SITE PREPARATION IN NEW ZEALAND

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SYNOPSIS

Methods of site preparation (mainly for afforestation with exotic conifers) in New Zealand, discussed at a Forest Research Institute Symposium held in March 1969, are described, together with special problems of re-establishment after clearfelling. Methods include felling with hand tools, mechanical clearing by tractors with or without ancillary equipment, the value and use of desiccants and arboricides and techniques for their application, and the use of fire. These are related to the national programme for the next 30 years in terms of types of terrain and vegetational cover. Costs are examined, and the economic relationship of site preparation to subsequent operations and yields is discussed. Some aspects of New Zealand practice, especially in mechanical clearing and in the use of fire, are compared with Australian methods, and possibilities for improvement are noted, together with suggestions for useful avenues for research.

INTRODUCTION

The New Zealand Forest Research Institute held a symposium on site preparation from 3 to 7 March 1969. Questionnaires were sent out in June 1968 and 25 replies were sent in. At the same time, papers were called for and 33 were received. At the symposium there were lengthy discussions on all aspects of site preparation in relation to the establishment and re-establishment of exotic conifer crops. This wealth of information and opinion has been condensed and will be published in the FRI Symposium series. The intention here is to present a brief synopsis of the ground covered, first to indicate New Zealand practice, and secondly to show those fields where there could be technical improvement. The symposium began with a general discussion of the facts and figures — areas, types of terrain and cover, costs and methods of clearing. Then followed detailed consideration of the methods used — hand felling, machine clearing, use of chemicals, and burning. Special problems in the re-establishment of logged exotic stands were covered in a separate session. Finally there was a discussion on the relationship of site preparation to subsequent silvicultural operations and to yield. This paper will follow the same sequence.

Among respondents to the questionnaire were four Australian organizations. Their replies, especially in relation to mechanical land clearing methods and the use of fire, can with profit be compared with New Zealand practice. Further information on this subject can be found in Chavasse (1969), and in the record of the full proceedings of Symposium No. 11.

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A major difficulty in trying to present a general picture of New Zealand practice is the wide range of ideas on all aspects of site preparation. This came out in replies to the questionnaire, in discussions, and, very clearly, in a tactical exercise carried out during the proceedings. This was designed to find a consensus in dealing with a 760 acre block in Whakarewarewa Forest. Eleven syndicates presented plans. These plans ranged from simple prescriptions, involving hand felling or crushing and burning, covering a period of six months, to very elaborate combinations of methods (hand, machine, chemicals and fire) to be used over two or three years. Estimated overall costs were from $10,000 to $23,000 (not including access costs), and there were very wide differences in individual items: for example, the lowest for hand felling was $2,200 and the highest $9,000; for desiccation nil to $12,550; for machine crushing $560 to $6,000; and for burning from $680 to $6,650 (including firebreaks).

Therefore, although an attempt is made in the following report to present a coherent picture, it must be borne in mind that this is a field of very considerable diversity of practice and opinion.

Areas to be Developed for Exotic Production Forests

Figures presented to the symposium for new planting of exotic forests during the next 30 years were without benefit of the recommendations of the Forestry Development Conference held in February 1969. They are therefore some 18% less than present proposed targets. They are given, under broad cover types, in Table 1.

TABLE 1: AREAS TO BE AFFORESTED FROM 1970 TO 2000

Broad cover types	*Area in acres**	%
Generally open country, fern, light scrub, etc.	512,000	40
Heavy or difficult scrub	398,000	31
Residual bush, cutover, etc.	382,000	29
Total	1,292,000	

*Not including farm and local body planting.

Of the area to be afforested, only 52% is on sufficiently easy terrain to be cleared by crawler tractors, and a high proportion of this has light cover. The major problem is therefore clearing heavy cover from difficult terrain. In contrast, the Australian replies indicate that 90% to 98% of their country available for exotic afforestation is operable by crawler tractors, at least in Victoria, Tasmania and Western Australia. There are, however, marked differences between regions in New Zealand. In Rotorua Conservancy, 67% of the country to be planted is open, or with a light cover, and 74% is suit-

TABLE 2: COVER TYPES OF COUNTRY TO BE PLANTED 1969 TO 1978

Cover type	*Acres*	*%*
Manuka- or kanuka-dominated associations; some areas with bracken fern, and most with other broadleaved species or with gorse (17,000 acres)	133,000	26.4
Cutover podocarp forest, with enclaves of other types	113,000	22.4
Bracken fern, often with scattered scrub	70,000	13.8
Native grasses and low heathy scrub	57,000	11.3
Gorse-dominated associations: often with bracken fern and some broadleaved species	38,000	7.5
Broadleaved scrub: includes 1,500 acres with gorse	30,000	5.9
Cutover beech forest: includes areas of fern, etc.	28,000	5.5
Introduced grasses and other exotic plants	26,000	5.2
Other difficult species (broom, bramble, Himalaya honeysuckle, yellow lupin, barberry and tutu); 1,500 acres contain gorse	10,000	2.0

able for tractor operations. At the other end of the scale, Westland Conservancy has 98% of country in heavy scrub or cutover native bush, and only 10% can be worked by tractor.

A more detailed breakdown of cover types on country to be planted in the next ten years is given in Table 2.

In view of the figures given in Table 1, it is clear that in future an increasing proportion of planting will be done in more difficult conditions. For example, the annual programme for clearing cutover forest from 1966 to 1968 was only 8,000 acres. This area is expected to double before the year 2000. In the long-term view, however, cutover is probably the most important reserve of good land remaining in New Zealand for planting exotic trees. The area of cutover native forest in all tenures is about 1,120,000 acres, and the annual accretion at present is some 30,000 acres. The annual net increase in the area of abandoned cutover is thus about 22,000 acres, less land that might be developed for farming. Beech forests are easier to convert to exotics than are podocarp forests; but in both cases it is cheaper and easier to prepare the site for planting immediately after logging, because after a few years there is a dense growth of broadleaved species. However, many areas currently being logged are not well sited in relation to market outlets, and there is an understandable tendency to clear the easier country first. Moreover, in some cases there are good grounds for leaving cutover. For example, some stands of tawa or beech could be required for pulpwood in the future, and could be cleared in conjunction with the extraction of merchantable produce. However, it is apparent that, with a markedly increased planting target, more attention will have to be given to cutover areas.

Another trend is for an increase in the re-establishment of exotic cutover. The mean figure for the next ten years is estimated as 15,000 acres per annum, but by the year 2000 this is expected to increase to some 37,000 acres per annum — that is, a larger area than current *de novo* planting.

Planning and Objectives

There are apparent deficiencies in planning which may be a legacy from the days when the only land preparation necessary was a good burn. It is only over the last few years that many organizations have considered it necessary either to lay down precise objectives, or to do any detailed planning. In marked contrast, Australian practice is to define clearing specifications and objectives with some precision. In New Zealand there is also a tendency (conspicuously absent in the large company forests) to by-pass difficult areas. This practice was strongly condemned at the symposium, especially by logging experts and those who had already been faced with the problems of re-establishing logged exotic stands. Occasionally there are legitimate reasons for by-passing certain areas.

In the discussions, E. H. Bunn stated that, in order to define objectives clearly, the following points must be considered:

(1) Ready access must be provided for men.

(2) Clearing methods must not degrade the site, resulting in uneven survival and growth.

(3) Residual slash must not prevent planters from planting trees well, in straight lines at regular spacing.

(4) Competition from aggressive weeds must be eliminated or severely checked.

(5) Havens for damaging animals should be eliminated.

(6) Trees must not be subjected to excessive exposure or desiccation immediately after planting.

The immediate difficulties in establishment might be less important than future costs. Australian practice has evolved to eliminate vigorous competition from eucalypts and wattles but in New Zealand, in many instances, areas have been entirely swamped by gorse and other weeds despite a clean site at the time of planting.

The need for detailed planning has become more evident because of the introduction of more varied methods and because, in many cases, site preparation (as distinct from mere removal of the vegetative cover) involves a series of related operations. While in the past all operations had been designed to induce good burning conditions, this is not now universal; but even for burning there may be a need for a sequence of operations involving hand felling, tractor crushing, and aerial desiccation. There is also the important factor, sometimes blithely ignored in the past, of safe and effective burning. A forest planted from the south-east, when the only good burning wind comes from the north-west, will always be difficult and dangerous to develop. Although it was felt that, owing to rapid development of techniques, it is sometimes difficult to lay down detailed plans, there was general agreement at the symposium that they are essential.

METHODS AND COSTS

Although figures presented were not complete, Table 3 indicates the methods currently being used, in relation to cover types. Most of these methods are used in preparation for burning; chemicals are normally used as a supplement to other methods. The figures in the table refer to individual operations which might, in some circumstances, form part of a series.

TABLE 3: COVER TYPES AND METHODS OF CLEARING, BY AREA*

	Method of Clearing					
Broad cover type	*Axes & slashers*	*Power saws†*	*Machinery & power saws*	*Machinery*	*Chemicals*	*Fire only*
Cutover bush	—	7,010	1,150	1,360	—	—
Heavy tall scrub	2,320	190	30	900	100	210
Heavy low scrub	3,550	20	60	5,620	940	1,320
Light scrub	1,410	—	—	2,930	940	1,370
Bracken fern	—	—	—	960	—	2,660
Tussock, heath	—	—	—	150	—	Mainly
Grasses, lupin	—	—	—	1,950	1,000	—
Totals	7,280	7,220	1,240	13,870	2,980	5,560+

*Mean for the years 1966-68.
†Sometimes supplemented with axes and/or slashers.

Methods will be covered in more detail below, but an overall view shows some salient features which can form a useful background to those details.

(1) On present showing, some 200,000 acres are to be felled by hand in the next ten years. Currently half the manual felling is being undertaken with axes and slashers, and the remainder with power saws.

(2) Of machine-cleared areas, almost 60% are cleared with conventional tractor and blade. The remainder is prepared using a variety of ancillary equipment, from a heavy log to comparatively specialized machinery designed for specific jobs — such as V-blades and crushing rollers. There seems to be a general tendency towards more use of such equipment.

(3) Use of chemicals, with some notable exceptions, is still somewhat tentative. They are often employed to retrieve the situation where other methods have been unsuccessful.

(4) Fire is still the major land-clearing tool. It is becoming apparent, however, that indiscriminate use of fire (and chemicals also) is causing some alarm among conserva-

tionists, which foresters would in future be less able to ignore in view of burgeoning public opinion about multiple use of forest land. In some cases, the general intention to clear land completely could be inimical to other interests — soil conservation, for example.

(5) There is a tendency towards more complicated procedures for clearing land, involving the use of a variety of techniques and equipment. In many instances clearing is started earlier (in relation to time of planting) than in the past, and covers a longer period.

The costs presented to the symposium varied widely. Some of this variation can be attributed to differences in site conditions, and some to methods of payment. But in several instances there seems to be much room for improvement. For example, there is a good deal of evidence to show that (with very rare exceptions) power-saw felling is markedly more efficient than felling with axes and slashers. There is evidence that costs can be reduced significantly by bonus incentive payments, or by the employment of contractors. In the field of machinery, costs using ancillary equipment tend to be lower than those for conventional tractors and blades. V-blading costs are especially low, and it seems surprising that this equipment is not more used.

Although per acre burning costs appear low, there is a wide range, from 10 cents to $13.80 per acre; while Australian burning costs are seldom in excess of $1 and frequently between 20 and 40 cents per acre. If New Zealand burning costs could be brought down to $1 per acre, the annual saving would be over $150,000.

During the discussions, agriculturists brought up the question of the use of stock for land clearing. This has been attempted on a small scale in some parts of the country, but forest managers lack knowledge of stock requirements, and it has not been pursued with vigour. Nevertheless, there are distinct possibilities, provided sufficient time is available to make full use of this method; at least five years is required. An advantage is the revenue that could be obtained from the stock. Further study is warranted.

Manual Methods

There is little doubt that currently the only efficient tool is the powered chain-saw for hand felling. There are occasional circumstances where there is a case for supplementary work with slashers, but trials carried out by the New Zealand Forest Service and forestry companies show conclusively that using axes and slashers is highly inefficient in terms of cost and manpower. However, there is clearly a wide range in the efficiency with which power-saw gangs are used; the work is arduous, and incessant use of power saws is injurious to health. To obtain maximum efficiency, careful attention must be given to motivation, job organization, work standards and specifications, standards of supervision, training and safety, and worker health.

There seems to be doubt about the best power saws to use. Bush felling for land clearing is a totally different operation from production felling, and there is evidence that different classes of tools are required for different types of cover. There has been some detailed comparative testing, but this is an important field for study and development.

Although power saws are perforce used on country unsuitable for tractors, there is also much power-saw felling on easier country because of the nature of the cover. In some of the more efficient operations (from the point of view of cost) tractors with ancillary equipment are used to crush understoreys, after which power saws are used to fell the larger trees. This will continue to be an important form of combined operation, since tractor pushing (uprooting) frequently leaves areas in a condition in which it is often very difficult to obtain a clean burn. This is in marked contrast to conditions in Australia, where pushing, usually followed by windrowing, is the normal practice. Even there, however, power saws are used for felling the largest trees.

It is generally agreed that power-saw felling will continue to be a major method of site preparation for a long time to come, and it is encouraging to see the continued development of lighter and more efficient saws.

Mechanical Clearing

The major operation continues to be crushing, normally with tractor and blade.

Windrowing is undertaken in some instances, also normally with tractor and blade. It appears that root rakes that have been tried (with one exception at Pureora) are unsatisfactory. Windrowing is sometimes preferred because, even if a burn is not possible, the site can still be planted. Loss of productive area can be important — 10% appears to be the minimum, but in some cases this can amount to over 15%. Moreover, windrowing, especially with blades, can often have an adverse effect on the site owing to removal of topsoil or pugging of the soil, resulting in a poor strike, poor growth of trees and a heavy invasion of grasses and sedges. In these circumstances the windrows are filled with earth and are in consequence difficult to burn. But windrowing does allow much easier planting conditions owing to clear ground, while often where heavy scrub is cleared felling or crushing and burning leaves the site encumbered with much debris.

It is only of recent years that more varied ancillary equipment has been developed, and ideas on these have not spread very widely. There is still a general tendency to consider site preparation to be concerned only with clearing, not with cultivation of the site. This attitude is again in marked contrast with that found in most parts of Australia, where site preparation normally consists in the removal of all vegetation and the preparation of the soil to allow easy planting (by machine in many cases), to provide good conditions for survival and growth of planted seedlings, and to eliminate releasing.

However, there has recently been some development of tools and techniques for cultivation — ripping in Canterbury, V-blading in Nelson and the Bay of Plenty, the use of cleated rollers, also in the Bay of Plenty, and discing in several localities. A review of machines in use overseas, however, shows that New Zealand generally lags behind in large-scale methods of vegetation removal. This may be due partly to the many small and scattered operations. But if the best methods and tools now in use were generally deployed throughout the country there would be a marked improvement, and several speakers at the symposium deplored the lack of communication between various parts of New Zealand. There is also a need to improve the pattern of machinery available — root rakes, heavy discs, ball and chain gear, blades (including angle shearing and V-blades), and crushing rollers — and also, in some cases, to develop new machinery for specific problems, provided that they are sufficiently widespread to warrant it. Among the suggestions were tools that would eliminate the need to burn — rotary or flail slashers; and cultivation machinery — rippers and scalpers.

There is no question that cultivation has improved establishment where the site is occupied by gorse, broom, bracken and other aggressive plants. Several speakers considered that it is in the development of machinery that advances must be made, specially in order to reduce the awesome amount of hand felling now contemplated. The development of V-blading techniques in Nelson has shown that machines can be used effectively on steeper country. Terrain that can be negotiated depends on soil type and condition as well as degree of slope, and many operations are not attempted beyond a slope of 20°. V-blading is normally carried out on slopes of up to 30°, with a maximum of 40°, in Nelson, and these are the usual limits in Australia. However, the regularity of the terrain is also important, and much of the country to be afforested in New Zealand is quite unsuitable for the use of tractors. There is thus a need to consider whether machinery can be developed for smashing vgetation on steep, broken land. Consideration of logging gear and methods leads to the view that devices drawn over the country by winches could be developed.

There was general agreement on the importance of sound machinery and skilled operators. These two points are universally stressed in Australia, and the efficiency of land clearing there is high in consequence. Land clearing is hard on machines, and efficiency can be maintained only by using gear in first-class condition. Hence it is important to contractors that jobs offering be sufficiently large or long-term (two to three years) to allow purchase of new machinery. Australian contracts are often 1,000 to 2,000 acres and normally include both felling and burning in the one contract.

Use of Chemicals

Chemicals are now widely used in land-clearing operations, but in most places in a small way and often without much

confidence. However, it is evident that where experience is being built up chemicals are being used with increasing effect. Lack of knowledge has apparently been the major cause of the present situation in most parts of the country. Chemicals do not behave in an identical fashion in different climates, and there are definite limitations on what can be done. It has not been appreciated in many instances that timing of operations in relation to the condition of the plant is of the greatest importance, and that this has to be worked out in each locality. Many forest managers have expected too much of chemicals. It has become apparent for example, that the use of desiccants and fire on gorse is not an effective way of eliminating this weed, even though it may give temporary control. Again, on multi-canopy cutover it is impossible to get sufficient penetration in many cases, and single aerial applications are usually ineffective. But chemicals are being used with increasing effect on low scrub, on single-storey vegetation, on regrowth on felled areas (as an aid to burning), and on troublesome weeds like lupin, tutu and nassella tussock.

Chemicals are often considered to be too expensive for general use, but they are of great importance as a supplement to other methods, to retrieve the situation where other methods have been only partially effective, or for tidying-up after burning. It is considered that, before they can be used with confidence, they must be proved to be effective for local conditions, that application techniques must be fully controllable, and that they must be at least as cheap as other methods with comparable results in terms of establishment of well-stocked stands.

Major applications are normally from the air, but there is a useful place for mistblowers and tractor-mounted equipment. There is still controversy over the relative advantages of helicopters and fixed-wing aircraft. While the latter are more generally favoured, there is scope for the use of helicopters in special circumstances, and costs are becoming more competitive.

The most useful and cost-effective chemicals continue to be the phenoxyacetics (of which 2,4,5-T is most commonly used), and it is considered that this will continue to be the position for some time to come. However, there is much evidence that the addition of other substances can in some circumstances give major advantages. The additives most favoured at present are ammonium sulphamate, paraquat and sodium chlorate. Experimental work on arsenicals, especially the monosodium salt of methylarsinic acid is showing considerable promise. There are other chemicals under development overseas which could also be of importance. At present there is a tendency to rely on single applications. Evidence presented from agricultural work in New Zealand, and scrub eradication in California, suggests that for some of the more intractable weeds a series of low-volume applications might be more effective.

The definiiton of objectives is not yet soundly based in New Zealand; many forest managers are not clear as to what they wish to achieve by using chemicals. There is also need for improvement in techniques of application, and for better

liaison between forest managers and operators in order to apply chemicals under optimum conditions; at present, spraying is often ineffective because it is done in marginal conditions. Valuable information was presented on the importance of droplet size, types of formulation, weather conditions, effects of surfactants, limitations of aircraft, and so on, which cannot be discussed here. It is clear, however, that proper use of chemicals is a complex matter requiring a high degree of precision and expertise. Until forest managers have mastered the subject, results will continue to be disappointing. Nevertheless, chemical methods are still in their infancy and prospects for the future are highly encouraging, to the extent that there is a good case for constructing permanent airstrips in forests; these would inevitably be used also for purposes other than vegetation control.

Use of Fire

In contrast to Australian practice, the use of fire in New Zealand is not particularly skilful, with some notable exceptions. Only one organization claimed that 90% of burns were successful. Over the whole country it appears that no more than 60% are wholly successful, 30% partially successful, and 10% more or less ineffective. While this is partly due to weather conditions, there are several other reasons for this unsatisfactory state of affairs. There seems, for example, to be more stress on safety than on the need to achieve a clean burn. There is very evident lack of planning; in some cases all burns in a forest are hazardous, owing to working against rather than with the prevailing dry wind. There is often serious lack of knowledge; while in some places there is great reliance on the experience of the local staff, there has so far been little effective weather analysis; fire behaviour and, arising from this, fire strategy and tactics are often not well understood; knowledge of the time taken for fuels to become sufficiently dry to obtain a clean burn is often sketchy. Methods of determining the right conditions for burning are not particularly efficient in comparison with those in Australia. In the majority of cases the scale of burn attempted is small and hence costly. There has been little effective development of fire-lighting tools and tchniques.

The relatively large amount of ineffective burning leads to many practical difficulties; whether to plant or leave until the following year, for example; such indecision is very costly. In many cases lines must be cut by hand through partly burnt areas before planting can be undertaken. But poor site preparation can have an adverse effect and lead to increased costs throughout the rotation. The need to improve burning practice is of great importance, since it is estimated that 90% of land to be planted will have to be cleared by fire.

While there was general agreement at the symposium that burning plans are essential, there was some criticism of the form of burning plan used bv the Forest Service. It was felt that the much simpler Australian plan would be preferable.

But simple plans would be appropriate only where fire bosses are highly skilled, and Australian expertise in the use of fire is based soundly on operational research. This is lacking in New Zealand. Nor could we slavishly copy Australian methods since effective burning is much more difficult in this country.

The need for proper land development planning was also stressed in the discussions. Most methods of land clearing are designed to prepare the cover for burning. Plans for five years ahead are needed to show the direction of working and the methods to be employed; these should not be amended without very strong reasons. Burning plans, as such, are more effective (being relatively short-term) if they are developed as a natural extension of these long-term plans.

There was some controversy about the concept and practice of "pre-burning" and the need for "land banks". Where, in any one afforestation project, most land is in heavy cover, it is almost certain that occasionally the whole programme will be set back by failure to burn. In these circumstances reserves of open land can be of major importance and some managers aim to produce these artificially by burning as much country as possible in favourable years. "Pre-burning" is also used in the sense of burning over a tract of country (usually where cover varies from light to heavy in a mosaic pattern) a few years before planting to see what areas are left to be treated by other means. It could be argued that spending money many years before planting is uneconomic. However, ample evidence exists that keeping land in a light cover (bracken fern, light scrub) can be done very cheaply by occasional burning. In many parts of New Zealand, if fire is excluded, native forest tends to develop, and this is a very costly type of cover to clear. Also, where there are various types of cover on a large tract of country, regular burning tends to erode the more difficult cover types so that, when final clearing is to be undertaken, it can be much simpler and cheaper. However, pre-burning can also lead to problems. Fire-induced bracken can be a troublesome weed, leading to costly releasing operations; and if some gorse, broom, lupin or other aggressive plant is already to be found on the site repeated burning leads to the eventual dominance of these species.

PROBLEMS OF RE-ESTABLISHMENT OF LOGGED EXOTIC FORESTS

The untended exotic stands now being logged in many parts of New Zealand result in sites for re-establishment carrying a great weight of slash. Depending on the logging method use, this often becomes concentrated in heaps. Furthermore, logging can have detrimental effects, over parts of the logged area, owing to removal of topsoil or to soil compaction. Where original establishment was patchy (a not uncommon situation resulting from the boom planting era in the early 1930s) there is often great difficulty in stocking failed areas, which also provide a reservoir of weed seeds and a harbour for damaging animals.

The situation will change markedly when fully-tended stands reach the clearfelling stage. The major problem is then expected to be dense understoreys of weeds, while the amount of slash will be small. The present problem is how to deal with slash in order to achieve full and effective stocking of all cutover areas. There has been a general tendency to think that slash can be reduced by extracting more wood during logging or by post-logging salvage. The evidence is that the amount of economically-usable material left on the site is very small and that the additional cost of extracting it is not warranted. This does not absolve the forest manager from policing logging operations to ensure that there is proper extraction. In some cases fire is used to demolish slash, but most forest managers are reluctant to resort to burning. In Australia fire is the normal tool for the removal of slash and it could probably be more used in New Zealand when it is better understood. However, logging practices can have a major impact on the condition of the site following clearfelling. Several speakers at the symposium found that hauler methods left the site in better condition for re-establishment than tractor operations. Most trials to improve the position have been undertaken in the Bay of Plenty, as this is the region where major logging operations are currently being carried out. It has been found, for example, that in tractor operations top hauling, rather than butt hauling, gives more satisfactory results. Again, the layout of operations using Skagit mobile haulers has a marked effect on the distribution of slash. One difficulty at present owing to historical processes, is that the responsibility of the logger ceases as soon as he has removed the log from the site. There is general agreement that the forest manager should have control of all aspects of logging operations, but some controversy as to whether the logger should be induced to take part in preparation of sites for re-establishment.

Logging planning is a somewhat neglected field. In logging native forests, for example, planning is virtually absent. Logging areas are not normally laid out in relation to the need for effective clearing for conversion to exotic crops, except in Westland. Proper detailed planning could be a means of improving prospects for using fire for clearing logged sites.

There is some scope for the use of machinery. Landings and other compacted areas have much reduced productivity unless they are ripped and fertilized. Efforts are being made to develop V-blades to push aside slash in planting lines; in this respect insistence on low stumps is important.

At present, in the major exotic logging areas, reliance is placed on natural regeneration and air seeding. In some parts of the country the effectiveness of natural regeneration has seriously declined in recent years and planting has been reintroduced. There is some criticism of seeding methods as they perpetuate the relatively low genetic quality of present stands: it is considered that planting with superior stock would be more satisfactory from the economic point of view in the long run. However, planting is relatively costly, especially through slash, and there are difficulties in obtaining full stocking by

this means. In some cases the sheer size of the annual programme makes this method impracticable.

THE RELATIONSHIP OF SITE PREPARATION TO OTHER ASPECTS OF SILVICULTURE

At the symposium there was general agreement that poor site preparation leads to poor establishment generally and a marked increase in costs of blanking, releasing, pruning and, in some cases, thinning. The major problem arising from poor preparation is low stocking and this has adverse effects throughout the life of the crop; yields are less, and log quality is reduced. However, not a great deal of study has been devoted to this question and actual costs or lowered yields have been determined only in rare cases. In the first place, on a poorly prepared site, it is often difficult to plant sufficient numbers of trees to ensure enough of high quality for the final crop; there are often gaps of unacceptable size not planted at all. The quality of planting is often low and lines are not straight: this leads to difficulty in finding trees during releasing. Poor site preparation often results in excessive weed growth: this makes releasing costly and blanking ineffective. Where persistent woody weeds are present (for example, gorse), access for pruning is either prevented altogether or pruning has to be delayed, and costs to obtain entry are high. Dense undergrowth can also have effects on costs of thinning. Moreover, evidence was presented that undue weed competition can depress growth rates significantly and lead to a high proportion of sabre butts in the crop. Patchy stocking leads to high pruning costs owing to large branch size and the difficulty of selecting sufficient well-formed trees for pruning. Early commercial thinning may have to be abandoned owing to insufficient volume and poor form. In the final crop the presence of gaps can lead to increased logging costs and slow initial growth due to weed competition can delay the end of the rotation.

Clearly this is a field needing further study. Forest managers have for some years been asking, "How much can I afford to spend on site preparation?" without obtaining a satisfactory answer. The information presented to the symposium indicates that frequently a good deal more could be spent, not only to improve economic prospects for the whole rotation (and to some extent the following rotation also), but to avoid in future the alarming total losses which have been found in some forests during the last few years.

CONCLUSIONS

The symposium performed a valuable function not only in bringing together such a wealth of information and opinion, and in indicating where improvements could be obtained, but also as a forum for the dissemination of information. Certain aspects are especially worth noting, as they were reiterated from session to session. The first is the question of scale. In the use of machinery, in burning, in optimum use of resources

generally (including staff), the New Zealand forest manager is faced with trying to work on too small a scale. There are, for example, 93 exotic planting programmes currently being undertaken by the Forest Service, while the national target has been only 27,000 acres. Secondly, it became clear that the performance of forest managers varies from excellent to scarcely tolerable. This is reflected in managerial skills and in the training and competence of subordinate staff and, equally important, labour. The great disparity in costs of comparable operations highlighted this aspect, while throughout the discussions the importance of skilled men, especially those operating expensive equipment, was frequently stressed. There are difficulties in attracting and retaining good men, but some managers are not aware of the need for sound training and motivation and do not make proper use of incentives. There is also, in this context, the possibility of making more use of skilled contractors.

The question of managerial skill and knowledge was also highlighted by discussions on objectives and planning. It was clear that objectives are not always well defined; that planning is often at best sketchy; that "a good drill" (in the words of the Director of Research) has not been worked out for hand or machine clearing, for the effective use of chemicals, or for efficient burning. There is a serious lack of knowledge of weather and fire behaviour; of the use and limitations of aircraft and chemicals; of the available mechanical equipment and effective methods of using it. In fairness it must be added that the forest manager has often been faced with "crash programmes" without sufficient resources being made available (finance, manpower, and good quality machinery) by higher management.

The symposium also indicated that there is scope for much improvement in the dissemination of information and for the introduction of improved gear and techniques throughout the country. Coupled with this is the need for formal testing and where required, development of machines and techniques to deal with what are essentially endemic problems.

Finally, there is ample scope for research into weather, fuel, fire behaviour, effects of chemicals, and into the economics of plantations, especially into the relationship of land clearing to the remainder of the rotation. Forest managers need to be given some yardsticks by which to judge their own performance, to discover their shortcomings, and from this to emulate the best practitioners in the country. Let it be said, in conclusion, that the best are highly efficient and, if their standard could be generally reached throughout New Zealand, we would have cause to be proud of our performance.

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