creekton B, Creekton BX, Esperance BX, Arve B and Arve X. All BX designated treatments had windrows stacked by excavator so results represented differences between machine type.

Aerial photographs of Creekton B and BX taken after clearing were used to assess the relative areas of land available for planting in each treatment (Fig. 1). Treatment areas and their total lengths of windrow were measured with a Graphtec digitiser (Model KD 4030) and an IBM compatible personal computer using DCAD3 software. Measurements were made of windrow widths and windrow area calculated per treatment area. A minimum of

22 windrow widths were measured per treatment. Windrows in Creekton B were compared with those of Creekton BX. Only those windrows free from topographical constraints were included in the comparison. Degree of soil inclusion within the windrow was assessed on an arbitrary scale of one to five, one and five being the minimum (free of soil) and maximum (approximately 50% soil inclusion) respectively.

At the end of operations at Esperance BX, the area of ground covered by the discrete piles (Fig. 2) was surveyed. Each pile was considered a rectangle for the purpose of calculating non-plantable area or length of lost rip-line. The area of ground lost at Esperance BX was compared with that lost using continuous windrows at Creekton B and BX. Piles were visually assessed for degree of soil inclusion as were the windrows at Creekton. Both sites were examined for evidence of general disturbance, puddling and removal of topsoil.

Aerial photographs after clearing were not available at the Arve site, hence windrow area was not calculated. Using two transects across both Arve B and Arve X, windrow width and scaled estimate of soil inclusion were assessed for 22 windrows of each treatment.

Draining

At Creekton and Esperance, removal of ponded water was essential for successful site establishment. Using a 2.0 m wide mud bucket, the excavator formed 2073 m of contoured spoon drains across approximately 10 ha included in Creekton B and BX. These drains were directed into an existing watercourse.

At Esperance BX, a 2.0 m wide central drain was dug for the length of the block using a bucket excavator and exploiting natural fall, and a 1.2 m wide drain, dug in herring-bone pattern through the buttongrass/bracken, was fed into the central drain from each side of the block (Fig. 2).

Costing

The same procedure of costing was used at all sites in all years. Total cost per designated operation for individual machine type (bulldozer, B; excavator, X) were expressed on a per hectare basis in 1991 dollars using an inflation rate of 6% per annum from 1989. Draining costs were expressed in 1991 dollars on a per metre basis.

Results

The costs of clearing using bulldozers only at Creekton B and Hastings B were $971 and $764/ha respectively (Table 2). At Creekton BX, the costs of the bulldozer and excavator were $507 and $681/ha, giving a total cost of $1188/ha for clearing. The preparation of the site at Esperance BX by bulldozers cost $444/ha; the subsequent clearing by the excavator was $829/ha (Table 2). Man hours associated with excavator operation at Esperance BX averaged one full working day (8 hr) per hectare cleared, or $100/ha. At Arve X, excavator costs for clearing, stump removal and windrowing were $1615/ha compared with $914/ha for bulldozers.

At Creekton B and BX, the cost of drainage was $2.48/m, and at Esperance BX, $0.64/m. At both sites, water could be seen flowing off the site immediately after draining, and ponding has been absent since that time.

The mean windrow widths at Creekton B were 8.1 and 7.6 m in compartments A and B, and for Creekton BX, were 4.9 and 5.3 m in compartments C and D. As a result, the total area of windrow and area of windrow as percentage of cleared area were at least half as much again in Creekton B compared to Creekton BX (Table 3). Windrows formed by excavator at the Arve ranged from 4.2 to 8.4 m, with a mean value of 5.9 m, and those formed by bulldozer ranged from 5.6 to 12.2 m, with a mean width of 8.0 m (Table 3). Differences in windrow composition were most apparent at this site (Photo 2), with the major portion of excavator windrows

Table 2. Costs (1991 dollars) associated with clearing and cultivation at individual sites.

Site	Treatment	Bulldozer ($/ha)	Excavator ($/ha)	Bulldozer + excavator ($/ha)
Creekton	B	971		
Creekton	BX	507	681	1188
Hastings	B	764		
Esperance	BX	444*	829	1273
Arve	B	914		
Arve	X		1615	

* This cost may be considered as that incurred in getting the coupe to a stage equivalent to post clearfelling.

Table 3. Cleared ground area, windrow length, width and calculated area at Creekton, Arve and Esperance, and the consequent percentage of total non-utilisable ground at the sites.

Site/Treatment	Cpt*	Cleared area (ha)	Windrow length (m)	Mean windrow width (m)	Windrow area (ha)	Windrow area as % of cleared area
Creekton B	A	20.0	4010	8.1	3.3	16.3
Creekton	B	21.7	4020	7.6	3.1	14.1
Creekton BX	C	22.3	3890	4.9	1.9	8.6
Creekton	D	19.5	3910	5.3	2.1	10.6
Arve X		30.0		5.9		
Arve B		43.0		8.0		
Esperance BX		9.0			0.25	2.8

* Compartments as given in Figure 1.

successfully removed by fire. At Esperance BX, the piles occupied only 2.8% of the cleared area compared to the best obtainable with windrows at Creekton BX, 8.6% in compartment C (Table 3).

The scaled estimates of the amount of soil in windrows at Creekton were quite variable for compartments A and B comprising Creekton B (means 3.1 ± 1.0, 3.4 ± 0.9 respectively) but were consistently low in compartments C and D comprising Creekton BX where all windrows scored 1.0 in compartment C and averaged 1.1 ± 0.3 in compartment D. Similarly, windrows formed by excavator at Arve X were scored at 1 (with the exception of one windrow that scored 2) whereas those formed by bulldozers at Arve B scored a mean of 3.3 ± 0.7. The 39 piles at Esperance Road were all scored at 1.

Puddling occurred with both excavator and bulldozer operations within the swampy areas at Creekton, and within the buttongrass area at Esperance during draining operations with the excavator. Draining alleviated the problem at both sites.

No topsoil removal was evident at the Esperance site. There was slight evidence of

Photo 1. The 30-tonne excavator (above) raking and (below) stacking slash at Esperance BX, with a six-pronged finger raker and thumb grab.

Photo 2. Windrows (above) pushed by bulldozer at Arve B, and (below) stacked by excavator at Arve X, after burning.

topsoil removal from Creekton BX whereas some areas were virtually scalped of topsoil in Creekton B and overall some topsoil loss occurred on the steeper slopes of this treatment. There was no apparent topsoil removal in the section cleared by excavator at Arve X. Visible losses occurred in Arve B on steep slopes and gully sides although soil losses must also have occurred elsewhere given the results of the windrow soil inclusion assessment.

Discussion

A major focus for the establishment of eucalypt plantations in Australia over the last 15 years has been in Tasmania. However, there are still deficiencies in our research and operational knowledge of how to manage these plantations through a full rotation, and more consideration has to be given to the implications of clearing strategies for first rotation on options for re-establishment and growth of second and subsequent rotations. While plantation managers are briefed to minimise costs for establishment of the first rotation, this should not be at the expense of the growth potential, unit costs of wood production or integrity of the site in the long term.

Costs for clearing were minimised at all sites when bulldozers alone were used but were \$207/ha more at Creekton B than at Hastings B where there was less residual slash. At Arve B, clearing by bulldozers was comparable to that at Creekton B. Conversely, the total costs of clearing and windrowing/piling exceeded \$1100/ha at all sites when the excavator was used to supplement the bulldozer (Creekton BX), where the excavator was used alone (Arve X) or following preparation of the slash by the bulldozer (Esperance BX).

The higher costs of using the excavator at Creekton were partially attributable to the requirement that it remove all stumps. In the Southern Forests, large oldgrowth stumps are readily broken up and pushed whereas some regrowth stumps (approximately 70 years of age and > 60 cm in diameter) are often tight and difficult to remove. Thus, the unit costs of removing the greater proportion of stumps is similar, but the final 10 to 20% become increasingly more expensive to break out as total removal is approached. In spite of only 90% of stumps being removed at Arve X, the greater proportion of regrowth stumps may have contributed to the higher total cost of clearing by excavator at this site. Future assessments should include a survey of the number of stumps and their type before and after clearing.

On Creekton BX, all stumps were successfully cleared and stacked. The total cost was \$217/ha more than for the partial removal of stumps by bulldozers only on Creekton B (Table 2). The proportion of the total cost in Creekton BX attributable to the excavator (\$681/ha) was about 60%. ANM/FM, who supervised the clearing, estimated that up to two-thirds of this amount was for stacking wood into windrows. Removal of this wood prior to clearing through greater use of on-site chipping would have reduced costs for all clearing operations.

Total stump removal and the straighter windrows (see in particular Fig. 1, compartment D) achievable by excavators enable straighter and more accurately spaced rip-lines ensuring optimum plant spacing, ease of access for plant delivery and post-planting management, and decreased costs of harvesting and clearing for subsequent rotations.

Windrows stacked by excavator occupied < 10% of the total cleared area in Creekton BX compared to > 15% where windrows were pushed by bulldozers in Creekton B. Relatively, widths of the windrows in the Arve blocks (Table 3) were smaller when formed by excavator. At Esperance BX, where the excavator only was used for clearing, < 3% of the area was occupied by the piles.

The use of bulldozers for stacking resulted in topsoil loss as indicated by major ground disturbance on slopes and the inclusion of soil in windrows at Creekton B and the area cleared by bulldozer at Arve B. Little or no soil was included in the excavator-stacked windrows at these sites.

Narrower, more densely packed windrows formed by stacking with an excavator at the Creekton and Arve sites burned more successfully than those pushed by bulldozer (Photo 2) and improved access for within-windrow planting.

The cost of establishment of plantations on sites which were formerly wet forest sites, including clearing by bulldozers, is high but given a mill-door green value of \$45/t (1 t = approximately 1 m^3) and mean annual increments of 14-25 m^3/ha at age 15 years, Net Present Values adequately justify this investment (Neilsen 1990; Turnbull *et al.* 1991).

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