PLANTING BARE-ROOTED SEEDLINGS OF RADIATA PINE ON DIFFICULT TERRAIN

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ABSTRACT

Success in restocking radiata pine cutover for sustained yields of high quality tree crops depends on the careful integration of all logging, site preparation, nursery production, planting and tending operations.

Until quite recently fire has proved a popular tool for clearing cutover of unmerchantable branches and stems (slash) to improve access for replanting and tending operations.

However research trials have shown nutritional benefits of slash retention and these combined with environmental concerns have dramatically reduced the use of fire.

Unfortunately, slash greatly restricts access for restocking operations, particularly planting. It makes all terrain difficult to negotiate, affects the physiological workload and mental attitude of planters and the quality of their work. Slash also makes tending operations more difficult and can cause other survival and growth problems after planting.

Keywords: Planting, seedlings, slash, site preparation, establishment, toppling, windthrow, terrain, mental attitude, physiological workload, quality control.

INTRODUCTION

Over the past decade plantation establishment research plus the development of new techniques and equipment, have allowed dramatic reductions in initial stocking levels from 1600 stems/ha to present stockings of between 550 and 1000 stems/ha. High quality genetically improved tree stocks, propagated and outplanted through carefully integrated nursery production and field establishment systems, usually guaranteed acceptable survival levels on all but the most difficult sites (Trewin and Cullen 1985). Even when there were small discrepancies in nursery and field practices, the overall strength of the system ensured survival and uniform growth of sufficient well formed trees for final crop stockings of between 200 and 300 stems/ha.

An important component of most successful plantings, has been the use of fire to clear cutover of harvest residue (slash) and other vegetation. Clear sites significantly reduce costs of planting operations and promote good initial growth by exposing soils to the warming effects of the sun. Warm soils promote root growth, and on frost flats raise air temperatures, thereby reducing mortality rates. Vegetation which prevents the soil warming effect of sunlight or drainage of cold air has been shown to increase frost damage significantly (Menzies et al 1981). Many large plantings on the Central

North Island Pumice Plateau failed until a bare earth policy was adopted.

The effects of slash cover on soil temperatures and air drainage are likely to have similar adverse results.

Balneaves 1990, demonstrated long term nutritional and associated crop growth benefits of retaining slash, duff layers and other organic material, normally destroyed by fire. Environmentalists and the general public have also become concerned with large burn-offs which blacken the sky. These concerns have led to a rapid decline in the use of fire, and because of this, slash has increased planting difficulty on all terrain types.

The area of mature radiata pine plantation to be harvested and consequently restocked, will increase substantially in the near future. To ensure that replanted stands are high quality and yields are sustained, it is important that weaknesses in cutover re-establishment operations are eliminated. The presence of slash, particularly in high concentrations, makes all terrain difficult to plant and manage. This paper outlines some impacts of slash on early growth in plantations and, in particular, the physical workloads of planting through slash on different terrain types.

A. EASE AND QUALITY OF PLANTING

Ground cover, slash, duff and other vegetation increases planting difficulty, particularity the cultivation and opening of a good planting hole. Because the roots of well-conditioned pine seedlings are numerous, they become tangled when planted in small planting holes, ending up like a bird's nest (Trewin and van Dorsser 1985). Unfortunately roots distorted at planting tend to remain permanently deformed, giving rise to instability and toppling in young stands (Trewin and Cullen 1985).

Toppling of young trees and windthrow in more mature stands of radiata pine is a problem. A countrywide survey revealed that at least 20% of all planted trees topple (develop a wind induced lean > 15 degrees), and the resulting butt sweep degrades wood quality and reduces final crop values significantly (Mason & Trewin 1987). On high fertility sites stem growth often exceeds the anchoring ability of roots particularity on difficult terrain where good root placement at planting is not easy. Concern that this problem may increase with the introduction of faster growing tree breeds, and more difficult planting conditions, has prompted investigations on ways of modifying nursery conditioning regimes to promote development of more stable root configurations (Trewin & Menzies 1989).

While initial survival and growth of outplanted seedlings are generally excellent, the development of rigid anchoring tap-roots and laterals roots is often inadequate to support fast growing stems (Mason 1985).

Current nursery conditioning treatments may be too intensive, encouraging development of numerous fibrous feeder roots at the expense of large diameter anchoring roots (Trewin and Menzies 1989). After outplanting, abundant fibrous roots absorb water and nutrients quickly for good early growth, but at planting, these small roots prove difficult to orientate naturally. Should top growth be too vigorous the poorly positioned roots then fail to anchor trees firmly.

Box pruning as a nursery conditioning treatment (the pruning of roots on all four sides in-bed) has been shown to promote better root development (Trewin and Menzies 1989.)

However, this conditioning technique was not used commercially in large pine nurseries until 1990, when a specially designed hand operated across-bed root pruning disk was developed and demonstrated (Trewin, unpubl data). Before this, box-pruning with a spade, was slow, labour intensive, and not practicable on a large scale.

A very important feature of box-pruned stock is that lateral roots are cut short, to 5 centimetres, in the nursery bed (standard hand-trimming is approximately 10 centimetres). This greatly reduces changes of root distortion at planting and also eliminates the need for hand-trimming during outplanting.

B. PLANTING QUALITY AND WIND FIRMNESS TRIALS

In 1990 field trials were established in the North and South Island to further evaluate the effects of across-bed lateral root pruning, and other nursery conditioning treatments, on planting quality and windfirmness.

On the North Island cutover site, ten replications of ten trees/treatment (100 trees/treatment) were planted through varying levels of untreated slash. In heavy slash concentrations, large and small branches made planting spot clearing and planting difficult. In light slash there was little planting difficulty.

A health assessment, six months after planting, revealed that seedlings in very light slash, were all growing vigorously (see Table 1. Reps 9 & 10). Those planted in heavier slash (see Table 1. Reps 3-7) were less healthy and many had died.

While it is difficult to isolate reasons for poor initial growth and survival in replications 3-7, it is evident that as slash density decreases (see Fig 1. Rep 1-2 & 9-10), health of trees increases significantly.

Table 1: Health of Seedlings Decreases as Slash Density Increases

EFFECTS OF SLASH DENSITY ON SURVIVAL AND HEALTH						
Rep No.	Slash Density	Very Healthy	Healthy	Unhealthy	Dead	Missing
9	VL	8	2			
10	VL	8	2			
1	L	1	7	1	1	
2	M	1	6		3	
8	M	3	4	1		2
3	H	2	3	3	1	1
4	H		5	1	4	
5	H		3	4	3	
6	H	2	5	1	2	
7	H	1	4	3	2	

VL = Very Light, L = Light,
M = Medium, H = Heavy

INDICATOR PLOTS

To gain a better understanding of the effects of slash on planting quality and initial growth, indicator plots were established at Omatoroa Forest. Trees were planted in June 1991 on steep land (slopes > 30 degrees) through untreated and roller crushed slash, either side of a common boundary.

In the uncrushed plot of 0.18ha 146 trees were located (811 stems/ha). The crushed plot of 0.15ha contained 114 trees (760 stems/ha). Seedlings were relatively easy to locate, but between-row, and in-row spacing varied considerably due to crushed slash concentrations in which planting was difficult, if not impossible.

In December 1991, six months after planting, seedling health and growth in the two plots were assessed.

Trees were graded as 1. Very Healthy (good growth with dark green needles to the stem base), 2. Healthy (some new growth with green needles to the stem base), 3. Unhealthy (No new growth with lower stem devoid of needles), 4. Very unhealthy (a large number of unhealthy brown needles), 5. Dead.

There were no dead trees in either plot, reflecting care taken in seedling transporting, handling and planting. However, the percentage of healthy trees in untreated slash was approximately 61% as against 87% in the crushed area, (see Table 2).

Table 2: Health Classification of Trees Six Months after Planting

	Untreated Slash %	Crushed Slash %
Very Healthy	7	4
Healthy	54	83
Unhealthy	31	10
Very Unhealthy	8	3

PLANTING QUALITY

During health assessment and growth measurement it was noted that several seedlings in the untreated slash area had not been firmed-in sufficiently. One seedling was so loose that it was inadvertently uprooted when removing the diameter measuring calliper. The fact that some seedlings were loose in the ground reflected considerable difficulty experienced by planters in firming-in trees.

TENDING PROBLEMS

Six months after planting, trees in the uncrushed slash plot had to be released by hand as weed growth was much more vigorous than in the crushed plot. This was despite both areas having received the same pre-plant aerial desiccant spray of escort + pulse.

As trees had not originally been planted in straight rows, due to slash concentrations, weeders had considerable difficult in locating plants. A quality control check later revealed that 34% of trees had been missed and had not been released. There were similar problems locating trees for measurement in the crushed area, where dense concentrations of slash had forced planters to make detours.

Although in-row, and between-row, distances were not checked, it was apparent that heavy slash concentrations, in crushed and uncrushed areas, cause large variations in spacing. This will make it difficult to locate seedlings for tending and the identification and removal of genetically inferior naturally regenerated trees.

It also appeared that high slash levels increased planting difficulty and possibly the work load of planters. To gain a better understanding of these difficulties, a pilot study was undertaken.

C. WORKLOAD OF PLANTERS - Pilot Study

As part of the pilot study, planter physiological workloads for three different slash densities and ground slopes were recorded. As no other known physiological studies have been carried out on planters in New Zealand, the aim was to obtain some understanding of planter workloads under New Zealand conditions.

Table 3: Mean Heart Rate/Element

THREE TYPES OF PLANTING WORKLOADS						
ELEMENTS	CONTOUR (Heavy Slash) n=420		UPHILL (Moderate Slash) n=182		FLAT (Ripped & Mound) n=392	
	MEAN HEART RATE (BPM)	% OF TOTAL WORK TIME	MEAN HEART RATE (BPM)	% OF TOTAL WORK TIME	MEAN HEART RATE (BPM)	% OF TOTAL WORK TIME
WALK	130.9	29	145.6	30	154.0	18
CLEAR SLASH	133.1	4	0.0	0.0	0.0	0.0
CULTIVATE	131.1	28	144.4	31	159.3	33
PLANT	131.3	22	141.8	37	157.5	32
GET NEW BOX	132.3	5	0.0	0.0	136.8	5
RETURN WITH BOX	130.3	1	0.0	0.0	135.4	4
CHANGE BOX	115.0	1	0.0	0.0	126.8	3
OPERATIONAL DELAY	133.3	2	134.5	1	127.4	4
PERSONAL DELAY	114.1	4	0.0	0.0	135.0	0.5
DAILY MEAN HEAR RATE	129.6		144.1		153.1	
PLANTING PRODUCTIVITY SEC/TREE	23		25		9.8	

The three Planting/Ground Conditions were:

(1) Contour planting through heavy slash cover on a 37° slope.

(2) Vertical planting through moderate slash on a 35° slope.

(3) Planting on flat ground that had been ripped and mounded.

METHOD & RESULTS

The planters heart rate was recorded at 15 second intervals using a Pe3ooo portable heart rate monitor. His activity (i.e., walking, clearing slash, etc) was also recorded at 15 second intervals using the Sifreq program on a Husky Hunter field computer. This process enabled the calculation of mean heart rates for each element of the planting cycle (Table 3).

Previous studies (Åstrand and Rodahl, 1970; Rodahl, 1989) have established that a worker carrying out hard physical labour can work all day without becoming fatigued if the worker does not exceed 40% of his/her maximal aerobic capacity (VO_2 max). To calculate 40% of estimated VO_2 max you:

1. Subtract the workers age (30 years) from 220. This gives the workers maximal heart rate of 190 beats per minute (bpm).

2. The workers resting heart rate (75 bpm), is then subtracted from the 190 bpm to give 115 bpm.

3. 40% of 115 is 46 bpm which is then added to the resting heart rate (75 bpm) to give a final figure of 121 bpm.

This figure of 121 bpm is approximately equal to 40% of the workers aerobic capacity. If the workers heart rate does not go above 121 bpm, then he/she can work all day without becoming fatigued. In each of the three planting situations, the 40% of aerobic capacity level was exceeded. Contour planting required 47%, vertical planting 60% and flat planting 68% of the planters aerobic capacity. Average ambient temperatures given as wet bulb globe temperatures (WBGT) from each site ranged from 7.6°C to 12.6°C, therefore having no notable influence on overall heart rate fluctuations.

The mean heart rate figures shown in Table 3 detail just how physically demanding planting can be under different situations. Using the Christensen scale (Table 4) it can be seen that all the planting situations result in readings that fall between the high and very high physiological workload limits.

Table 4: Workload Ratings

PHYSIOLOGICAL WORKLOAD RATINGS	
HEART-RATE (bpm)	**WORKLOAD**
75	Very Low
75 - 100	Low
100 - 125	Moderate
125 - 150	High
150 - 175	Very High
175	Extremely High

Table 5: Mental Fatigue Levels

MENTAL FATIGUE LEVELS			
HEAVY TO MODERATE SLASH		RIPPED AND MOUNDED	
START	31	START	35
BEFORE LUNCH	37	MID DAY	34
AFTER LUNCH	33		
END	33	END	31

As well as heart rate, mental fatigue was recorded using a Critical Flicker Fusion Frequency (CFFF) device. The CFFF device uses a flashing strobe light to measure the speed at which the persons brain detects the lights movement. The person looks into a hand held box and a small dial is turned until the person can no longer detect any flashing (i.e., solid light) and the corresponding numeric reading is recorded. As the person becomes more fatigued, the numeric reading decreases. This device enables the quick and easy measurement of mental fatigue throughout the working day. Fatigue measurements for the different situations are shown in table 5.

DISCUSSION ON WORKLOAD STUDY

The levels of physiological workload being experienced by the planter were far higher than expected. Slash densities had the greatest impact on the planters physiological workload demands and production levels. It was initially expected that the steeper slopes with heavy slash densities would correspond to the highest workload levels. The logic being that the steep gradient and denser slash layer would require more energy to move over and manoeuvre through.

However, contour planting through heavy slash, caused the planter to spend more time trying to either find an appropriate place to plant, or clear slash away. The result was that these interruptions to the work cycle enabled the planters heart rate to recover, thereby lowering the overall workload effect of that particular situation (Figure 1). Production rates for planting was 23 seconds/tree.

Vertical uphill planting through moderate slash had a similar occurrence with the high workload demands of planting uphill being compensated somewhat by the corresponding reduced workload demands of the downhill planting element (Figure 2). The planting production rates in this situation was 25 seconds/tree.

Planting on flat ground, which had been ripped and mounded, unexpectedly produced by far the highest workload demands. This was largely attributed to the mental attitude of the planter who knew that in such a situation he could meet target and make money by simply working at a fast rate. The result was a constantly high production rate which in turn resulted in a high workload demand as there were few interruptions in which to allow the heart rate to recover (Figure 3). The planting production rate in this situation was 9.8 seconds/tree.

The mental fatigue of the planter tended to match his workload demands. In the heavy to moderate slash densities mental fatigue over the entire day slightly decreased. This could be attributed to the interest experienced by the planter in the testing procedure and variation through the day as different situations were tried. During the ripped and mounded trial the planter carried out only the one method all day. This factor combined with the very high workload demand resulted in an increase in mental fatigue over the period of the day.

It should be stressed that these results only apply to this pilot study and were gained from one planter alone. A further study covering a larger sample size must be undertaken before opinions can be expressed as to which situation and/or method would provide the best gains for planters.

TRAINING PLANTERS

Most forest companies hold short pre-planting-season training sessions for planters. However, it takes some time to change bad planting habits and care must be taken to ensure that sufficient tuition and follow up instruction is given.

Also, there is a need for managers to classify different planting site slash levels accurately in relation to planting difficulty and pay rates.

When questioning workers on planting targets some felt that it was hard to do a good job for the money paid. In those instances they tended to sacrifice planting quality so that reasonable targets and pay rates could be achieved.

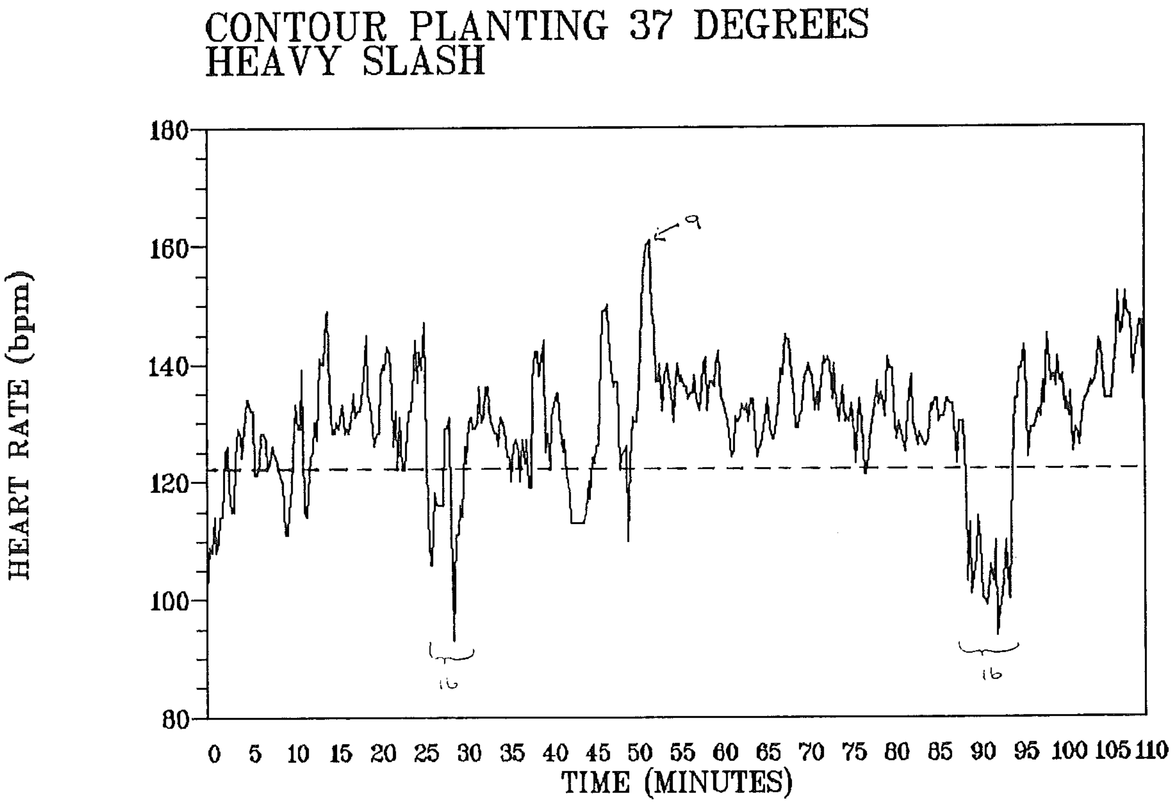

Figure 1.

Mean Heart Rate = 129.6 bpm **Production Rate = 23 seconds/tree**
9 = Get New Box, 16 = Personal Delay **---------- 40% Aerobic Capacity**

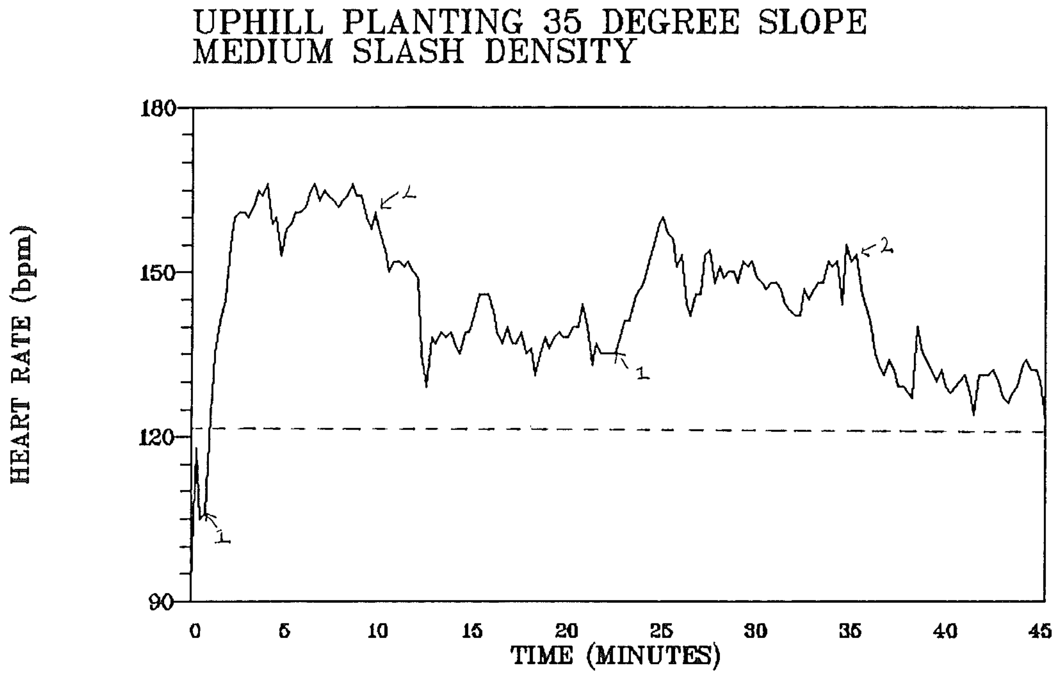

Figure 2

Mean Heart Rate = 144.1 bpm
1 = Uphill Planting, 2 = Downhill Planting
Production Rate = 25 sec/tree

Poorly trained and poorly motivated planters can not be expected to plant expertly. There is a need to improve the status of tree planters by offering good pay incentives for fault free work (Trewin 1991). Some forest managers have already introduced end-of-season competitions with good prizes. These help raise the status of tree planters and the quality of this difficult job.

CONCLUSIONS

High slash levels on radiata pine cutover make all terrain difficult to restock and manage, planting costs increase and unless workers are expert and well motivated, with good pay incentives, growth in plantations and final crop values are likely to suffer. Although planting through heavy slash is not as physically stressful as planting through moderate or no slash, it interrupts a workers' natural rhythm, making is difficult to maintain a positive attitude towards work quality. Slash also interrupts and diverts planting lines so that workers have difficulty in gauging, in-row and between-row, distances for specified stocking levels and supervisors have difficulty in locating trees for planting quality checks. Subsequent identification and removal of self-sown genetically inferior seedlings and harvesting unevenly aligned and spaced trees is also likely to prove difficult and costly.

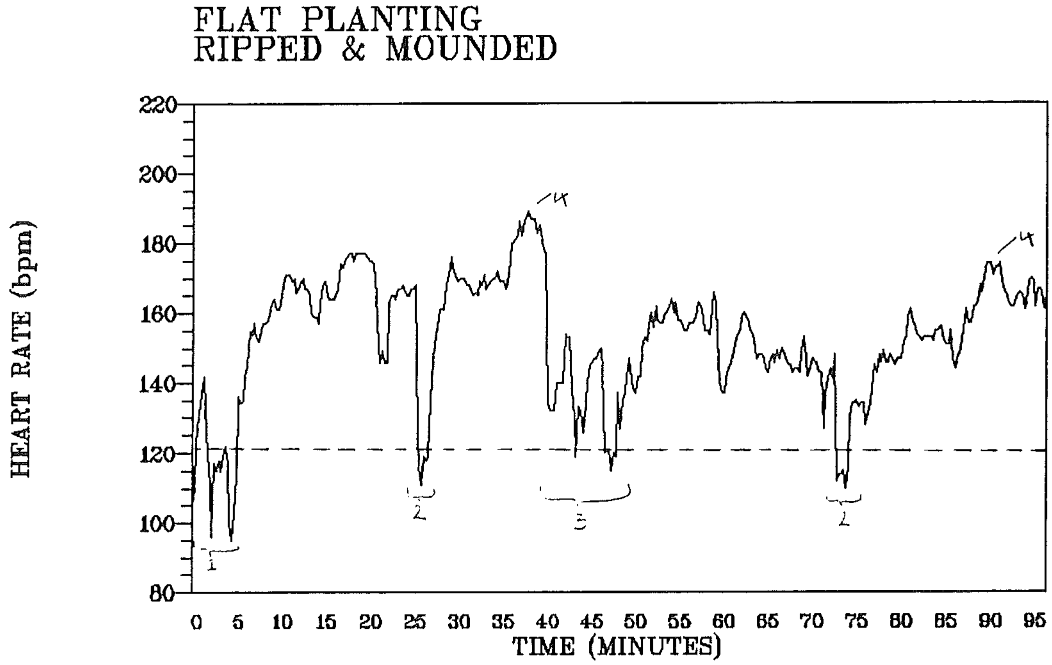

Figure 3

Mean Heart Rate = 153.1 bpm
1 = Instruction, 2 = Change Box
3 = Get New Box & Return, 4 = Hardground
Production Rate = 9.8 seconds/tree

Ideally slash levels should be low and uniform, and narrow lines cleared of slash for planting. Later, spreading roots can then take advantage of the recycled nutrients of decomposed old crop residue (slash) to help sustain yields. Where possible ground should be cultivated to facilitate planting and tending operations to provide uniform site conditions for good even growth.

Planters should be set targets which relate closely to planting difficulty. To reduce physical stress and maintain work quality, some restrictions should be placed on numbers of trees planted each day.

For lower slash levels and ease of restocking operations, recovery of wood must be improved. Ways of avoiding or treating Bird's nests on hauler sites and other slash concentrations must also be developed to reduce areas of unplantable cutover.

To achieve these aims, it is essential that harvesting and restocking operations are carefully integrated, ideally under the direction of one manager.

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