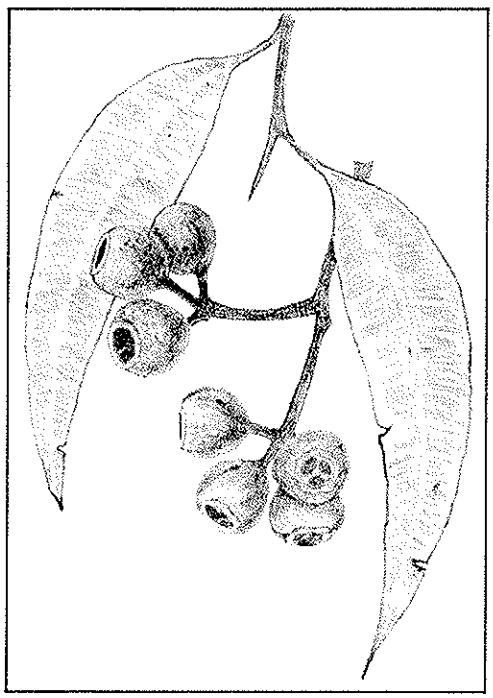
Silvicultural Guidelines for Virgin Southern Jarrah Forest

by F.J. Bradshaw



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CONTENTS

INTRODUCTION

A silvicultural system is a planned series of silvicultural operations aimed at achieving management objectives for the forest. Where wood production is one of the objectives, the operations include: logging to provide the required wood resource; and the establishment, protection and tending of the regeneration and the developing second growth forest. Each operation should facilitate the next in continuous cycles of production, regeneration and stand development. Silvicultural systems must be formulated to take into account management objectives, the silvics of the species, the forest's present condition, its protection needs, and the practical application of the operations.

Variation due to site and past treatment of the forest preclude a universal set of silvicultural prescriptions for the jarrah forest. Even within one broad site classification, variation in stand structure, regeneration status and protection needs are such that fixed prescriptions are seldom appropriate. While the principles are similar the application is not.

This paper is one of a series of guidelines being prepared. They are not intended to provide a comprehensive silvicultural system for the entire forest, but rather to outline silvicultural practices which are most critical to a particular forest and its stage of development. Sufficient of the rationale which has been the basis of the prescriptions is provided to allow forest managers to vary the treatment to suit particular stands while still meeting the overall objectives of silviculture and management.

These guidelines are specifically directed at those virgin jarrah forests of the Pemberton-Walpole area which have a management priority for wood production. However, the same principles of regeneration establishment and development apply to other land uses where wood production is a compatible, but not a priority use. The principles outlined here will have application to other similar jarrah forests outside this area. The emphasis is on regeneration establishment, integrated fire protection of developing regeneration, and the release of regeneration in sufficiently large groups to allow for subsequent logging to be carried out without excessive damage to the future crop.

While it is customary to name a silvicultural system according to one of the classically defined systems, this often leads to unnecessary strictures and a tendency for silvicultural practices to be adjusted to meet the strict definition of the system rather than to meet the particular requirements of the forest. In formulating rather than selecting an appropriate silvicultural system for this forest, a system has evolved which contains elements of several classical systems, including clearfelling, group selection, and uniform and grouped shelterwood.

1. SILVICULTURAL OBJECTIVES

Logging in the jarrah forest should meet one of three principal silvicultural objectives:

i Partial cutting to reduce the competition from the overstorey and to allow seedlings to develop into ground coppice (See Table 1 for definitions of the various stages of jarrah regeneration).

ii The removal of the overstorey to allow ground coppice to develop into poles and trees free of competition from the surrounding overstorey, and in sufficiently large gaps to allow the subsequent felling of adjacent mature trees without damage to the developing stand.

iii Thinning to promote the growth of selected retained trees or to provide an intermediate yield. Regeneration which will negate the thinning must be prevented.

Although all three practices may be carried out in the stand as a whole, only one objective should be sought on any discrete part (patch) of the stand at any one time (Fig. 1).

The minimum size of the patch is determined by the size of the area which would be required to allow subsequent felling of large adjacent trees without excessive damage to the regrowth. This is currently considered to be a minimum of 4 tree heights in diameter. An operation to meet any of the above objectives should be conducted within or aimed at creating patches (gaps or groups) in excess of these size limits.

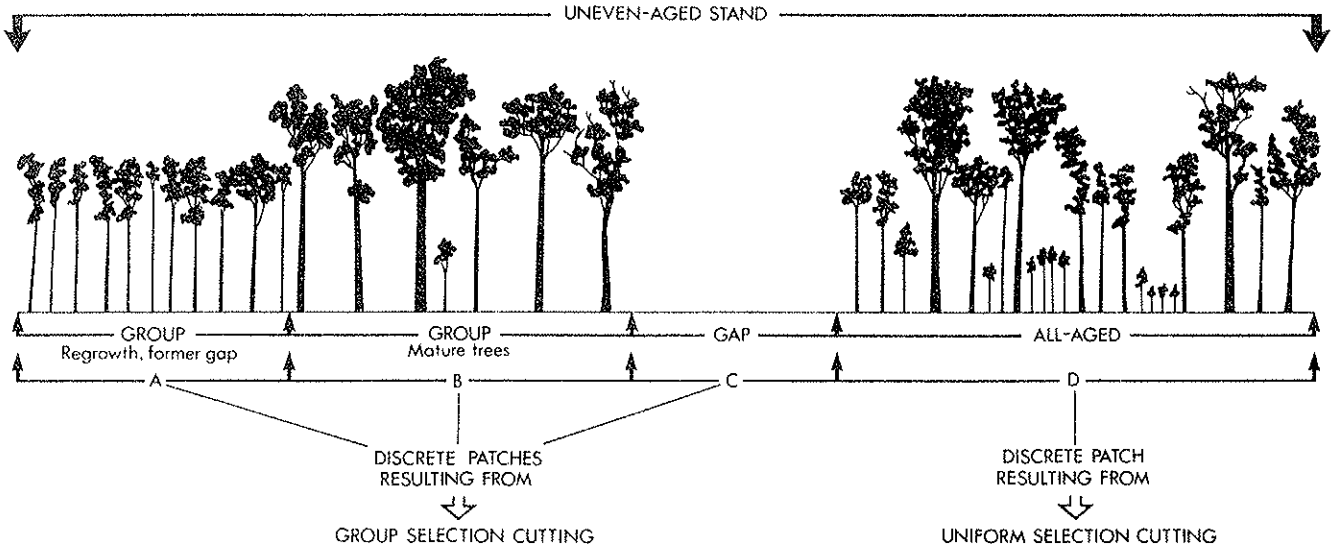


FIGURE 1: Diagrammatic representation of some of the terms used in this paper.

TABLE 1

Definitions of Stages of Jarrah Regrowth Development
(Abbott & Loneragan, 1984)

SEEDLING	<1 year old. Cotyledons present, no obvious lignotuberous swelling.
LIGNOTUBEROUS SEEDLING	Original shoot still present. Lignotuberous swelling developed (within 12 months of germination)
SEEDLING COPPICE	Multiple shoots after damage (fire or insect) has killed original shoot.
GROUND COPPICE	Shoot growth up to 1.5m with lignotuber developed to 15 cm in length (may be as small as 5-10 cm in southern forests).
Incipient Ground Coppice	Multiple shoots with no specific leader.
Dynamic Ground Coppice	Multiple shoots, but with one dominant leader.
SAPLING	Stem 1.5 cm to 15 cm DBHOB
POLE	Stem 15 cm to 45 cm DBHOB
PILE	Stem 45 cm to 60 cm DBHOB

DBHOB = Diameter at Breast Height Over Bark.

The application of these principles, together with other appropriate treatments, will ensure:

- adequate regeneration is obtained before final removal of the overstorey,

- satisfactory growth is maintained on developing trees,

- felling of mature trees can take place without excessive damage to growing stock,

all within the context of a group cutting system which can be perpetuated.

If, on the other hand, an attempt is made to satisfy more than one of these objectives on one patch, or the patch to which a single objective is applied is too small (in effect the creation of an all-aged forest), then eventually:

- over-mature or defective trees are retained because their felling could cause excessive damage to growing stock. These trees occupy space which could grow more useful and vigorous trees, and they compete with other growing stock resulting in reduced growth rates and the gradual degradation of the stand.

- or the removal of mature or defective trees excessively damages younger growing stock, with the loss of potential yield. A substantial part of the forest will always be occupied by regeneration which never reaches maturity before being smashed by the felling of larger trees.

These guidelines apply to virgin stands, or those which, having been lightly cut in recent times, have no significant development of second growth poles. Crown condition is generally poor, and there are few trees which could be classified as genuine growing stock. Only the first two objectives are therefore relevant: partial cutting to reduce the competition from the overstorey, and the removal of the overstorey to allow ground coppice to develop into saplings and poles.

2. SITE TYPES

The jarrah forest in the Pemberton-Walpole area occurs on a wide range of site types. Detailed vegetation classification of the type described by Havel (1975) for the northern jarrah forest is still being developed. Geomorphology has been partly mapped by C.S.I.R.O., but the maps have not yet been published.

Although standard Air Photo Interpetation maps are available for the whole area which provide information on stand height and structure, they do not provided information about the capacity to regenerate, the basis of silvicultural practice.

Until a more specific classification is completed, a preliminary classification may be based on soil types. The soils of the jarrah forest in this area may be broadly described as follows:

- gravels (laterite and gravelly podsols)
- yellow and grey podsols
- sands - including undifferentiated sands and humus podsols of depositional origin and sands developed from quartzite high in the landscape.
- red 'karri' soils

Regeneration in southern jarrah forest appears to be closely correlated with soil type.

3. STATUS OF ADVANCED GROWTH

The status of advanced growth is the basis for selecting the most appropriate regeneration treatment. Although all stages of regeneration (Table 1) may occur in any one area of forest, one stage tends to predominate in any particular patch. The stages vary throughout the forest and may be influenced by fire history, past logging and soil type.

In virgin southern jarrah forest two types of stands can generally be recognized:

- adequate advance growth is present in the small pole, sapling and ground coppice stages (1000 stems per hectare of ground coppice and saplings more or less evenly distributed would be considered adequate). This type most commonly occurs where the soil contains gravel.

- inadequate advance growth of saplings and ground coppice is present (seedling coppice may occur in large numbers). This is generally where:

  The scrub species are dominated by root stock species (e.g. ti-tree, *Agonis parviceps*, and emu bush, *Podocarpus drouyniana)* on deep sand and podsols.

  The scrub species are predominantly seed species (e.g. *Petrophille* spp and *Ac. browniana)* on podsols.

  The scrub species are dominated by seed species typical of the karri forest (e.g. netic, *Bossiaea laidlawiana* and karri wattle, *Ac. pentadenia)* on red 'karri' soils.

There are exceptions to this general pattern, the reasons for which are not clear.

A significant proportion of the southern jarrah forest has inadequate or undeveloped lignotubers, probably due to competition from an overstorey of mature trees common to the virgin forest, and additional competition from the high density of scrub on some sites.

4. THE EFFECT OF CUTTING AND BURNING

The effect of cutting and burning varies according to the stage of development of the advance growth. The following generalizations may be made:

(a) In Stands with Adequate Advance Growth of Ground Coppice or Larger

Removal of the overstorey competition by cutting in these stands results in the rapid development of ground coppice into sapling regeneration (van Noort, 1960). The most vigorous regeneration will come from broken or burnt off saplings. The root stock of ground coppice and saplings will withstand quite intensive tops disposal burns except where they are within heaps of debris, where some will die because of fire intensity (Harris, 1955). Survival is likely to be improved if the soil is moist at the time of the burn.

(b) In Stands with Advance Growth of Seedling Coppice or Smaller

When the overstorey is removed in these stands, there is no dramatic regeneration response because the lignotubers are immature.

They will continue to develop, but they may take many years to become saplings. Marri regeneration may develop more quickly under these circumstances. If left unburnt, scrub regeneration and growth will provide severe competition and slow lignotuber development.

These areas are often associated with a dense scrub layer, and small lignotubers on these sites are more vulnerable to fire. Even the advance burn may kill many of them because:

- in areas of dense scrub, particularly with a high component of ti-tree, a mild burn is difficult to achieve.

- in such dense scrub areas the lignotuber is often growing in the duff layer and is not insulated by the soil.

Therefore, complete cutting and subsequent tops disposal burning of these stands will usually leave the area understocked, with only small lignotubers or newly established seedlings which will take many years to develop into saplings, particularly under the heavy competition from scrub (van Noort, 1960). It is, therefore, preferable to maintain a partial cover of original forest while establishing a stocking of ground coppice. Logging, creation of ashbeds and regular burning all enhance lignotuber development (Abbot & Loneragan, 1984).

5. REGENERATION TREATMENT REQUIRED IN STANDS WITH DIFFERENT STAGES OF LIGNOTUBER DEVELOPMENT.

In order to determine the most appropriate silvicultural practice, it is necessary to identify those sites that will regenerate easily and those that will not. Research is continuing to determine the most appropriate technique for regenerating those stands which do not readily regenerate naturally. In the meantime it will be necessary to conduct operations on the basis of the best information available. The following silvicultural treatments are recommended:

(a) Stands with Adequate Advance Growth of Saplings and Ground Coppice

(i) Advance burn the area two years before logging to increase the visibility of lignotubers, improve access and reduce the volume of scrub to simplify the future top disposal burn.

(ii) One to two years after the advance burn, identify areas with adequate stocking of ground coppice or saplings (1000 stems/ha more or less evenly distributed).

(iii) Log these areas, completely removing the overstorey to allow unimpeded regeneration development. Trees should not normally be retained in the gap because they will suppress the development of regrowth, and their subsequent felling will further damage regrowth. Furthermore, isolated trees are very difficult to protect during the subsequent top disposal burn. Although it may be justifiable to retain occasional very high quality trees if they have not yet reached merchantable size, this is not usually an issue in the virgin southern jarrah forest.

There are rarely any intermediate size trees which could be regarded as genuine growing stock.

The minimum gap size created by this treatment should be 4 tree heights in diameter to avoid excessive damage to regrowth when felling surrounding trees. When there are no surrounding trees leaning into a gap, this size may be reduced to 2 tree heights. Where a large continuous area of this type occurs it may be necessary to limit the maximum gap size by retaining unlogged or partially logged groups or strips. This is not a silvicultural requirement but it may be necessary to satisfy aesthetic or hydrological needs.

It follows that retained groups should also exceed the minimum size mentioned above.

(iv) A tops disposal burn should be carried out after one summer's drying. A spring burn (or an autumn burn after the soil has become wet) is the most appropriate. A lignotuber of ground coppice can withstand a fairly hot fire if the soil is moist. A hot fire which completely burns off the above ground shoot is preferable to a cooler fire which merely damages the stem. If the shoot is completely removed a new straight stem will be produced. If it is only damaged, however, the stem may develop a kink or a fork.

(v) Additional treatment should include the poisoning of cull trees over 200 mm diameter. If additional regeneration is considered necessary smaller malformed stems may be coppiced to induce a stable shoot of better form than the original. Poisoning of larger culls is preferred to felling, in order to reduce ground debris and avoid the need for poisoning unwanted coppice from larger stumps.

(vi) Complete fire protection of the developing regrowth is required till it can withstand a mild burn, when it reaches a height of 5-6 m (at about age 10, depending on site). The first fuel reduction burn should not exceed an intensity of 70 Kw/m (Peet and McCormick, 1971).

This operation aims to achieve the second silvicultural objective (Section I p. 4).

(b) Stands with Inadequate Advance Growth

Scrub, Mainly Root Stock Species

(i) Two years before tree marking, advance burn to identify lignotuber status, improve access and reduce the volume of scrub for later treatment and burning. This is not aimed at protecting lignotubers.

(ii) Demarcate areas with an inadequate stocking of ground coppice or saplings and cut on a uniform selection basis, aiming to leave about half the original basal area (about 15-20m^2/ha) uniformly spread over the area. Preferably, remove jarrah with poor crowns and marri leaving a jarrah seed source on trees with growth potential.

(iii) Maximise soil disturbance, to remove the scrub's root stock and create an improved seed bed. This allows seedlings to establish or develop without the extreme competition of the scrub. It is unlikely that rubber-tyred logging machinery will provide sufficient disturbance. A dozer with a rake blade or flat blade with rear scarifier, working through the area at approximately 10 m spacing, should be satisfactory. However, field trials will be necessary to establish the best means of creating soil disturbance. Avoid soil compaction, which is detrimental to seedling establishment and development.

(iv) Top dispose and burn in a seed year. The burn should aim to create ashbeds without excessive damage to retained stems.

(v) Regular fuel reduction burns (about every 5 years) should follow, until the lignotubers have reached the ground coppice stage. This may take 20 years (Abbot and Loneragan, 1984).

The above operations are directed at achieving the first silivicultural objective (Section 1, p. 4).

(vi) The area may then be treated in the way described in Section 5 (a): Stands with Adequate Advance Growth of Saplings and Ground Coppice (See summary in Fig. 2).

Scrub, Mainly Seed Species On Podsols

The treatment for these sites is similar to that described in Section 5 (b): Scrub, Mainly Root Stock Species. However, soil disturbances need not be so severe since there is no need to remove the scrub root stock. Having established the new lignotubers, regular burning is important. At each burn the root stock species (in this case jarrah) will gain over the seed species (Peet and van Didden, 1973).

Scrub, Mainly Seed Species, On Red 'Karri' Soils

These stands are anomalous in that they support jarrah with a scrub layer and soil type typical of the karri forest. This type frequently occurs between the flats and karri ridges in the Walpole area.

Possibly jarrah has been maintained on these sites as a result of fire history rather than site preference. A series of fires which killed mature karri and subsequent regeneration before it was old enough to produce seed might allow jarrah to dominate. Frequent fires favour lignotuberous species over seed species.

If the areas are not too extensive it would be preferable to treat these sites in the same way as adjacent karri forest. Failing this, use a treatment similar to that described for the podsols.

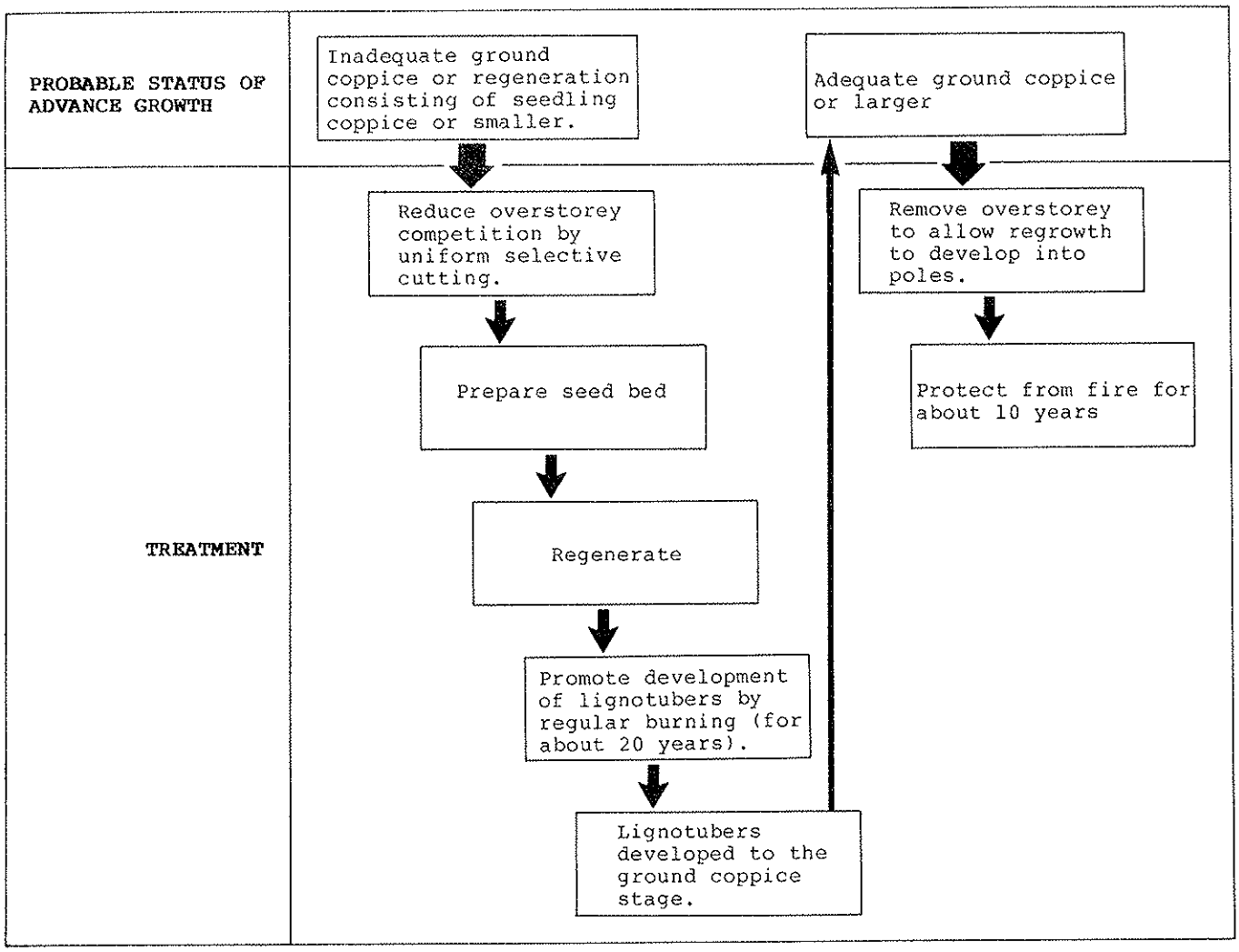


FIGURE 2: Summary of Stand Treatment.

6. INTEGRATION OF LOGGING, REGENERATION AND FIRE PROTECTION

A silvicultural system requires the integration of logging, regeneration and fire protection. It is pointless to acquire regeneration which will later be damaged by logging or fire.

The silvicultural treatment required for the two types - those that contain advanced regeneration and those that do not - are quite different, particularly with respect to fire management.

On one hand, types where logging is designed to release advanced regeneration require a top disposal burn to remove logging debris, but the burn is not constrained by the need to protect an overstorey. This is followed by a fire exclusion period of approximately 10 years.

On the other hand, types where regeneration has to be established require a top disposal burn which will not damage retained trees, followed by regular prescribed burning every five years for about 20 years.

These different types, however, occur as a mosaic within the one stand, occupying areas of a few hundred square metres to several hectares. The individual patches are too small to permit separate burning regimes, and burning programmes should be designed for the stand as a whole. The conflicting needs of the various components of the stand must be taken into account.

There are several alternative strategies, each with advantages and disadvantages, aimed at satisfying these conflicting needs.

(a) STRATEGY 1

This provides for gap creation to release existing regeneration (ground coppice) and uniform selection cutting to establish regeneration at the time of the inital cut. Protection of regrowth is given priority by not burning the stand for 10 years after the initial cut.

A diagrammatic illustration of the sequence of events is shown in Figure 3.

(i) Advance burn the coupe two years before the proposed cutting. This will improve visibility of the lignotuber development and allow sufficient time for the lignotuber to re-shoot after the burn.

(ii) Demarcate stands that contain very dense ti-tree and a low stocking of trees. These usually occur on deep sands or peat, and frequently contain blackbutt of poor form. These stands should not be logged.

(iii) Demarcate areas with an adequate stocking of regeneration of ground coppice or larger (see Section 5 (a): Stands with Adequate Advance Growth of Saplings and Ground Coppice) and create gaps by logging. Carry out a uniform selection cut in the remainder (Section 5 (b) Stands with Inadequate Advance Growth).

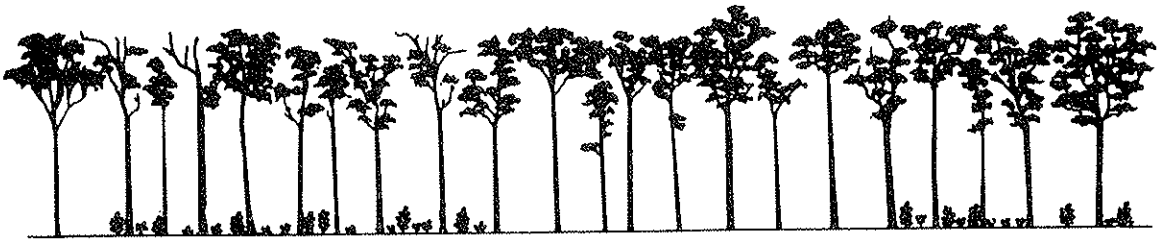
(iv) Carry out cull treatment in the created gaps, disturb the soil in the uniform selection cut patches, and burn tops in a seed year.

(v) Exclude fire from the stand till regeneration in the gaps is large enough to withstand a prescribed burn (5-6 m in height, or about 10 years).

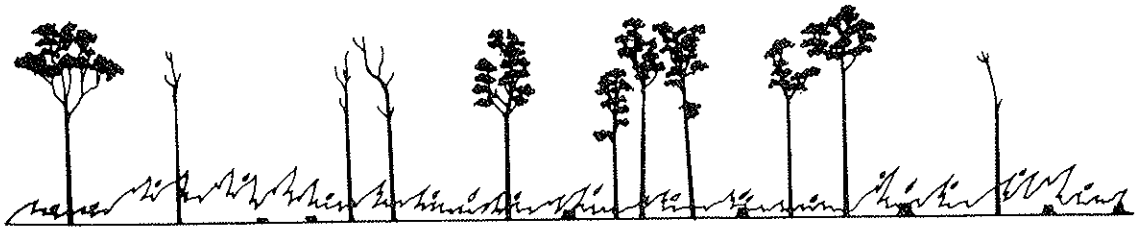
(vi) Following the fire exclusion period burn about every 5 years till regeneration in the uniform selection cut areas has developed to the ground coppice stage (about year 20).

(vii) Then cut, burn tops, and cull the uniform selection cut area in the same way as for previous gap cutting (Section 5 (a): Stands with Adequate Advance growth of Saplings and Ground Coppice). It is important to cut this area before the regeneration begins to develop into large saplings and small poles. If left beyond this time the regeneration which will be damaged by logging will be more difficult to burn back to ground level. This may result in excessive coppice development and malformed stems in the future regrowth stand.

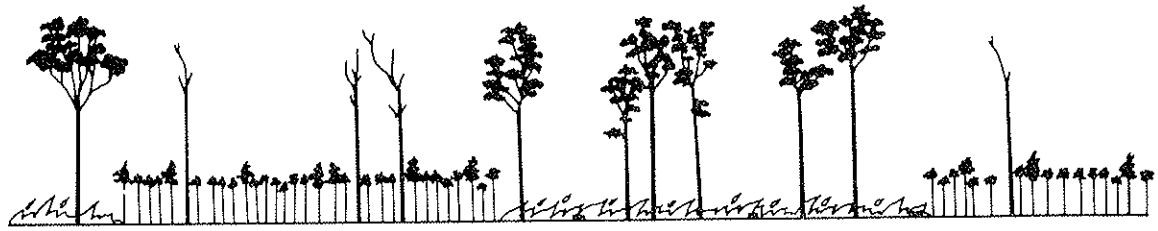
Following cutting, exclude fire from the area till the new saplings are old enough to withstand a mild fire (about 10 years) before resuming normal prescribed burning.



Year -2 Ground coppice is most visible 1-2 years after the advance burn.

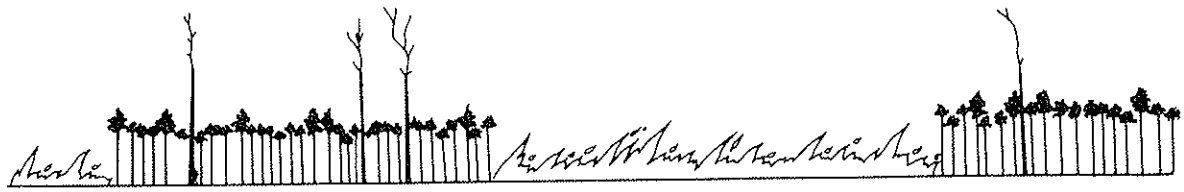


Years -2 to 0 Cut to create gaps where there is adequate ground coppice; uniform selection cut in the remainder; burn tops; poison culls in the gaps.



Years 10, 15, 20 Following 10 years of fire exclusion, prescribe burns to stimulate lignotubers in the uniform selection cut patches. Then resume normal protective burning cycles.

Year 20 Lignotubers in uniform selection cut areas become ground coppice.



Year 20 After advance burning, carry out a final cut in the patches of uniform selection forest to create new gaps; burn tops and poison culls.

Year 30 Fuel reduction burning may resume after 10 years protection.

FIGURE 3:
A representation of the sequence of operations in Strategy 1. Initial cutting involves gap creation to release regeneration and uniform selection cutting to establish regeneration. Released regeneration is protected for 10 years.

(b) STRATEGY 2

This provides for initial gap creation to release existing regeneration (ground coppice) and a delay of uniform selection cutting required to establish regeneration till the first protection period is complete (Fig. 4).

(i) Advance burn, demarcate and cut to create gaps as described for Strategy 1. Do not remove any trees from areas containing inadequate or undeveloped lignotubers.

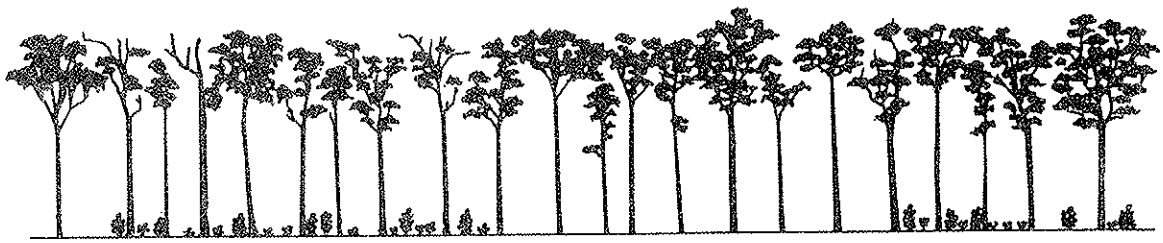
(ii) After logging, burn the whole area with the primary objective of burning the tops in the gaps. Poison or coppice culls in the gaps.

(iii) Exclude fire from the stand till the regeneration in the gaps is old enough to withstand a fire (5-6 m in height or about 10 years).

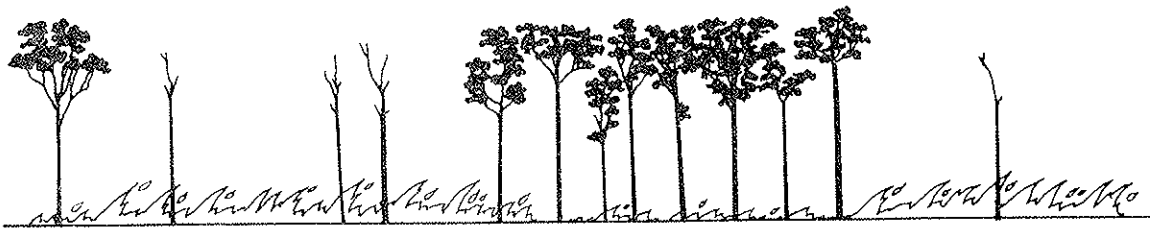
(iv) Following the first prescribed burn, cut the remaining areas on the basis of a uniform selection. Disturb the soil and burn tops in a seed year (see Section 5 (b)).

(v) Burn regularly till lignotubers have developed into ground coppice but have not yet become large saplings or small poles.

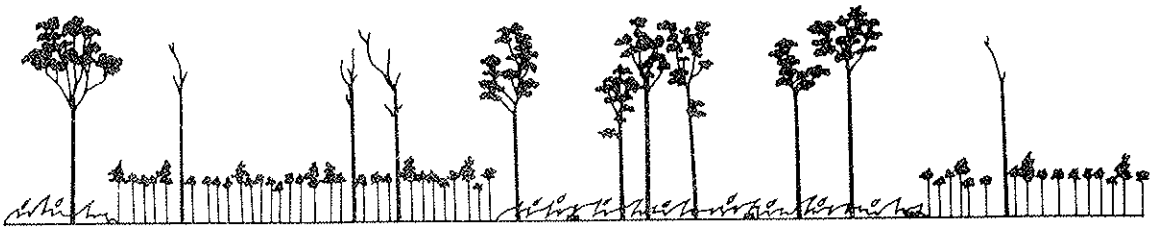
(vi) At this stage cut, burn tops and cull the uniform selection cut area in the same way as for previous gap cutting described in Section 5 (a): Stands with Adequate Advance Growth of Saplings and Ground Coppice.



Year -2 Ground coppice is most visible 1-2 years after the advance burn.

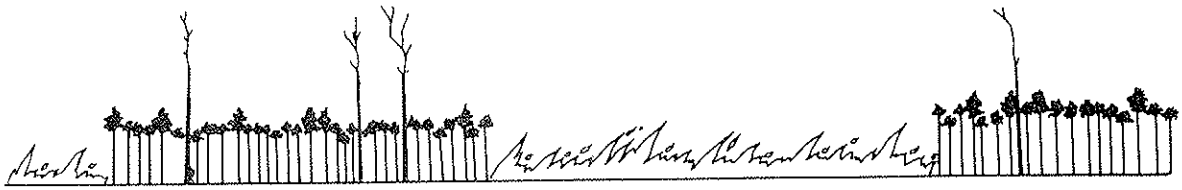


Years -2 to 0 Cut to create gaps where there is adequate ground coppice; burn tops and poision culls; area without ground coppice remains uncut.

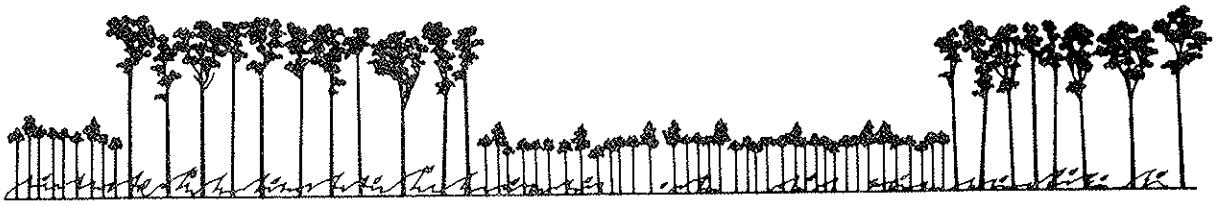


Year 10 After 10 years of fire exclusion, advance burn and cut the remaining areas as a uniform selection; burn tops.

Years 15, 20, 25, 30 Prescribe burn till lignotubers in the uniform selection cut patches become ground coppice.



Year 30 After advance burning, carry out a final cut in the patches of uniform selection forest to create new gaps; burn tops and poison culls.



Year 40 Fuel reduction burning may resume after 10 years protection.

FIGURE 4:
A representation of the sequence of operations in Strategy 2. Initial cutting involved gap creation to release existing regeneration. Uniform selection cutting is delayed till the protection period is complete.

(vii) Exclude fire from the stand till new regrowth can withstand a fire (a further 10 years). Then resume normal protective burning.

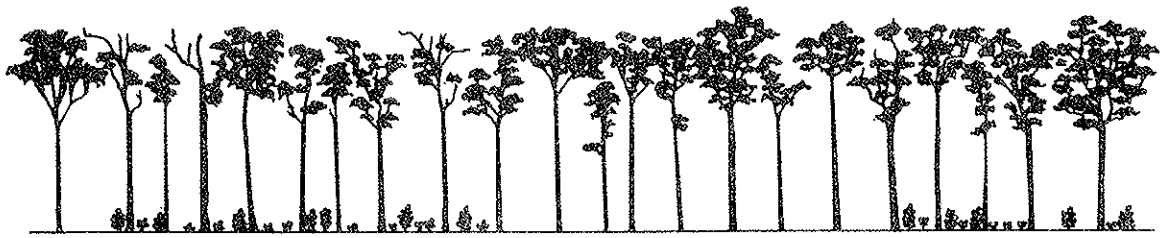
(c) STRATEGY 3

This provides for gap creation to release existing regeneration (ground coppice), and a uniform selection cut in other areas to establish regeneration. The initial fire exclusion period for the released regeneration is foregone in favour of frequent burning to stimulate the development of new regeneration in the selectively cut areas (Fig. 5).

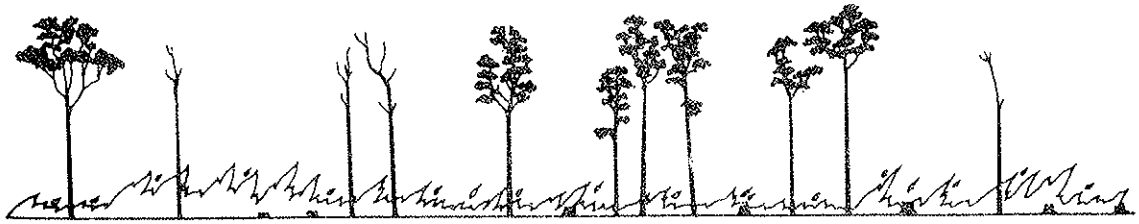
(i) The first stages of the operation (advance burning, group and selective cutting, and tops burning) are the same as for Strategy 1 (i-iv).

(ii) Following the top disposal burn, the area is burnt after 5 years. Regular burning stimulates the development of lignotubers in the selectively cut areas. This involves the risk of damage to regeneration in the gaps. However, if the gaps are free of overstorey and the scrub is not dense, leaf litter accumulation in the gaps will be very low. In such circumstances it may be possible to burn the whole area at year 5, without excessive damage to the regrowth in the gaps. This strategy then becomes feasible.

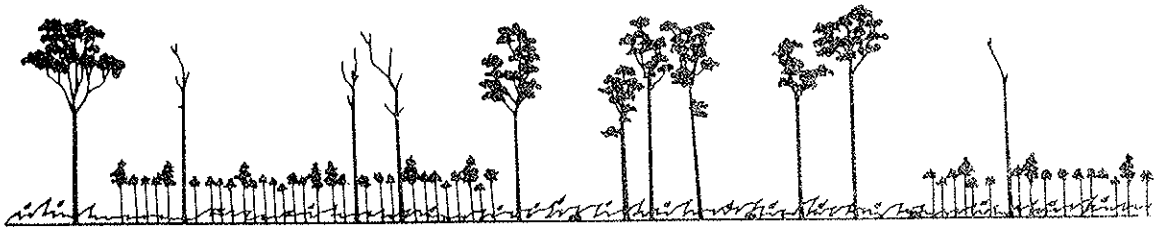
(iii) Subsequent final cutting of the selective areas and the follow up protection period of 10 years is the same as for previous strategies.



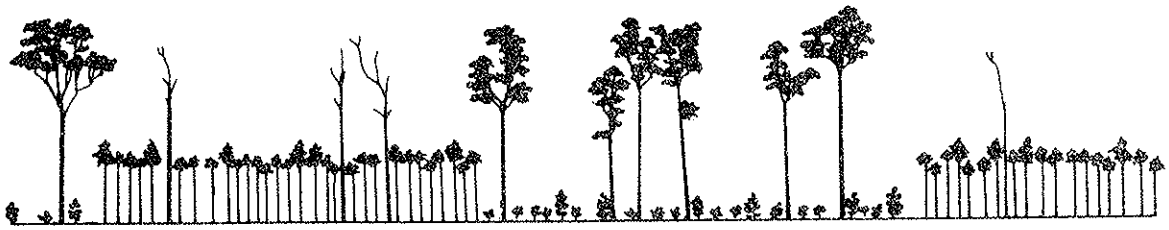
Year -2 ground coppice is most visible 1-2 years after the advance burn.



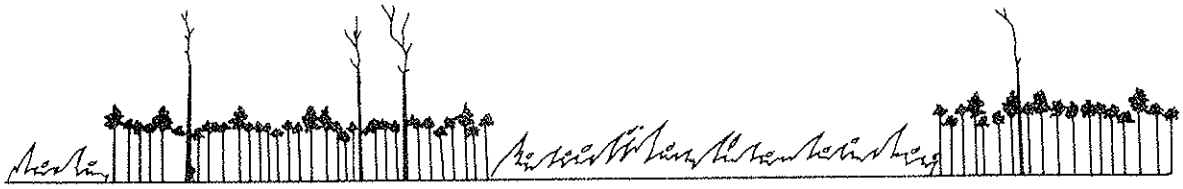
Years -2 to 0 Cut to create gaps where there is adequate ground coppice; uniform selection cut in the remainder; burn tops; poison culls in the gaps.



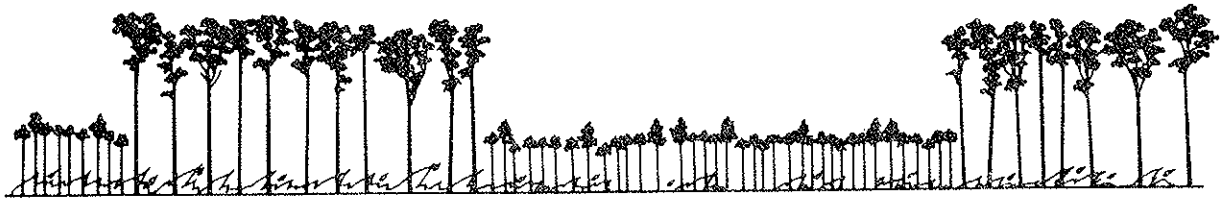
Years 5, 10, 15, 20 Regular prescribed burns to stimulate lignotuber development in the uniform selection cut patches.



Year 20 Lignotubers in uniform selection cut areas become ground coppice.



Year 20 After advance burning, carry out a final cut in the patches of uniform selection cut forest to create new gaps; burn tops and poison culls.



Year 30 Fuel reduction burning may resume after 10 years protection.

FIGURE 5:
A representation of the sequence of operations in Strategy 3. Initial cutting involves gap creation and a uniform selection cut. The protection period for released regeneration is foregone to favour regeneration establishment in selectively cut areas.

(d) STRATEGY 4

This is a special case where some cutting may be required to provide a resource, but regeneration is not immediately desirable because of the need for continued protective burning in these areas. This could apply in burning buffers or in coupes where the proportion of the area with adequate ground coppice is very low. In the latter case a large area could be under fire exclusion to protect a very small area of regrowth (Fig. 6).

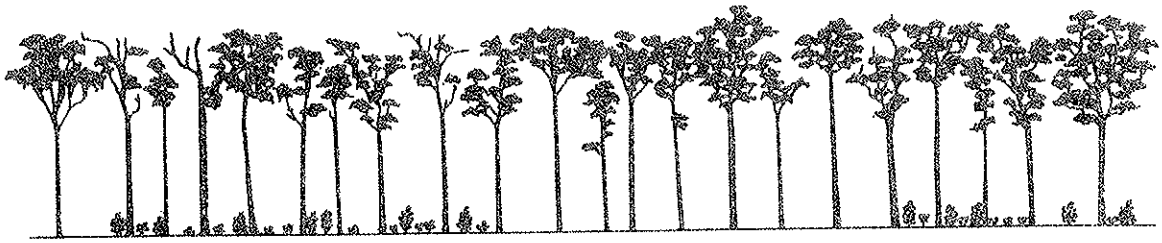
(i) Advance burn as for previous alternatives.

(ii) Demarcate areas with inadequate or undeveloped lignotubers and carry out a uniform selection cut as described in Section 5 (b). Disturb the soil and burn in a seed year.

(iii) Do not cut areas containing adequate ground coppice. In these patches it is necessary to maintain a full overstorey canopy to prevent this regrowth developing into saplings and poles.

(iv) Conduct regular prescribed burning to promote the development of lignotubers to the stage of dynamic ground coppice.

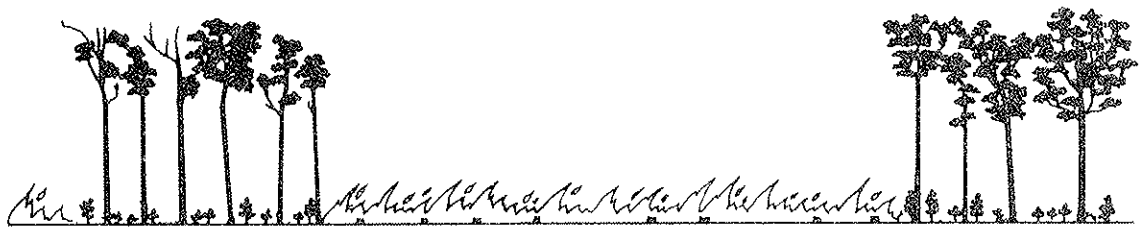
(v) At this stage the whole area should be stocked with ground coppice. Gap cutting can then take place when required, to the maximum size permitted by policy.



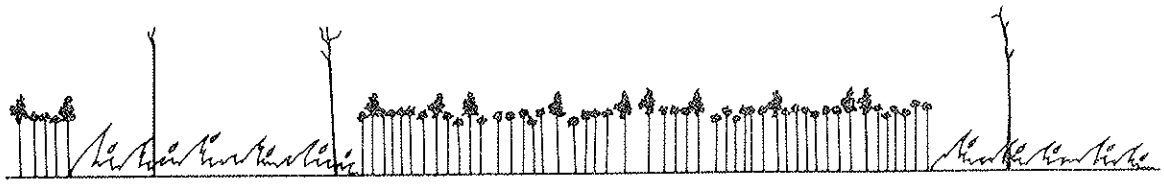
Year -2 Ground coppice is most visible 1-2 years after the advance burn.

Years 0, 5, 10, 15, 20 Uniform selection cut in patches with inadequate ground coppice; burn tops; regular prescribed burns to stimulate lignotuber development in uniform selection cut patches.

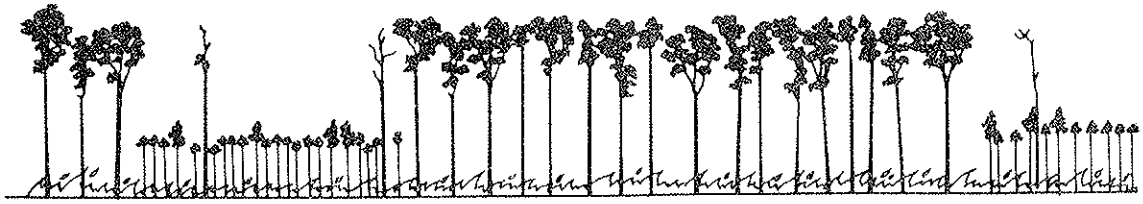
Year 20 Lignotubers in uniform selection cut patches become ground coppice.



Year 20 Cut to create gaps (preferably including selection cut patches); burn tops; poison culls.



Year 30 After 10 years of fire exclusion, advance burn and cut remainder to create new gaps when required.



Year 40 Fuel reduction burns may resume after 10 years protection.

FIGURE 6:
A representation of the sequence of operations in Strategy 4. Some cutting is required to provide a resource, but regeneration is not immediately desirable because of the need for protective burning.

Priority for gap creation should be those patches which were previously cut selectively, to prevent the continuing development of this regrowth to pole size among mature trees, and the difficulties of the all-aged forest (described in Section 1) which would then develop.

(vi) After 10 years of fire exclusion, the remaining area may be cut. Following the tops disposal burn the area is again protected for 10 years, before resuming normal fuel reduction burning.

(e) SOME APPLICATIONS OF ALTERNATIVE STRATEGIES

The choice of an appropriate strategy largely depends on management requirements. Table 2 lists relevant data for a number of parameters against each alternative. Each has its own characteristics.

Strategy 4, for example, delays the fire exclusion period for 20 years, but provides a low yield at year 0 and delays regeneration release for 20 years. This may be acceptable if immediate protection needs in a particular area are more critical than yield.

Strategy 3, on the other hand, delays the fire exclusion period for the same time (20 years), but it does so at the expense of proper protection of developing regrowth. For that reason it is not a preferred alternative unless it can be shown that lignotuber development is seriously impaired by a no-burn period in the first 10 years.

On the basis of this analysis of the advantages and disadvantages of the systems, Strategy 2 is the best choice from a silvicultural point of view. It may, however, produce some management problems by reducing the immediately available resource and in the process exacerbate protection problems. Management requirements are therefore important factors to consider.

Silvicultural requirements will have a marked effect on the timing of the availability of wood yield from particular stands and on strategic fire protection. Effective planning will depend on extensive surveys of lignotuber development well ahead of proposed logging. It is also clear that variable silvicultural requirements involve a commitment to thorough scheduling

and conduct of operations. This is made more difficult because of the long-term nature of the commitment. Improved techniques for recording, monitoring of stand development and scheduling of operations will need to be developed.

TABLE 2

Summary of Alternative Strategies

	1	2	3	4
1. Earliest Cutting Time (Year)	0 20 }	0 10 30 }	0 20 }	0 20 30 }
2. Protection Periods (Years)	0-10 20-30	0-10 20-40	20-30	20-30 30-40
3. Regeneration Release (Year)	0 20	0 30	0 20	20* 30
4. Conditions for protection of developing regrowth	Optimum	Optimum	Sub-Optimum*	Optimum
5. Conditions for development of lignotubers	Sub-Optimum*	Optimum	Optimum	Optimum
6. Resource available from 1st cut relative to total resource	Moderate	Low*	Moderate	Low*

NOTE: } denotes that following the uniform selective cut there is a commitment to do the final cut about 20 years later to prevent regrowth developing into poles beneath retained stems This 'commitment period' is shown by linking of dates in Item 1.

* denotes what might be considered the primary disadvantages of each alternative.

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GLOSSARY

Advance growth - young trees which have established themselves in openings in the forest, or under forest cover, before regeneration fellings are begun.

Clearfelling system - a silvicultural system in which the original crop is removed at one time over a relatively large area to allow regeneration to develop as an even-aged stand. Variations to facilitate regeneration establishment include strip clearfelling and clearfelling with seed trees.

Coppice - a shoot (or shoots) arising from adventitious buds at the base of a woody plant that has been cut near the ground or burnt back.

Coppice, to - to fell trees near to the ground with a view to their producing coppice shoots; to produce coppice shoots.

Cull - a tree which because of fault or degrade has no commercial value at present or in the near future.

Duff - the matt of undecomposed or partly decomposed vegetable matter on the forest floor, the original stuctures still being recognisable.

Gap - the space created in a stand of trees by complete or near complete removal of trees within a discrete area.

Ground coppice - a stage of lignotuberous development from which the plant is capable of rapid development into a sapling when released from competition. The above ground appearance is that of a small bush with multiple stems. Incipient ground coppice is when no leading shoot has developed. Dynamic ground coppice has multiple stems, but one dominant shoot.

Group - trees remaining in a discrete clump following the removal of some trees in the stand.

Group selection system - a silvicultural system in which the final crop trees are removed in groups, either to permit regeneration or to release advance growth.

Patch - a small discrete portion of a stand which is given uniform silvicultural treatment.

Seedling coppice - a lignotuber which has the above ground appearance of a small bush, but which would not immediately develop into a sapling if released from competition.

Shelterwood system - a system of forest regeneration where the original forest is partially felled and regrowth becomes established under the partial cover of the old trees. The parent crop is then removed, and the new crop is more or less even-aged. Variations include the uniform shelterwood and the grouped shelterwood.

Silvics - the laws underlying the growth and development of single trees and of the forest as a biological unit.

Thinning - the removal of some trees in an immature stand to increase the growth rate of the remaining trees without encouraging regeneration.

Top disposal - a tending operation after a felling in a stand, where the slash is cut away from the base of retained stems to avoid damage in any subsequent fire, prescribed or otherwise.

Uniform selection - a method of cutting wherein single trees are removed from the stand leaving relatively uniform distribution of trees. (i.e. not in groups).