NOTES ON THE SILVICULTURE OF MAJOR N.S.W. FOREST TYPES

11. RAINFOREST TYPES

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Forestry Commission of N.S.W.
28th September, 1989.

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11. RAINFOREST TYPES

The question is often raised by those concerned with the conservation of tropical forest ecosystems: do we have enough knowledge to formulate working plans for the sustainable management and development of tropical moist forests and thus to marry efficiently conservation and development of forests? The question is, intentionally or unintentionally, wrongly put. In this field the problem is not so much one of knowledge - although we all recognize that not sufficient is known at present of the functioning and "handling" of tropical moist forest ecosystems - as, primarily, one of the political will. It was political will, spurred by the need or shortage of timber for the Navy, or of wood for domestic and industrial energy, that was at the origin of the first working plans in Europe several centuries ago, at a time when there were no forestry schools or forest research institutes. Since then, many substantial improvements have been made to these plans, and continue to be made on the basis of research results. Does this mean that the states, communes and other entities who designed and implemented the first working plans were wrong and should have waited (how long?) to know more? Certainly not. It is also certain that more knowledge is needed and will have to be acquired gradually through research and experience. But there is need and room, now already, for cautious and conservative forms of forest management for the sustainable production of wood and non-wood products and services. And newly acquired knowledge will, in the future, allow for the improvement and refinement of these first plans.

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(From Guest Editorial, For. Ecol. & Mgt. 24 (4), p. 311, 1988)

1. INTRODUCTION

With possibly a minor exception in the case of those dealing with the Cypress Pine types (Silv. Notes No. 10), all previous Notes on the Silviculture of N.S.W. Forest Types have dealt with communities that are, both botanically and visually, distinctively Australian.

These present Notes, however, concern a group of forest types that share many features - at times even tree species, and commonly tree genera - with forests found in other parts of the world. A N.S.W. forester with local rainforest experience does not find conditions particularly strange or different in most of the World's tropical rainforest areas (the "tropical moist forest ecosystems", referred to by Lanley in the opening quotation), nor in the temperate rainforests of the Southern Hemisphere or of tropical mountains. Because of these similarities, much experience and research concerning rainforest in other countries has fairly direct application to the understanding of the local rainforest areas.

Within historic times, rainforest has not made up more than about 2 per cent of the total forested area of N.S.W., yet this relatively small area (often colloquially known as brush or scrub) has played a disproportionately important role in the development of forestry in N.S.W., and indeed of the State generally. The Australian timber industry had its origins in 1790 in the Red Cedar[1] brushes of the Hawkesbury River; exploitation of the valuable Cedar logs led to the subsequent settlement of the coastal river systems; cleared of their rainforest cover, these river flats and nearby basalt plateaux provided some of the State's finest farmlands; efforts to re-establish Cedar in the 1880s were among the first attempts at silviculture in N.S.W. Besides Cedar, rainforest has yielded many of the State's

[1] For botanical names of species mentioned in text, see Appendix 1.

most beautiful or valuable woods - White Beech, Hoop Pine, Coachwood and many others - and for decades more than 10 per cent of the State's wood production came from its limited rainforest area, along with a continuing supply of minor products. At the same time rainforest had other notable features - its obviously different appearance from the otherwise almost ubiquitous eucalypt forest; its rich floristic diversity, with nearly half of all the native tree species present in N.S.W.; the apparent strangeness of many of its life-forms; its often distinctive fauna. These combined to give the rainforest high recreational and scientific appeal, and certainly from the 1930s areas of rainforest were being preserved as national parks or, within State Forests, as Flora Reserves.

Until the 1950s it was conventional wisdom that the N.S.W. rainforests could not be managed for sustained timber production. During the 1930s this belief led to a policy of creating Hoop Pine plantations on land carrying cut-over rainforest - primarily to demonstrate that the land was being gainfully used, and to forestall agitation for its conversion to farm land. Even when it was finally realised that the stands could be managed as rainforest, the political will, stressed by Lanley, was lacking. Royalty rates for many of the rainforest timbers were pitched way below the true worth of those timbers; industries, utilising these timbers, were established with appetites far in excess of the capacity of the stands to sustain; in some, though not all, areas the intensity of logging was much greater than was silviculturally desirable, aesthetically acceptable or politically wise. The stage was set for events that had the inevitability of a Greek tragedy. As environmental awareness in the community increased, so did concern over rainforest logging, and in 1982 the Government, after long deliberation, decided to transfer large areas of rainforest (and even larger areas of eucalypt forest) from State Forest to national park, and to accelerate the phasing out of routine rainforest logging. In the process some of the most potentially manageable areas of rainforest, much of it previously harvested, were lost from the State Forest estate, and the skills in the techniques of rainforest harvesting rapidly decayed.

Nonetheless the Forestry Commission still remains the custodian and manager of the largest part of the N.S.W. rainforest area, with about half of this area logged in the past and with capacity for long-term management with timber as one of the benefits being obtained. In the future it is possible that these areas will again be used to support a continuing timber industry, this time at a level geared to the productivity of the stands and to their various other values, with the financial returns more commensurate with the special attributes and values of at least some of the rainforest timbers.

These Notes are intended to bring together some of the information obtained in the past about rainforest silviculture in N.S.W., and about the factors that affect it, in the hope that this may in the future serve to avoid some reinvention of the wheel, and also to remind foresters that despite assertions to the contrary (e.g. Moore, 1982; Callaghan, 1986) the N.S.W. rainforests can indeed be managed for multiple use purposes, including the production of their fine timbers.

2. FOREST ECOLOGY AND BOTANY

2.1 Features of Rainforest

2.1.1 Life Forms

To understand both the structure of rainforest stands and the way rainforest responds to various forms of treatment and disturbance, it is important to have as a starting point some knowledge of the life-forms exhibited by rainforest plants.

An excellent review of the rainforest life forms is given by Richards (1952[2], chapters 4 and 5), while a briefer review, relevant to the features of main silvicultural interest, was presented by Baur (1968, chapter 3). A summary of these features, taken largely from these sources and applicable to conditions in N.S.W., is given in Appendix 2 and should be at least scanned by anyone using these Notes. As set out in Appendix 2, the life forms considered are: trees, shrubs, herbs, palms, vines, epiphytes, stranglers and others (parasites, saprophytes).

[2] This book was responsible for sparking a vast amount of interest and subsequent research in rainforest. It is inevitably now somewhat dated; nonetheless it appears to remain the best general account of rainforest ecology to have appeared.

These life forms in turn provide the building blocks, which, together, define the structure of rainforest stands.

2.1.2 Structure

When the structure of rainforest patches, which have had no major disturbance for a lengthy period, is examined, most N.S.W. stands fall into several fairly distinct and consistent groups. These can be portrayed in profile diagrams, either actual (e.g. Baur, 1962; see also Fig. 1) or stylised (e.g. Webb, 1959; Cameron-Smith, 1986), or in other ways, e.g. tabular (Baur, 1957).

Four major forms of rainforest occur in N.S.W. and, as will be seen later (Section 2.3), these closely correspond to the botanical or floristic composition of the stands. As modified from Forestry Commission of N.S.W. (1989), the definitions of rainforest used by the Commission, and of these four forms of rainforest, are:

Rainforest: A closed, moisture-loving community of trees, usually containing one or more subordinate storeys of trees and shrubs; frequently mixed in composition; the species typically, but not invariably, broadleaved and evergreen; heavy vines (lianes), vascular and nonvascular epiphytes, stranglers and buttressing often present and sometimes abundant; eucalypts typically absent except as relics of an earlier community.

Four subformations are recognised:

Subtropical Rainforest: Contains three tree storeys; very mixed in composition; buttressing, lianes and vascular epiphytes common. (See Fig. 1A).

Dry Rainforest: Two tree layers, the upper layer usually being discontinuous (sometimes absent) and containing deciduous or xerophytic species; the lower layer dense and continuous, often very mixed in composition; lianes common; buttressing and vascular epiphytes usually rare, but occasionally abundant in sites receiving frequent fog and mist (e.g. parts of Upper Macleay valley, in stands dominated by Shatterwood; observation by D. Binns). (See Fig. 1B).

Warm Temperate Rainforest: Two tree layers, the upper layer being continuous; tendency towards one species being dominant; buttressing rare; lianes and vascular epiphytes present but seldom conspicuous. (See Fig. 1C).

Cool Temperate Rainforest: One or two layers, the lower (where present) being scattered and discontinuous; simple composition with one species usually clearly dominant; buttressing, vines and vascular epiphytes usually rare; leaf size smaller than in other subformations. (See Fig. 1D).

This terminology has become well accepted in N.S.W. (e.g. Adam, 1987; Cameron-Smith, 1986), though earlier publications often used other terms, or used the same terms for different communities[3]. Corresponding terms from the classification developed by Webb (1959) are:

These Notes	**Webb**
Subtropical Rainforest	Complex notophyll vine forest (NVF)

[3] The earlier confusion is well typified by publications of Baur, whose synonymy with the terms used here is:

These Notes	**Baur, 1962**	**Baur, 1957**
Subtropical	Subtropical	Tropical
Dry	Dry	Dry
Warm Temperate	Submontane	Subtropical
Cool Warm Temperate	Temperate	Temperate

Dry Rainforest	Araucarian notophyll vine forest (AVF)
	Araucarian microphyll vine woodland (AVW)
	Microphyll vine woodland (MVW)
Warm Temperate Rainforest	Simple notophyll vine forest (SNVF)
Cool Temperate Rainforest	Microphyll mossy forest (MMF)

Besides these major forms of rainforest, several other forms have been recognized and warrant mention:

Littoral Rainforest: A derivative of subtropical rainforest (but often with the structure of dry rainforest) found on coastal headlands and sand dunes. May reach 20m in height in favoured sites (sheltered swales of dunes), but often reduced to low, wind-shorn thicket.

Gallery or Riverain Rainforest: Narrow belts of rainforest growing along creeks and other watercourses, and extending in these favoured sites well beyond the areas where rainforest is a dominant landscape feature. Often of distinctive composition and showing affinities with dry and subtropical rainforest.

Gully Rainforest: A name for rainforest stands confined to gully sites in forested areas, often as a result of fire. Not a structural form.

Depauperate Rainforest: Name sometimes applied to rainforest of poorly developed structure and low height, and lacking species of commercial interest either as a result of removal by past logging or of a natural deficiency due to occurrence under conditions marginal for successful rainforest development. Often with massive vine occurrence.

Several other comments on the definition of rainforest are warranted.

Firstly, mangrove communities are sometimes included with rainforest as local examples of “closed forest”. They are however quite distinct from rainforest, and are not considered further here.

Secondly, the distinctions between subtropical rainforest, as defined above, and rainforest found in the lowland and lower montane tropics are largely ones of degree: Baur (1968) included subtropical rainforest as a subformation of the “Tropical Rainforest Formation”, and at this he may have been correct. Subtropical rainforest tends to be less rich in species; to have on average a somewhat smaller leaf size - a dominance by the notophylls, rather than the mesophylls, of Webb (1959); and to show fewer, and less extreme, examples of some of the characteristic tropical rainforest life-forms. Thus drip tips and cauliflory are less common and well developed in subtropical rainforest and stilt-rooting is absent, while in the tropics buttressing and stranglers sometimes assume quite unusual and extravagant forms and more types of palms, of distinctive appearance, are present. Nonetheless the differences are not great; the similarities are much more striking.

Thirdly, as will be mentioned at various points through these Notes (e.g. Section 2.6), rainforest species, and sometimes ultimately a recognisable rainforest community, may develop beneath or with eucalypts and their associates, including Brush Box. Depending upon one’s outlook such stands can be regarded as sclerophyll forest with a dense, moist understorey; rainforest with a transitory (though rather lengthily transitory) overstorey; or a mixed forest. No approach is entirely wrong or entirely right, though under certain circumstances any one approach may have comparatively greater correctness or usefulness than the others. The Forestry Commission of N.S.W. (1989) recommends that in such cases the vegetation should be shown as overlapping types, with both the eucalypt forest and rainforest presence recognised. Such recognition is important silviculturally, as some such mixed communities can prove refractory to regenerate back to eucalypts. In these Notes consideration is given to rainforest in its narrow, but more usual, sense.

Figure 1: Profile Diagrams of N.S.W. Rainforest (Scale in metres as indicated by vertical bars)

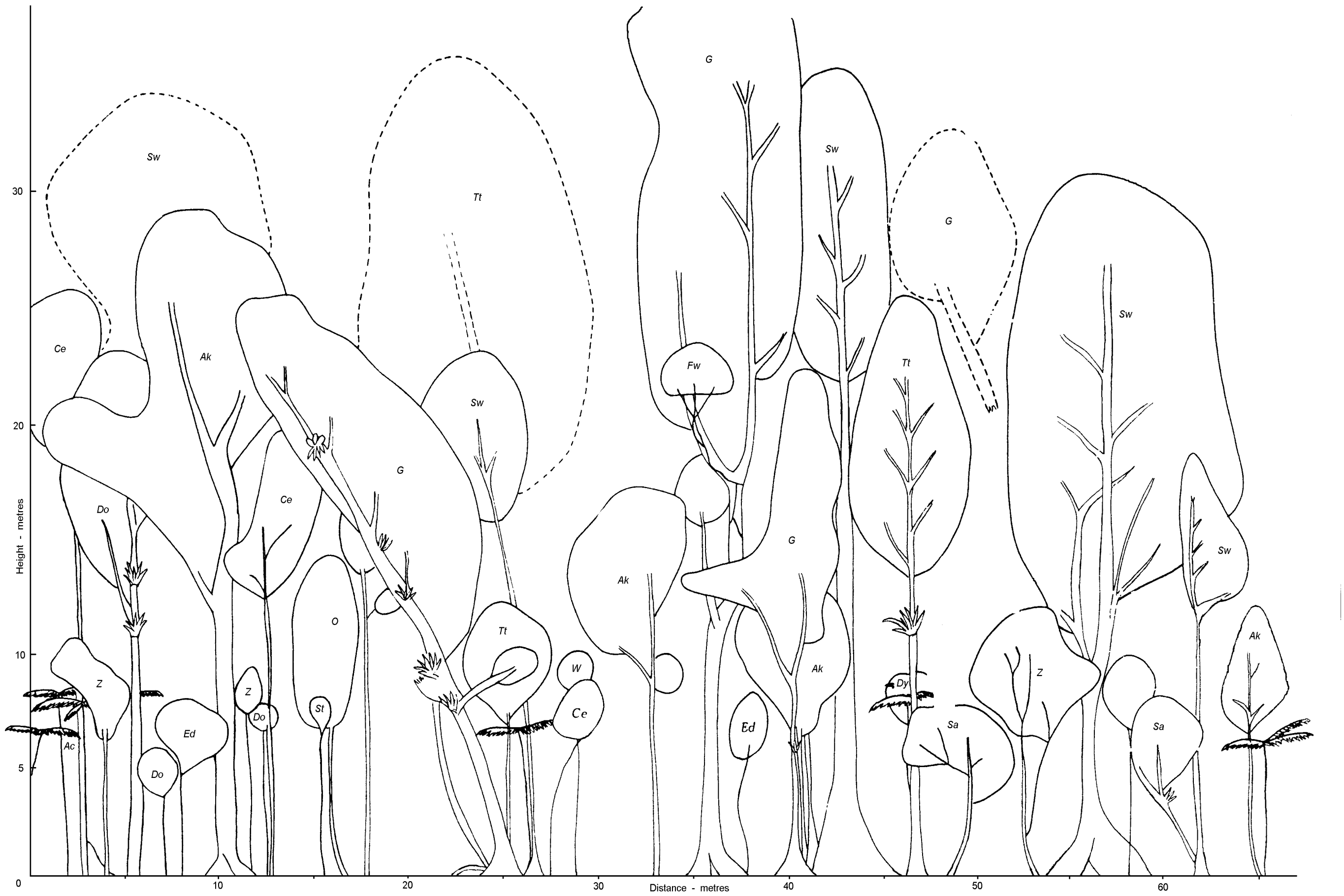


Figure 1A: Subtropical Rainforest: Former Wiangaree State Forest (Northern N.S.W.)
Transect 60m long, 7.5m deep, Stems < 6m high omitted

Key to Species Symbols:

Ac - Bangalow Palm	*G - Red Carabeen*	*Prickly Tree Fern*
Ak - Corkwood	*O - Prickly Ash*	*Birds Nest Fern*
Ce - Pigeonberry Ash	*Sa - Maidens Blush*	*Staghorn Fern*
Do - Sassafras	*St - Scrub Beefwood*	
Dy - Rosewood	*Sw - Yellow Carabeen*	
Ed - Domatia Tree	*Tt - White Booyong*	
Fw - Green Leaved Moreton Bay Fig	*W - Wilkiea*	
	Z - Satinwood	

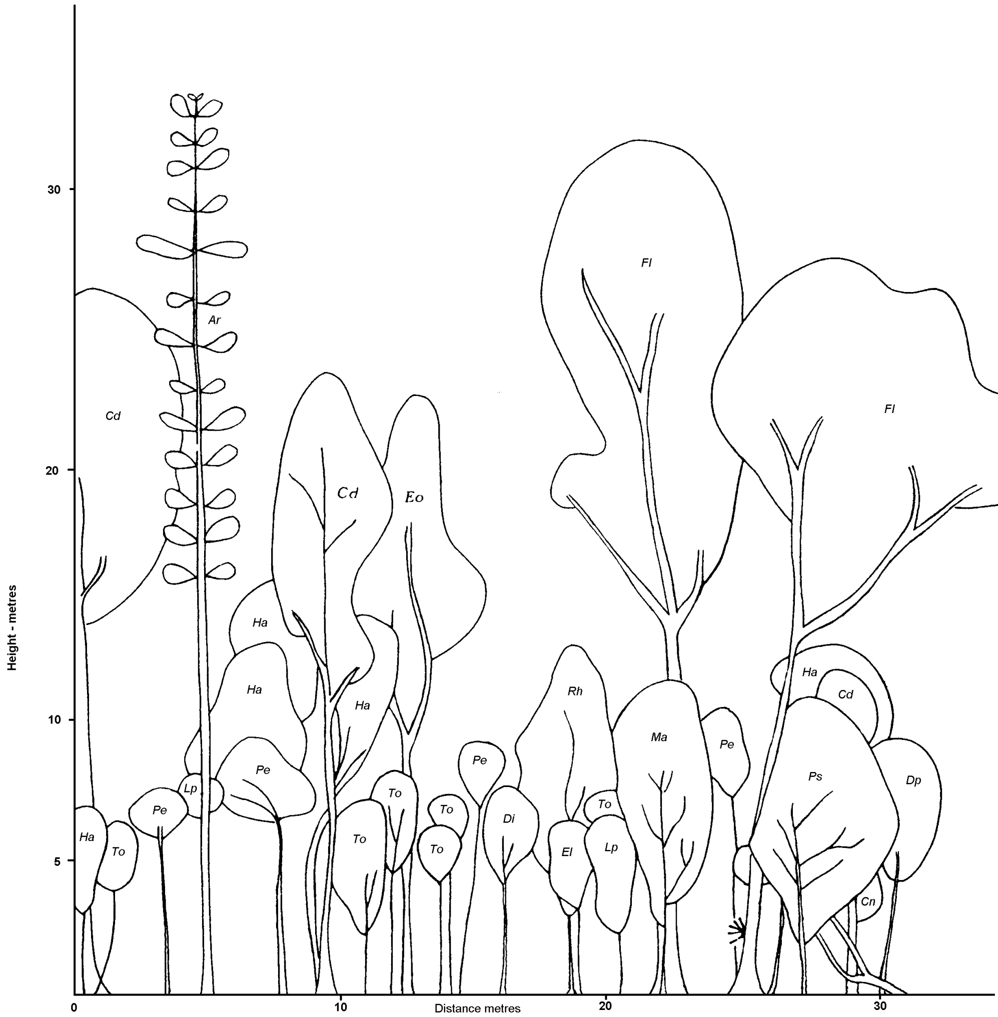


Figure 1B: Dry Rainforest, Unumgar State Forest (Northern N.S.W.)
Transect 30m long, 7.5m deep, Stems < 6m high omitted

Key to Species Symbols:

Ar - Hoop Pine	*Ha - Yellow Tulipwood*
Cd - Orangebark	*Lp - Shining Leaved Stinging Tree*
Cn - Native Pomegranate	*Mn - Mallotus*
Di - Black Myrtle	*Pe - Pencil Cedar*
Dp - Denhamia	*Ps - Whalebone Tree*
El - Elattostachys	*Rh - Rhysotoechia*
Eo - Blueberry Ash	*To - Toechima*
Fl - Crows Ash	

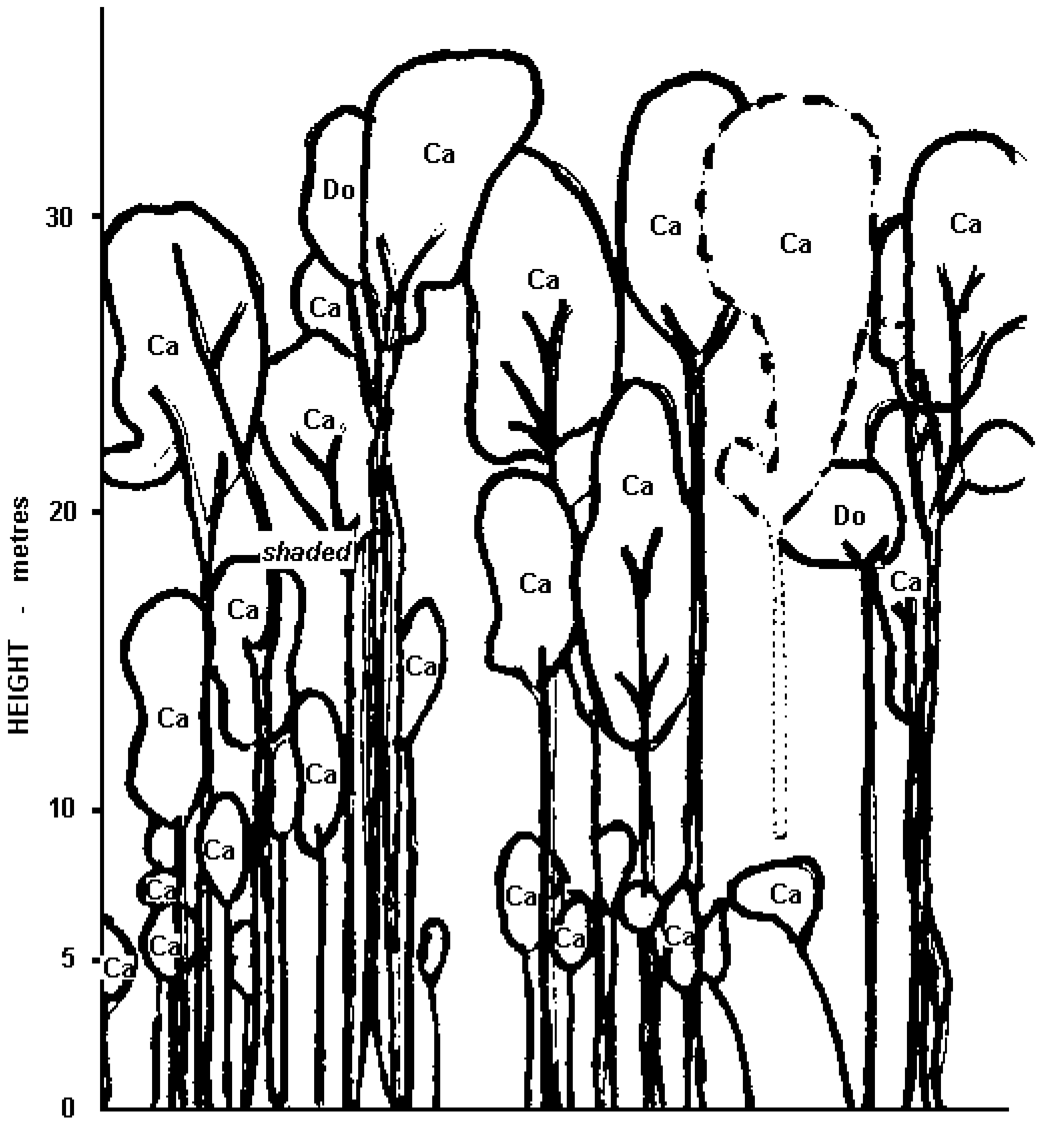


Figure 1C: **Warm Temperate Rainforest: Moonpar S.F.**
Transect 30m long, 7.5m deep, stems < 6m omitted
Dom. spp.: Ca, Coachwood; Do: Sassafras

Figure 1D : Cool Temperate Rainforest: Point Lookout
Transect 30m long; 7.5m deep; stems < 2m omitted
Dom. spp.: Nm Negrohead Beech
with Do Sassafras and Cr Coachwood

2.1.3 Disturbed Patches

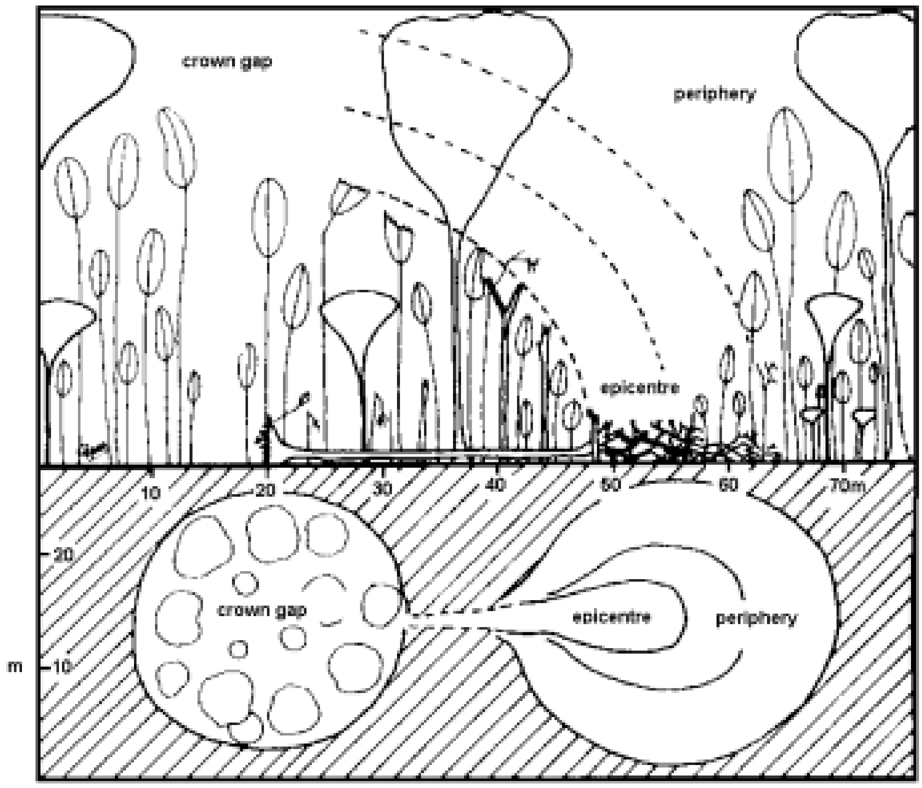
The descriptions of the major forms of rainforest in the previous section are based on the features found in stands that have been relatively undisturbed for lengthy periods.

However such patches make up only part of any rainforest stand, and in some places only a small part at that. Rainforest is a very dynamic community, and even without human interference there is a continual process of disturbance taking place, based particularly on the death of individual trees or clumps of trees. Such deaths result in the creation of gaps within the forest, and these may be small where the tree dies and decays while still standing; larger where the tree falls; and quite extensive where a clump of trees or even larger stands of forest fall together, as may happen from heavy logging or, in Nature, from severe storm damage.

The individual falling tree, whether falling naturally or as a result of human activity, is probably the most usual agent of gap formation in rainforest, and an appreciation of the significance and dynamics of these gaps is basic to an understanding of many aspects of rainforest silviculture. Rainforest gaps will be a recurring feature in these Notes.

Oldeman (1978) states: *"The fall of a tree, its impact on the forest, the fallen tree itself, and the resulting destruction are together described by the medieval French word 'chablis'[4] ".* Oldeman's illustration and accompanying description of such a *chablis* are reproduced in Fig. 2. Although the term has not been widely used in Australia, the concept is an important one in rainforest management.

Fig. 2 The chablis. Tree fall produces distinct energetic environments: crown gap with intact lower storeys, epicenter of crown fall (macroclimatic), and its periphery with gradual transition from macroclimate to forest microclimate. In each, sylvigenesis is different. In diagram, intact forest is hatched, and periphery extends beyond destruction because of lateral light offer.



[4] It is understood that the grape used to produce chablis wines was originally found as a variety typically occurring in forest gaps resulting from tree falls.

Much rainforest disturbance results in considerably larger gaps than those caused by a single falling tree. Vines are usually plentiful in the regrowth that develops in these larger openings. Where the damage is frequently repeated, as in sites prone to repeated cyclone or storm damage, the vines may effectively become the permanent dominant plants, blanketing the opening and enveloping the occasional standing trees as “vine towers”. Progression beyond this stage is halted while ever the disturbance continues. Examples are not uncommon in northern N.S.W., particularly in the vicinity of steep, wind-catching escarpments (e.g. near Billilimbra Trig., Washpool/Billilimbra/Ewingar S.Fs), while outstanding examples occur in the cyclone belt of North Queensland (e.g. east face of Bartle Frere Range); in West Africa elephants have been a major factor in perpetuating such vine tangles. Sometimes the vine dominance may persist for lengthy periods even without any apparent recurring disturbance, in what Tracey (1985) has referred to as “locked succession”: the vine-filled gullies found in various N.S.W. forests (particularly where scattered large eucalypts have in the past been harvested from above a low rainforest “scrub”) are examples that warrant further study. (Often site conditions may be marginal for the development of well-structured, tall rainforest, but in places this is not so, with the vines (particularly Native Grapes) forming such a dense and continuous cover that further development becomes long deferred).

Disturbed patches, such as those mentioned, represent an important feature in any rainforest. A useful review of canopy gaps in rainforest generally is given by Whitmore (1989), as the lead paper in a special feature of **Ecology** (70(3), 1989; pp. 535-576) dealing with tree fall gaps and forest dynamics.

2.2 Floristics

The floristic richness of rainforest worldwide is legend, and although the N.S.W. stands hardly match those of the equatorial zone they do contain a large segment of the State’s woody vegetation.

The problems in identifying individual species from within this richness are well known, and are accentuated because so many species, often completely unrelated, can appear extremely similar at first sight, and often also because of the relative inaccessibility of the foliage of the trees. For a long period the most accessible guide was the book by Francis (1951; 1st edition 1929), but this was sketchy in relation to many N.S.W. species and its keys were of dubious utility; nonetheless “Francis” for about half a century was the most valuable reference to the State’s rainforest trees. More recently the position has greatly improved, with the publications by Floyd (1976-83, 1977a, 1989) describing and providing keys to the rainforest trees of N.S.W., and with the publications from the University of New England (Harden and Williams, 1979; Williams and Harden, 1979, 1980; Williams et al., 1984) providing excellent illustrated keys. Each of these publications has its special values, and all should be available to those working in or with rainforest in N.S.W.

As a measure of the floristic richness, Floyd (1976-83) describes 344 species of trees, plus several varieties, from some 59 families; Floyd’s key (1977a) identifies 157 species of trees attaining a basal diameter greater than 30cm; Williams et al. (1984) include 463 species of trees and shrubs from N.S.W.; and Williams and Harden (1980) cover 140 species, from 81 genera and 51 families, in dealing with N.S.W. climbers. These totals exclude herbs and epiphytes, along with other minor life forms.

To a very large extent the rainforest flora is quite distinct from that of the far more widely spread eucalypt-dominated forests and other communities in Australia. Until relatively recent times the rainforest flora was regarded as consisting of two elements, an Antarctic element (e.g. *Nothofagus*) with affinities in other south temperate land masses and an Indo-Malaysian element (e.g. *Meliaceae)* whose affinities lay in Southeast Asia and the Malaysian archipelago. Both were regarded as having invaded the Australian continent, where a third, typically Australian element (e.g. *Eucalyptus*) had separately evolved.

Plate-tectonics and more recent palaeogeographic research suggest a rather different picture, in which much of the Australian rainforest flora is derived from plants present in the ancient supercontinent of Gondwanaland prior to its break up 50-100 million years ago (see, e.g. O'Neill, 1980; Webb et al., 1986). This Gondwanic flora appears to have had its own two elements, one temperate (largely corresponding to the former Antarctic element) and the other probably subtropical and encompassing the ancestors of much of the present day Australian rainforest flora.

With the break up of Gondwanaland examples of both elements occurred on the various resultant continental plates. To a large extent these account for or contributed to the rainforest communities in these areas - South America, Africa, India and Australia. In Australia further evolution within these elements provided what is commonly regarded as the typical Australian element (e.g. *Eucalyptus, Acacia*), while there has also been invasion and enrichment (though to a lesser extent than was previously believed) from Southeast Asia over the past 15 million years. The similarities between rainforest in different parts of the world appear to owe much to Gondwanaland (Barlow and Hyland, 1988).

The Australian rainforest flora contains an unusually high proportion of genera retaining what are generally accepted as primitive floral characters (Specht et. al., 1974; see chapter 10, pp.606-628). While most of these relict genera of flowering plants occur in North Queensland, about a third of them (43) are represented in N.S.W. rainforests. This adds further credence to the venerability of rainforest, and its distinctive flora, in Australia. It should perhaps be added that, although apparently retaining primitive features, many of these genera are clearly very successful groups of plants, including the widespread Pepper-bushes and the families Cunoniaceae and Lauraceae.

2.3 Rainforest Types

In Section 2.1.2 it was shown that distinct structural forms of rainforest could be recognised in N.S.W. These forms in turn are closely paralleled by the floristic composition, but within each form a number of types, showing different patterns of composition and dominance, can be recognised.

The number of such types recognised will vary with the intensity of the classification used. The Forestry Commission of N.S.W. (1989), in its latest overview, describes 24 rainforest types, split between four leagues that correspond broadly to the four main structural types. As slightly modified from this publication, the descriptions of these leagues, and résumés of the included types, are given in Appendix 3. The types so described are:

(a) **Subtropical Rainforest League**
1. Booyong
2. Yellow Carabeen
3. Corkwood - Sassafras - Crabapple - Silver Sycamore
4. Black Bean
5. Booyong - Coachwood
6. Fig-Giant Stinger
7. Palm

(b) **Warm Temperate Rainforest League**
10. Coachwood League
11. Coachwood - Crabapple
12. Coachwood -Sassafras
13. Water Gum-Coachwood
14. Lilly Pilly
15. Sassafras

(c) **Cool Temperate League**
16. Negrohead Beech
17. Negrohead Beech-Coachwood
18. Pinkwood
19. Mountain Quandong
20. Mountain Walnut

(d) **Dry and Depauperate Rainforest League**
21. Hoop Pine
22. Yellow Tulipwood
23. Myrtle
24. Tuckeroo
25. Headland Brush Box
26. Viney Scrub

These types, with a few minor exceptions of limited extent, have generally proved satisfactory in covering the rainforest communities encountered in N.S.W. for Forestry Commission needs. However for other purposes more detailed or different approaches in classifying the State's rainforest communities may be desirable.

A.G. Floyd, who has carried out the most comprehensive study of the composition of rainforest stands in N.S.W., has listed some 60 communities (“suballiances”) for the State (Floyd, 1984), with 43 of these coming from northern N.S.W. (Floyd, 1987). Floyds classification starts, like the Commission’s, with the 4 main forms, though in several cases individual communities may appear as thicket or closed scrub, rather than rainforest. Within these forms he recognises 16 alliances that are further subdivided into the 60 suballiances. Appendix 4 gives the outline of Floyd’s classification and suggests the comparable Forestry Commission type in each case.

Webb et al. (1984) have suggested a different approach to the classification of rainforests in Australia as a whole. Their species classification divides first into three “ecofloristic regions”, with the N.S.W. stands mostly in A (temperate and subtropical humid evergreen rainforests) and to a small extent (some dry rainforest communities) in C (subtropical moderately seasonal humid/subhumid raingreen forests); the regions are further divided into eight “ecofloristic provinces”, of which five occur in N.S.W., and a number of separate elements are in turn recognised within these. The approach appears to have limited utility for land management purposes; its value in a more strictly ecological sense has still to be evaluated.

2.4 Environmental Factors

2.4.1 General Comment

As with any plant community, rainforest occurs in response to the interactions of a large number of environmental factors.

The usual name of the formation, rainforest, suggests that rain is the major determining factor, but this is not so. Certainly most forms of rainforest require access to adequate moisture, but this need not be solely from rain, and indeed some communities obviously derived from rainforest (e.g. some western scrub communities, probably better developed in Queensland than in N.S.W.: see Beadle, 1981, pp. 181-193) occur under relatively arid conditions.

Many writers on rainforest have reviewed the environmental features determining its occurrence, e.g. for N.S.W., Baur (1957) and Adam (1987). In the following sections these factors will again be briefly examined, with a degree of emphasis on the features of silvicultural significance.

2.4.2 Climate

Summaries of the climate from a number of sites where, or close to where, rainforest occurs are given in Appendix 5. These sites, and the types of rainforest occurring nearby, are:

Location	**Latitude**	**Altitude**	
Condong	28º 19'	5m	Booyong type
Whian Whian	28º 36'	380m	Booyong; Coachwood-Crabapple
Casino	28º 52'	25m	Hoop Pine; Yellow Tulipwood; Black Bean
Clouds Creek	30º 6'	590m	Booyong; Coachwood-Crabapple
Brooklana	30º 18'	567m	Coachwood; lower limits of Negrohead Beech
Coffs Harbour	30º 19'	3m	Booyong-Coachwood; littoral RF
Styx River	30º 37'	1036m	Coachwood; Negrohead Beech; Yellow Carabeen
Camerons Camp	31º 12'	840m	Negrohead Beech; Coachwood
Katoomba	33º 43'	1011m	Coachwood-Sassafras
Ulladulla	35º 22’	9m	S limits of Subtropical RF; Coachwood
Nalbaugh	37º 4'	731m	Close to Pinkwood, Mountain Quandong

The following points about the climatic influence on rainforest occurrence in N.S.W. should be noted:

- In broad terms, subtropical and warm and cool temperate rainforest become a significant landscape feature in northern N.S.W. where rainfall exceeds about 1 500 mm a year, and at slightly lower levels further south.

- Dry rainforest develops where rainfall exceeds about 1 100-1 200 mm in northern areas.

- The availability of soil moisture, due either to soil features or topographic position, can compensate for lower rainfall, as can the frequent occurrence of mist and cloud.

- While all N.S.W. rainforests show some degree of seasonality, dry rainforest in particular occurs in response to a regular and extended dry season.

- Negrohead Beech stands usually occupy perhumid sites (very high rainfall, frequent mist) at high elevations. Temperature seems to limit their lower altitudinal boundary, probably more by restricting the growth of otherwise more efficient competitors from lower altitudes than by adversely affecting the growth of Beech itself. (Negrohead Beech can be successfully grown in Sydney, where it will regularly flower.)

- Temperature appears to exercise a broad control over species composition, and to be largely responsible for the reduction in the number of rainforest species as one progresses southwards, and hence for the relative impoverishment of the more southern stands compared with those further north. (Almost any sizeable rainforest stand can be claimed as the southernmost known occurrence of some species; more rarely it may be the northernmost occurrence of some species of temperate affinities).

- Well-developed rainforest can develop in areas where frequent winter frosts occur in openings, and to some extent in areas where snow is an annual event.

- In littoral sites, wind appears to have a major role in providing (as aerosols) the nutrients needed to support rainforest on otherwise highly infertile sands.

- Elsewhere the role of wind is generally destructive. Strong winds will blow trees over, and thus have a significant part in maintaining gap structure; periodic cyclones may destroy rainforest stands over large areas (one in February, 1954 effectively clear felled about 80 ha of subtropical rainforest on Yabbra S.F.); sites frequently affected by cyclones or similar storms will develop a typical structure dominated by vines; constant winds may cause wind-shearing on exposed margins (e.g. littoral rainforest; also in some montane sites), and elsewhere will tend to limit the height development of the rainforest.

- Exposure to desiccating westerly winds is probably a major factor in determining the western boundary of rainforest stands - possibly more by favouring frequent fire damage than by limiting rainforest growth *per se*.

- Wind influences evapotranspiration, and sites subject to constant wind tend to have species possessing rather sclerophyllous leaves.

2.4.3 Microclimate

Microclimate is not really a factor of the environment - rather the reverse, in that it represents the influence of the vegetation on the climate. An understanding of rainforest microclimate is basic to rainforest silviculture and management generally, and the subject was well reviewed by Richards (1952; chapter 7); some data relating particularly to south Queensland conditions are given by Yates et al., (1988). Here, again, a few points only will be stressed.

In a well-structured patch of tall rainforest, the climatic conditions experienced by the treetops are vastly different from those at ground level:

- The tree top climate is broadly similar to that in an extensive clearing at ground level, while at lower levels in the stand all of the climatic effects are damped down and modified.

- The effects are greater in the denser and more complex stands than in open and simpler stands.

- Wind velocity can drop from gale force to a very gentle breeze at ground level - a feature favouring some of the very delicately foliaged plants of the understorey.

- Light at ground level is commonly less than 4 per cent of that in the open, with most of the light coming from the transient sunflecks (50-70's), a small amount (about 5%) coming from skylight passing through holes in the canopy, and the remainder being shade light, transmitted through the leaves and reflected from the foliage and trunks.

- Precipitation is retarded, and in light showers almost no rain may reach the ground. With prolonged rain the situation alters, with much reaching the ground by stem flow, though a significant proportion probably never reaches the soil, being used by epiphytes, absorbed by the leaves and bark, or re-evaporated into the air.

- The daily temperature range is greatly reduced at ground level. Minima in the rainforest are higher (Baur, 1968, records a minimum temperature about $11C^0$ higher under rainforest at Clouds Creek S.F. than in a nearby grassland opening), while the maxima under hot, sunny conditions probably show even greater differences.

- Humidity is, next to light, probably the factor most affected by the rainforest canopy. Although specifically referring to tropical rainforest, Richards comments (pp. 173-4) summarise the position well:

  "…in the tropical rainforest there is no humidity gradient at night, the atmosphere at all levels being near saturation. The rise of temperature in the morning causes a ... fall of relative humidity, beginning at the top storey of the forest. During the morning, the warming of the lower layers of the atmosphere and the mixing of upper and lower layers by wind and convection currents cause the saturation deficit to increase even at low levels, but the evaporation from the soil and transpiration from the leaves, combined with the lower temperature in the shade and the smaller amount of air movement, prevents the saturation deficit from ever rising as high in the undergrowth as in the upper storeys. The range of humidity therefore diminishes sharply from above downwards, and a gradient of humidity is set up which changes in steepness, and probably in form, as the day goes on."

Because of this gradient, the daily range of humidity in the undergrowth is always much smaller than in the upper storeys, allowing the understorey to retain its essentially mesomorphic characters even in sites with an extended dry season.

- These high internal humidities are most significant in giving little disturbed rainforest a high degree of natural protection from fire.

Microclimate represents the one segment of the climate that is capable of ready manipulation in management. Logging creates gaps ranging from a single tree chablis through, in some cases, to extensive openings. In these the microclimatic gradients that exist in a little disturbed patch are immediately changed:

- Light conditions are improved, allowing the survival and active growth of plants that cannot tolerate very low light intensities.
- The temperature range on the ground is increased, and there is evidence that this (either by higher maxima or by the greater daily fluctuation in temperature) triggers the germination of some species whose seed is stored in the soil.
- Reduced humidity in the lower crown levels and greater exposure to wind appear to be major causes of crown dieback in many temperate rainforest stands.
- The generally lower humidity levels make disturbed areas of rainforest more prone to damage should fire occur.
- At the higher altitudes, large openings can develop into frost hollows.

2.4.4 Soil

Rainforest in N.S.W. occurs on soils derived from a wide range of parent materials, including coastal sands, granite, basalt, rhyolite, shale, metamorphosed sediments, alluvium and limestone. Within any area it is commonly observed that the types of rainforest present are strongly influenced by soil conditions:

- Subtropical rainforest almost invariably occurs on heavy-textured soils with a high fertility status, such as those from alluvium or with a strong basaltic influence. Lambert et al. (1983) and Lambert and Turner (1986) have reported on the nutrient relationships of various species in such a stand.
- Under similar climatic conditions to those where the more fertile soils support subtropical rainforest, soils of lower fertility status (notably low phosphorus availability; Baur, 1957; Florence 1963, 1964) tend to support warm temperate rainforest dominated by Coachwood.
- At higher latitude, as at Mt. Wilson, warm temperate rainforest with Coachwood occurs on basalt-derived soils, suggesting that its absence from such soils further north is due to competition from species that are absent in the south. The same effect is shown by some stands at high altitude in northern N.S.W. (e.g. Dingo Creek F.R.).
- Negrohead Beech stands are commonly found on basalt, but this probably merely reflects the fact that most of the higher altitude, perhumid, escarpment sites favoured by this species coincide with basalt flows; Beech stands also occur on other soil types (e.g. on metamorphosed sediments on eastern Dorrigo Plateau).

- Although the basaltic krasnozems can become very dry in their surface layers during rainless periods, well developed subtropical rainforest often occurs on such soils on ridge or plateau tops (e.g. Chapmans Plan F.R., Cedar Pit F.R., Red Cedar F.R.) where, on the adjacent sedimentary soils, warm temperate rainforest is confined to sheltered gullies. This possibly reflects the greater depth, and hence greater access of tree roots to retained soil moisture, of the basalt soils; the greater nutrient richness, resulting in denser vegetation and somewhat less fire-prone foliage, probably also is relevant.

- Dry rainforest appears almost invariably to be confined to heavy-textured soils of high fertility.

- Rainforest only appears on sandy soils where there are supplementary sources of moisture and nutrients, e.g. on coastal sands and on alluvial or colluvial deposits in sandstone areas. Whilst Coachwood rainforest occurs on soils with much lower fertility than the subtropical stands, it is unlikely that rainforest would ever have occupied most of the highly infertile sandstone deposits in N.S.W.

- Limestone deposits on Carrai S.F. support dry rainforest.

- Despite the luxuriant appearance of the vegetation, many rainforest soils are not of high fertility, and efforts to convert such land to agriculture have often been markedly unsuccessful (e.g. the Coachwood stands of the eastern Dorrigo Plateau, opened for soldier settlement after World War 1). (Outside of Australia, this is a major reason for objections to some of the recent transmigration schemes under way in rainforest areas of Brazil and Indonesia).

- N.S.W. rainforests are normally not rich in species known to fix nitrogen, and the ultimate source of nitrogen in the stands remains rather uncertain - thunderstorms may be a major source.

- Many of the species typical of warm temperate rainforest are notable aluminium - accumulators. Lambert et al. (1983) provide a striking comparison from two species growing on the same site: Prickly Ash (a common species in warm temperate rainforest) and White Booyong (a characteristic species of subtropical rainforest):

Al content - ppm

Species	Foliage	Bark	Sapwood	Heartwood
Prickly Ash	6790	1690	6475	1425
White Booyong	55	45	30	15

- Lambert and Turner (1986) have demonstrated the accumulation of other nutrients by particular rainforest species, which were often more prevalent on disturbed than on undisturbed sites.

- Where rainforest species occur beneath an overstorey of eucalypts, the rainforest component tends to have a much higher nutrient content and annual requirement than the overstorey: Turner and Lambert (1983) report a 27-years old Flooded Gum stand where the rainforest understorey comprised only a small proportion (9.3 per cent) of the above-ground biomass, but it contained 33, 35, 16, 24 and 49 per cent of the above ground distribution of N, P. Ca, Mg and K respectively, and it was responsible for an annual net accumulation of 55, 59, 30, 44 and 69 per cent of the same nutrients.

With rare exceptions, rainforest litter tends to break down rapidly, so that there is normally no large build up of fuel on the forest floor and considerable expanses of bare soil are usually evident.

2.4.5 Topography

Topographic conditions act largely to modify climatic or soil conditions. As a result, through much of eastern N.S.W., where conditions tend to be rather marginal for rainforest development, the rainforest occurrence pattern is strongly influenced by topography:

- In many districts rainforest develops on southerly and easterly aspects, but is absent from those exposed to the north and west. To some extent this may be a result of the drier conditions being unfavourable for rainforest development, but it is suspected that the main cause is fire occurrence, which in turn is strongly influenced by topography.

- Gallery rainforest directly depends on the existence of streamside topography.

- The common restriction of rainforest to gullies similarly is a result of topography. Better moisture conditions, accumulations of nutrients, protection from desiccating winds, and again perhaps most of all shelter from fire all appear to have a role in these occurrences.

- On exposed sites, rainforest may be reduced in height or be wind-shorn, or in places be subject to frequent storm disturbance.

- Some species largely, if not exclusively, restricted to creek banks appear to occur there because their seeds are normally water-distributed: e.g. Black Bean, Silver Quandong. By contrast in North Queensland Silver Quandong has its seeds distributed by cassowaries, and the trees can appear in all topographic positions.

- Silky Oak, another species largely occurring on stream banks, has litter that appears to render the site unsuitable for its own growth (Webb et al., 1967). In this case flooding may assist in preventing a build up of the toxic element in the soil.

2.4.6 Fire

The remaining environmental factor of particular importance in relation to rainforest distribution and occurrence in N.S.W. is fire.

As noted, a little-disturbed patch of rainforest is an unfavourable environment for fire: the normally high internal humidity levels, the mesophytic foliage and the rapid breakdown of litter mean that fire will not burn readily, and that a fire burning into such a stand tends to extinguish itself rapidly.

Nonetheless, under extreme conditions fire may continue to burn through rainforest stands, often patchily and with the burning largely confined to surface litter. In November, 1957 a fire entered Mt. Boss S.F. from the northwest and was able to spread through same 3000 ha of State Forest, including about 230 ha of rainforest, of which about 40 ha was classed as heavily damaged. Under the conditions at the time the "*rainforest litter (was) almost as dry as hardwood litter*", and much of the spread of the fire (at least 10 spot fires over a distance of 9 km) was attributed to *"dry moss in heads of old Negrohead Beech".* This fire appears to have been exceptional, possibly largely due to the amount of epiphytic moss and lichens present in cool temperate rainforest. Another fire resulting in considerable damage occurred in the dry rainforest at Mt. Pikapene S.F. about 1915, though in this case it is probably that litter from earlier logging may have contributed to the fires severity. More usually the surface fire may do relatively little damage, except where litter has accumulated round the base of trees which may either be killed directly, if thin barked, or else partly burnt through if woody material is in the litter pile. The fire scars sometimes seen at the base of some trees in what appears to be undisturbed rainforest would have originated from such fires. Accounts of damage from fire to rainforest in southeastern Queensland are given by Ridley and Gardner (1961).

Where the rainforest is substantially disturbed, whether by logging or storm, fire is more likely to burn and the resultant damage will be more severe. Humidity levels will be lower, temperatures higher, wind effects greater, there is much more fuel on the ground and this may be much drier and hence more inflammable than would be the case in a little-disturbed patch.

Rainforest trees generally are less resistant to fire damage than those of the eucalypt forests, though the degree of resistance varies greatly between species, with smooth, thin-barked species being most susceptible. Nonetheless, many rainforest trees have the capacity to recover from fire damage. No data are known from N.S.W., but Stocker (1981) has reported on a North Queensland study where a patch of rainforest was felled and burnt. Most genera and some 24 tree species, out of 82 species originally present, were ones also occurring in N.S.W., and after 23 months 74 of the species had coppiced and 10 had produced root suckers. Thirty four species had also regenerated from seed.

Rarely will a single fire totally exterminate an area of rainforest, though it may well open it up sufficiently for eucalypts and associated species to establish, and these will typically develop ahead of the rainforest regrowth. However if the burning is repeated frequently enough, either by a small scale nibbling away at the boundary of undisturbed rainforest or by repeated fires in a previously disturbed and burnt site, then gradually the rainforest will disappear and be replaced by sclerophyll forest or similar. Kershaw (1976) has inferred that the arrival of Aborigines resulted in a replacement of rainforest by sclerophyll forest in North Queensland as a result of burning, and there is evidence that this process occurred widely in eastern Australia (e.g. Beck, 1986).

Certainly the major immediately limiting factor to rainforest occurrence in N.S.W. at the time of European settlement appears to have been fire, and with the subsequent abandonment of regular Aboriginal burning there has been a tendency for rainforest to expand from its common gully strips and other sites into the adjoining eucalypt forest.

* * * * * * *

Adequate moisture, soils of at least moderate fertility, and an absence of repeated fire. These appear to be the major factors that have determined rainforest occurrence in N.S.W.

2.5 Other Ecological Effects

The fauna of the N.S.W. rainforest is to some extent remarkable, at least among the vertebrates, for the relatively few species that are largely or entirely confined to rainforest. As Adam (1987) points out in a very useful review (pp 32-38), the wet sclerophyll forests, with their combination of eucalypts and associated trees with an understorey often rich in rainforest elements, provide the most diverse faunal assemblages. An explanation for the lack of rainforest “specialists” in N.S.W. is given by Winter (1988).

Notable among the birds are two groups, the fruit-eaters and birds that feed on invertebrates in the ground litter. These are among the most characteristic of the rainforest birds, and their feeding habits have some silvicultural significance, in the former case by distributing the seeds of fleshy-fruited species and in the latter both by producing exposed soil surfaces for seed germination and also by scratching out young seedlings. Included among these two groups are a number of the State’s rarer birds, e.g. Coxen’s Fig Parrot and Wompoo Pigeon (fruit eaters), and Rufous Scrub-bird and Albert’s Lyrebird (ground scratchers and feeders). The Noisy Pitta is another ground-feeder, whose stone “anvils”, used to crack open snail shells, are a distinctive feature in many northern N.S.W. rainforest stands. Some of these birds, notably the pigeons and Brush Turkey, have through much of the period of European contact with rainforest also served as the target for sport shooting and food (e.g. see Frith, 1982).

No mammals are confined to rainforest in N.S.W., though several species including the pademelons and the Mountain Possum are fairly characteristic of rainforest and adjacent eucalypt forest with patches of rainforest or scrub. (C. Mackowski, formerly research forester, Coffs Harbour, observes that the Mountain Possum can occur in very high population densities in rainforest, but at much lower densities in wet sclerophyll forest.) Similarly relatively few N.S.W. reptiles or frogs are essentially rainforest species; those that are include the Southern Angle-headed Dragon and the unusual Pouched Frog.

Invertebrates undoubtedly contain many species that are confined to rainforest. Included are oddities such as the giant earthworms of the basalt soils on Toonumbar S.F. and elsewhere and various primitive creatures mentioned by Adam; butterflies and moths whose larvae feed on specific rainforest plants; the extraordinary wasps responsible for fertilising figs; distinctive land snails; and a number of insects of unusually large size. Ground leeches are common; rather strangely, termites are rare. The invertebrate rainforest fauna is still far from being adequately known (Hill and Michaelis, 1988).

The rainforest fauna represents one of the more popular features of N.S.W. rainforest for the public generally, ticks, leeches and the occasional snake notwithstanding, and its conservation, in the broad sense of the word, is an important part of rainforest management.

2.6 Relationships with Other Communities

The rainforest communities will normally ultimately adjoin some form of eucalypt forest stand. Sometimes the local cause of the boundary is a soil change, with the fertility of the eucalypt soil too low to support rainforest (e.g. where basalt caps and creek side strips carrying rainforest adjoin sandstone soils). Most usually, however, the reason for the boundary is fire that has tended to restrict the area of rainforest in N.S.W. to something - probably a substantial something - less than the potential area capable of supporting rainforest.

Where the fires are frequently repeated the boundary will be distinct, and one can pass from open, grassy-floored eucalypt forest into the rainforest over a few metres. More commonly however the boundary is less distinct, reflecting various past fire events of differing frequency and severity.

Wet sclerophyll forest typically has an understorey of mesophytic shrubs, often of species found in rainforest. Sometimes conditions are such that the understorey will not naturally develop beyond this shrub stage (e.g. Cumberland S.F.), but elsewhere, and particularly in areas near tall, well structured rainforest, freedom from fire will allow the understorey to progress through to rainforest, with the sclerophyll overstorey element gradually dying and not being replaced (e.g. Norman V. Jolly F.R., Bruxner Park F.R.). Various intermediate stages occur, with the understorey, although often capable of developing to rainforest, being reburnt at irregular intervals.

It seems likely that, in Aboriginal times, frequent burning maintained many rainforest patches with clear boundaries, often deliberately so maintained to protect the rainforest as a source of foods or for religious or other purposes (see Byrne, 1987). Occasional accidents would allow fire to enter the adjacent rainforest, causing sufficient damage and stand openings for the eucalypts, Brush Box or other sclerophyll associates to regenerate and to develop with, but above, the rainforest regrowth. Sometimes this might lead to a new boundary, and a further loss of rainforest; elsewhere it seems that the original rainforest boundary would be more or less restored.

With the cessation of regular Aboriginal burning many of these boundaries have become much more dynamic, with rainforest advancing in fire-free periods and retreating when the now usually more severe wildfire occurs, resulting in larger areas of “mixed forest” than would have occurred two centuries ago. In some places that advance creates silvicultural problems, as where the relatively low statured Myrtle type (e.g. Grey Myrtle on South Coast, Ironwood on Central Coast) or Viney Scrub have advanced in this way and produced stands that would now only burn under extreme conditions, causing the loss of significant areas of formerly high quality eucalypt forest.

Some interesting matters relating to fire, rainforest and the existence of mixed forest in Tasmania have been summarised by Bell (1983), and the paper explores further some of the complex interrelationships and feedback mechanisms involved. Much of the material has relevance to N.S.W. conditions.

Rainforest has given rise to a number of species that occur in western scrub patches (or in the understorey of other inland forest types). Some of these (e.g. Quinine, Red Ash) are the same species as occur in the eastern rainforests; others are relatives of typical rainforest species. Where occurring as distinct "scrubs" these communities form part of a spectrum of communities with subtropical rainforest at one end and with dry rainforest in an intermediate position. The communities are discussed by Beadle (1981, pp. 181-193).

In a few areas rainforest abuts directly on to or surrounds small areas of grassland that existed prior to European settlement. Such grassland enclaves are known from the Bunya Mountains of southern Queensland and from North Queensland; from the vicinity of the Big Scrub, where they were known to the early settlers as "grasses" (e.g. Minyon Grass, adjoining Whian Whian S.F.); from upland rainforest areas on the Dorrigo and Carrai Plateaus (e.g. Chapmans Plain, Paddys Plain, Daisy Plain); and from Tasmania. Various explanations for these clearings have been given, including an inference of heavy textured soils for the Dorrigo "plains" (Cambage, 1918). The Bunya Mountains grasslands have been attributed to regular Aboriginal feasting when the Bunya nuts ripened (Herbert, 1938), though Webb (1964) preferred to invoke a "palaeoclimatic interpretation" for their origin. For the Dorrigo plains, which are all on basalt, Baur (1959) suggested that cyclonic destruction might have initiated the clearings, which were then maintained by severe winter frosts and possibly fire. Byrne (1987), referring to the Big Scrub grasses, suggests deliberate maintenance by Aboriginal burning, probably in part at least as an aid in hunting drives for pademelons along the rainforest margins. While their origins remain unknown, it seems that in most cases burning would have assisted in their maintenance. Chapmans Plain F.R. shows clear evidence of a once much larger grassland that has progressively shrunk as the rainforest has invaded under the shelter (from frost) provided by a narrow, fringing band of Sydney Blue Gum.

3. OCCURRENCE AND DISTRIBUTION

At the time of European settlement in Australia, there were five major occurrences of rainforest in what is now the State of N.S.W.:

Richmond-Tweed area, including lands along the McPherson Range, on the Queensland border. Mostly subtropical and dry rainforest forms. This area contained the Big Scrub, one of the largest rainforest occurrences in eastern Australia at the time of European settlement, occupying the extensive, low basalt plateau north and east of Lismore.

Dorrigo Plateau, and extending round the head of Bellinger Valley. Subtropical and warm and cool temperate forms.

Hastings Catchment, including adjacent plateaus. As for Dorrigo.

Barrington Tops Escarpment. Cool temperate on the tops and upper slopes, giving way to subtropical on lower slopes.

Illawarra District, extending discontinuously towards the Shoalhaven River. Mostly subtropical form.

In addition there were significant occurrences along the alluvial flats of all major rivers from the Shoalhaven north.

Figure 3

Rainforest Distribution in N.S.W.

(indicative rather than accurate)

Despite these larger rainforest occurrences, the overall pattern was nonetheless of widespread, but individually smaller, patches of rainforest in valleys, basalt caps and other favoured sites, from the Victorian to the Queensland border and from sea level to altitudes of over 1 000 m. Even some of these patches were relatively large, such as those in the Washpool area, west of Grafton.

The area of rainforest in N.S.W. in 1788 is estimated to have been about 1 million ha, but about three quarters of this area was subsequently destroyed for settlement purposes. Recent inventories indicate a present area of about 266 000 ha of rainforest in N.S.W. (Pople and Cowley, 1981, Forestry Commission of N.S.W., 1985), and details of this are given in Table 1. “Depauperate rainforest” in this table includes littoral rainforest stands (1 280 ha) plus stands, of various types, of naturally poor stature or structure. A map showing the general pattern of distribution is included as Figure 3.

Table 1
RAINFOREST IN N.S.W. - TENURES AND TYPES
('000 ha)

Type:	Subtropical	Warm Temperate	Cool Temperate	Dry	Depauperate	TOTAL
Tenure						
State Forest						
Multiple Use	53.7	19.4	9.7	12.5	36.1	131.4
Reserve	5.2	0.9	1.2	2.4	0.5	10.2
All State Forest	59.0	20.3	10.9	14.9	36.6	141.7
National Park*	30.5	15.9	6.2	6.7	13.8	73.2
Other Crown Timber Lands	0.8	1.7	0.3	0.1	12.3	15.3
Other Public Reserves	0.2	1.0	-	0.1	0.1	1.3
All Crown Lands	90.4	38.9	17.4	21.8	62.9	231.4
Private Property	7.3	9.7	1.8	3.5	12.3	34.7
TOTAL	**97.7**	**48.6**	**19.2**	**25.4**	**75.2**	**266.1**

* National Park category includes nature reserves: National Parks and Wildlife Service manage both.

Virtually all forest management areas in coastal areas and in the escarpment zone contain some rainforest stands though, as shown in the map, it is most plentiful in the north and diminishes to the south. Table 2 (from Forestry Commission of N.S.W., 1985) shows the geographic spread by forestry regions, regardless of tenure, and by grouping the regions into northern, central and southern zones the percentage of each major form in each zone is:

NSW Region	Subtropical	Warm Temperate	Cool Temperate	Dry	Depauperate	All Forms
Northern	73	74	32	99	69	72
Central	26	10	41	neg.	24	22
Southern	neg.	15	28	neg.	7	7

Notable here are the virtual restriction of dry rainforest stands to the northern areas and the increasing relative significance of cool temperate rainforest towards the south.

The rainforests of southern Queensland are, like those of northern N.S.W., today largely concentrated in the ranges: the more accessible areas were mostly cleared for farmland last century. The stands are chiefly of subtropical rainforest, giving way to dry rainforest in the lower rainfall districts. Further north rainforest is of very limited occurrence in the central districts, but becomes the dominant vegetation form in a coastal and escarpment belt from north of Townsville to Bloomfield: this is the largest belt of rainforest in Australia, and despite a much richer flora it shows many similarities, floristic and structural, to the rainforests of N.S.W.

Rainforest in Victoria is very limited in occurrence, being found chiefly in sheltered gullies: the distribution appears primarily a reflection of Victoria's fire history rather than of an environment physically limiting for wider rainforest occurrence. The main occurrences are in East Gippsland, the Central Highlands, Wilsons Promontory and the Strzlecki and Otway Ranges. Both warm and cool temperate rainforest are recognised, the former typically dominated by Lilly Pilly and the latter in the east by Southern Sassafras and Mountain Quandong and further west by Myrtle Beech (Rainforest Technical Committee, 1986).

In Tasmania the rainforest can all be classed as cool temperate, with three main classes represented: lowland to subalpine rainforest, ranging from tall rainforest with Myrtle Beech and Southern Sassafras to more scrubby stands with a dense tangled understorey and a variety of overtopping trees, including the endemic conifers, Myrtle Beech, Southern Sassafras and Leatherwood; riverine rainforest on floodbanks, often with Huon Pine; and Blackwood Swamp forest, a valuable management type on poorly drained sites in the Northwest (Forestry Commission, Tasmania, n.d. & 1987).

4. VALUES AND UTILISATION

Aboriginal use of rainforest will be looked at in Section 5.2. Here the use made since European settlement will be considered.

Undoubtedly the major use of rainforest since 1788 has been as a source of **land** for agricultural and pastoral purposes. The apparent fertility of the sites (not always borne out in practice); the greater vulnerability of rainforest to fire, and hence the easier clearing compared with eucalypt forest; the easier chopping of the generally softer rainforest timbers; the usually faster rotting of the stumps and logs; and in time the development of "drives"[5], allowing a hectare or more of rainforest to be felled at a time - these combined to make rainforest stands an early and prime target for conversion to cleared land in coastal districts. In consequence probably three quarters of the original area of rainforest in the State was destroyed, most during the 19th century but extending up to the 1920s, and subsequently at a minor rate only. Some areas (e.g. many of the alluvial flats along the major rivers) have continued as productive farmland to the present; some (e.g. many of the basalt plateaus) have shown declining fertility, though continuing as viable farm lands where markets permit; some (e.g. the Coachwood stands of the eastern Dorrigo Plateau) proved unsuitable for farming until, in recent decades, fertilisers became widely used.

The earliest interest in the rainforest by the new settlers was prompted by its **timber**, particularly Red Cedar, with logging of this tree under way along the Hawkesbury River by 1790. This tree, undoubtedly the most romantic of all Australian trees (Vader, 1988), continued as a mainstay of the rainforest timber industry for about a century, until all accessible stands had been logged out or cleared. In the meantime other rainforest timbers came into use.

In all, about 300 species from the N.S.W. rainforests attain tree size. About half of these grow to greater than 30cm DBH (Floyd, 1977), probably all having at some time been milled for at least small timber production. Bootle (1983) gives details of the properties of over 60 timbers from the N.S.W. rainforests and refers to another 10 "*of potential importance in woodcraft work*" (see Appendix 1). These species cover a great range of properties and attributes, often fitting them uniquely well for certain specific purposes. Where availability and value of the end product have been such as to make it economically feasible, the timbers have been used for these purposes (e.g. Hoop Pine was for a lengthy period the preferred timber used for butter boxes, and efforts were made to have stands reserved for this purpose), but in many cases the timbers have been diverted to more general, lower value use. Some of the special uses have been carried out through virtually the whole period of European settlement and are very much part of our heritage, e.g. fine furniture crafted from Red Cedar, or boats planked and decked with White Beech. Other uses are more recent, though no less part of the Australian heritage, e.g. use of Crabapple (White Birch) in Sydney's Opera House or the recent use of selected rainforest species in the Bicentenary Commonwealth Parliament House building. The 'Notes on some uses for wood" (pp.375-402; Bootle, 1983) should be consulted as a guide to the versatility and wealth of uses available from the States rainforest timbers. Not all rainforest timbers have such specialty values of course, and many species have probably never been used for

[5] Drives would typically cover an area of heavy forest fanning out down slope. Each tree in the area would receive a scarf and a partial backcut. Finally a large tree at the top of the area would be felled into its cut neighbours, which would in turn fall into their neighbours so that the whole area would progressively fall under the impact of the initial tree. A drive in the Gloucester district is portrayed in the 1930s film, "Tall Timber'.

purposes much beyond case timber. Nonetheless some of the better known specialty timbers now attract high prices, as reflected in the prices paid at recent private auctions of rainforest logs at Wingham, e.g. at a sale in 1987:

* Red Cedar: 41 logs, total volume 60 m^3 average value \$443/m^3 range \$32 to \$1072/m^3.

* Rosewood: 27 logs, total volume 54 m^3 average value \$156/rn^3 range \$60 to \$250/m^3.

* White Beech: 7 logs, total volume 10.4 m^3 average value \$380/m^3.

* Bollywood: 7 logs, total volume 21.6 m^3 average value \$84/m^3 range \$34 to \$131/m^3.

With the cessation of routine rainforest logging, the value of these and other craft timbers must be expected to continue to rise.

Prior to the cessation of routine rainforest logging, and at the time when all logs were sold under a stumpage appraisal system, N.S.W. rainforest trees were divided into six groups which were intended to reflect the relative value of their timbers. These groups, and the price margins they attracted in 1981 over or below the value of Group B species (medium logs - 60-79cm centre diameter), are detailed in Appendix 6.

Besides yielding timbers, rainforest has been the source of a number of **minor products**. Worldwide these are, or have been, of truly major significance (e.g. various spices from Southeast Asia, responsible for Columbus's discovery of the Americas; Para rubber; etc.: see Baur, 1968, pp. 163-165). However in N.S.W. in recent decades only a few have been utilised: Lawyer Cane, for use in furniture and lobster pots, and Duboisia, as a source of medicinal drugs, have been the main plants yielding commercial minor products, albeit on a generally diminishing scale. Many rainforest plants contain alkaloids (Webb, 1949 and 1952) and other phytochemicals, and some of these have attracted considerable attention from organic chemists (e.g. a toxin extracted from Black Bean shows some promise against the AIDS virus; Beckmann, 1988), but apart from Duboisia none of these have developed into commercial undertakings.

The N.S.W. Macadamia is one of two related species that appear to provide Australia's only contribution to world agriculture, as a source of **nuts.** Production is from plantations rather than from trees growing in the rainforest. Other rainforest plants also provide edible products, but these are only utilised on a casual basis though some are the subject of horticultural study. Still others supply **decorative items** (e.g. Crows Ash capsules; Black Apple seeds), **short canes** (e.g. Walking-Stick Palm) and other objects, again obtained on a casual basis.

In Tasmania Leatherwood is the source of a popular and distinctively flavoured **honey**, and at least one apiarist in the Narooma district markets honey obtained from the closely related Pinkwood.

A large number of N.S.W. rainforest plants, including trees, shrubs, palms, ferns, orchids and vines, have entered regular horticultural use (see Jones, 1986). About 40 species of rainforest trees alone are commonly encountered in Sydney's parks and gardens, being grown for their general form or their decorative shoots, flowers or fruits, and many others have potential for such use. A number of such plants receive international use. Rainforest plantings are featured at both the Sydney and Melbourne Botanic Gardens: the former has a "Rainforest Walk" with annotated guide, while the Melbourne collection has been described by Seddon (1984).

Occurring in the highest rainfall districts of the State, rainforest plays a significant role in protecting **water catchment** areas, although at the same time being a major user of the water that falls.

Since World War II, N.S.W. rainforests have been used to provide **military training** for jungle warfare.

All the above uses have very tangible results to them. However there are other forest uses where the results may be less tangible, but where, in the view of many, they are far more important than any of those listed previously. Typical is the view expressed by a former Director of the Royal Botanic Gardens, Sydney, in the notes for the Gardens' rainforest walk. Referring to Coachwood, he wrote: "*Whether exploitation of the remaining natural, semi-natural or regenerated stands - should continue has recently generated much controversy. Biological reasons exist for holding that it should not . . .*" It is a statement that possibly reveals greater ignorance of forest management than knowledge of biology, but it nonetheless reflects a widespread community belief that needs to be heeded.

These intangible benefits of rainforest include:

- **Landscaping**, with the rainforest providing contrast with the otherwise almost ubiquitous eucalypt forest; a contrast enhanced by the periodic spectacular flowering of trees like the Flametree and Silky Oak, and at closer viewing by its wealth of unusual life-forms.

- Its great **biological diversity**: species richness, life forms, the mutual dependence of many species, and the maintenance of the mixed communities, different life histories and strategies.

- Its ancient lineage, providing openings into **evolutionary activity** and the history of vegetation through the past 100 million or so years.

- The possibility that some plants may still prove the source of products of great value to humanity.

- Its sheer attraction and fascination, which combine to make rainforest stands places of high **recreational appeal** and to give them a level of public interest (and often misconception) unmatched by any other form of vegetation in Australia.

- Flowing from this, the role of rainforest as an **educational resource**, with sites deliberately developed for teaching or learning purposes, and with rainforest itself providing the basis for a relatively major publishing industry aimed at satisfying the need for information.

- Resulting in turn from these recreational and educational appeals, the development of some rainforest areas as major **tourist attractions**.

- Their importance, in various areas, as sites of **social, cultural, archaeological or historical significance.**

The relative value given to these various benefits, tangible and intangible, may always be a subject of debate, but in the future management of rainforest stands these benefits must all be carefully considered and provided for.

5. HISTORY OF USE AND MANAGEMENT

5.1 Prehistory

The main features of the origins and prehistory of rainforest in Australia have already been outlined:

* The break up of Gondwanaland over a period of 50-120 million years ago, with Australia and South America rifting from Antarctica late in the process.

* The presence on the Australian plate of a flora containing the ancestors of most rainforest plants, in what were probably fairly distinct subtropical (northern) and temperate (southern) Gondwanic elements.

* Continued evolution within these elements, providing both new rainforest species and species capable of tolerating the more arid conditions experienced as Australia rafted northwards, and also the decreasing fertility of many Australian soils. Eucalypts and the sclerophyll Proteaceae were among the groups evolved over this period.

* About 15 million years ago an approach towards the Southeast Asian land mass, allowing a further influx of rainforest species to enrich the existing rainforest flora.

* Continued climatic change, leading to restriction of rainforest to the more favoured sites and to an expansion of the sclerophyll communities.

* A further major contraction of rainforest about 40-50 thousand years ago, probably coinciding with the arrival of the Aboriginal forebears and their widespread use of fire.

* Still more changes in distribution, reflecting the altering balances between climatic change, burning and vegetation, to give the pattern of rainforest occurrence present when the European settlers arrived.

5.2 Aboriginal Use

Byrne (1987) has provided a comprehensive review of the use made of rainforest by Aborigines in what is now N.S.W., and of the significance of rainforest to the Aborigines.

Referring to rainforests as a source of food, Byrne notes:

The lists of available foods in N.S.W. rainforests demonstrate the potential of the rainforest habitat as a food resource. But what at first glance seems to be a bountiful plantfood resource on closer inspection poses harvesting problems: the great variety of edible species would be difficult to translate into bulk harvestable food. The fruit of the rainforest trees and shrubs may have been frequently eaten and greatly enjoyed without ever amounting to a staple food. (The likely potential of the rainforest as an important source of medicinal plants is noted but not investigated in this Report). It may be that the carbohydrate-rich roots and stems (e.g., cunjevoi) of the rainforest margins made a more significant contribution to the diet. The assessment of available animal foods also points to the rainforest margin as especially productive of food.

Byrne pays particular attention to the numerous reports of Aborigines hunting pademelons, often by way of drives where a group of Aborigines would encircle the animals, which tend to rest by day near the rainforest margin, driving them into nets, into confined spaces within the rainforest by tightening the circle, or out of the rainforest on to adjacent cleared ground where they could more easily be dispatched with the aid of dogs. Byrne believes that fire-maintained grassland areas and open, grassy eucalypt stands, as enclaves within the rainforest or at its margin, might have been particularly important in pademelon hunting.

Flying foxes were also hunted in a systematic and often large-scale manner, with other animals of solitary habit taken on an ad hoc basis only.

The Aborigines seem rarely to have camped in the rainforest, though in the larger stands forays involving overnight or short-term stays apparently occurred. On the other hand there is much evidence of often large, long-term camps established outside, but near the margins of the rainforest:

> *The rainforest foods which ... were used were either widely dispersed and amenable to opportunistic rather than large-scale exploitation or, alternatively, were concentrated in the rainforest margins where they were amenable to systematic and large-scale exploitation but could be exploited as easily, or more easily, from camps situated outside rather than inside the rainforest. In the former group are the available fruits, seeds, leaves, etc. of the rainforest trees and shrubs, together with most of the animals, including the carpet pythons and brush turkey (and eggs). In the latter group are plant roots and the pademelons.*

Byrne distinguishes between the lowland rainforests, in districts that supported large Aboriginal populations and where the rainforest resource - or that of its margin - was regularly used, and the upland rainforests that were in areas of lower population, often on the periphery of tribal territories, and that in general probably received only intermittent and small-scale use. However during the period of contact with European settlement last century some upland or hinterland rainforest areas were used as refuges by displaced Aboriginal groups.

Sacred and significant sites occur in various rainforest areas, though in most cases these appear to relate to the landscape generally, rather than to the rainforest specifically.

5.3 Early European Use

The use of rainforest by the European settlers dates from the earliest years of colonisation. Red Cedar was being felled along the Hawkesbury River, west of Sydney, in 1790, though it is probable that even earlier than this two rainforest plants, although not actually locally growing in rainforest, were being utilised - Cabbage-Tree Palms, which grew along the Tank Stream, and Callicoma (“Black Wattle”), which formed thicket stands near Blackwattle Bay and which proved a suitable base for wattle-and-daub buildings.

The Hawkesbury River stands were soon cleared away to provide the rich market garden flats of Pitt Town, Wilberforce and elsewhere, and this set the pattern for much future development on the coastal lowlands: Cedar-getters, the “pioneers of pioneers”, would enter an area and then be followed by more permanent settlers (Jervis, 1940; Forestry Commission of N.S.W., 1979). The first export shipment of Cedar went to India in 1795; by 1801 cutting had extended to the Hunter River and the first controls over Cedar cutting were introduced; the Shoalhaven and Illawarra districts were entered in 1811, with cutting banned for a period 3 years later because of clashes with Aborigines: a pattern repeated not infrequently elsewhere (see, e.g., Swain, 1912). From these beginnings the development of the Cedar industry is a history of the opening up of the North Coast, with activities continuing till about 1890. After that Cedar continued to be obtained from remote stands, but the pioneering, picturesque era of the Cedar-getters was finished - as were the former stands.

Following the Cedar-getters, the more accessible rainforest stands - initially notably those along the major coastal rivers - were cleared away to provide farm land: as noted earlier, for much of the past 200 years rainforest has been valued chiefly as a source of land. In the Illawarra district clearing of the rainforest was well under way by the 1830s, in the Big Scrub by the 1870s and on the Dorrigo and Comboyne Plateaus by the 1900s. The policy of throwing open rainforest stands for settlement continued till after World War 1, when soldier settlement schemes were carried out in the Coachwood stands of the eastern Dorrigo Plateau. As late as the 1930s agitation to revoke State Forest along the Queensland Border (Acacia Plateau, on Koreelah S.F.) for the development of dairy farms led the Forestry Commission to start a programme of Hoop and Bunya Pine planting in order to show that the cut-over rainforest sites were being gainfully used.

The first Timber Reserves were proclaimed in 1871, in part because "*the magnificent cedar forests of the State were largely despoiled"* (Kethel, 1909), and they included *"some of the magnificent forests of brush and hardwood in the Clarence Pastoral Districts"* (Annual Report, Forest Branch, 1882-83). The first Forest Branch (initially in the Department of Mines) was established in 1882, with one of its earliest projects being *"planting out young cedar trees in the forest reserves in the cedar-growing districts"* (Annual Report, 1884). Work commenced on the (Don) Dorrigo Forest Reserve in August, 1884. By 1888 over 25 000 seedlings had been planted, and it was reported (Annual Report, 1888): "*Approximately the area upon which cedar-trees in all stages of growth are found on this reserve is about 10 500 acres (4 100 ha); and if the scrub and saplings were removed from around these trees it would greatly improve and hasten their growth."* Some such clearing treatment was indeed carried out that year.

In 1890, the new Director-General of Forests, J. Ednie-Brown, inspected these Dorrigo plantings and was highly critical of the results: "*I very much regret to say that it was not carried out in such a satisfactory manner as should have been done, nor in accordance with the usual method adopted under such circumstances*." He estimated that only 5 000-6 000 plants still survived, and these were largely of "somewhat stunted growth" (Annual Report, 1890).

So what? Two years later the Annual Report regrets "*that the Don Dorrigo Reserve should be cancelled for the purpose of selling the land."* It was a story that was not unusual at that time; later generations would see the pattern repeated, but with national park, not sale for farmland, being the outcome.

Ednie-Brown was much happier about a Cedar-planting project commenced at Hogan's Brush, near Gosford, in 1888: *"It is with much satisfaction I am enabled to report most favourably of it"* (Annual Report, 1890). Other species were also planted in this project, which at least in part survives adjacent to Narara Creek, in Strickland S.F.

Whilst Red Cedar dominated the timbers obtained from rainforest throughout the 19th century, other species were being utilised. Maiden (1917, but much of the text written in the 1890s) gives details of 18 other rainforest species with useful timber qualities; some of these were obviously well established timbers, sometimes produced in considerable quantities (e.g. Hoop Pine, Rosewood, Crows Ash, White Beech), others were apparently less commonly used but considered by Maiden to warrant further promotion. Baker (1919) noted that the "brush timbers" most generally found on the market included Red Cedar, Red Bean, White Beech, Hoop Pine, Crow's Ash, White Booyong and Yellowwood. Referring to the Bellinger valley, Swain (1912) observed that as the Cedar resources became scarcer, White Beech, Silver Ash, Hard Quandong and Rosewood began to be exploited and exported.

Maiden (1917) rather deprecatingly referred to Hoop Pine as *"our principal cheap softwood",* while Baker and Smith (1910) noted that in N.S.W. it was *"almost a tree of the past",* and reported that a mill to cut pine had been established at Lismore in 1856, and was followed by several others elsewhere in the Richmond River district, resulting in its depletion on the lower Richmond, though *"on the ranges at the head of the Richmond ... there is a vast supply, which one would think* *inexhaustible."* They noted that it *"is largely used for furniture, as safes, dressers, kitchen tables, etc."* Despite their forecasts, Hoop Pine continued to be produced in some quantity for several decades, for a period clearly dominating rainforest production (see Section 5.4). Apart from its other uses it was highly valued for its use in butter boxes, after treatment with an anti-taint spray (Boas, 1947).

The passage of the 1909 and 1916 Forestry Acts was followed by the dedication of many of the former reserves as State Forest, with much greater security of tenure, and it was rather apt that the first two State Forests, today Koreelah and Beaury, should have been largely rainforest areas.

With this greater security of the resource, thought began to be directed towards the management of the forest areas. Whilst most attention (and virtually all the action) related to the eucalypt and Cypress Pine stands, Hay (1912) included "**brush or jungle**" in his notes on "**re-afforestation**." Planting or sowing of desirable species was held to be necessary, with *"the best results ... attained by complete felling in sections ... and by subsequently burning off ... Successive brushing down of inferior growths until the commercial varieties are established is a requisite part of the treatment."* There is no known record of any such treatment actually being attempted. A year or so later Hay (1913) presented some growth figures for native trees, including seven rainforest species which showed a mean annual diameter growth of 0.59 inches (1.5cm) and an approximate age when mature of 45 years. Unfortunately his estimates were wildly optimistic.

R. Dalrymple Hay was no forester, though he headed the N.S.W. Forest Service, in its various guises, from 1896 to 1926. His successor, N.W. Jolly, was a distinguished forester and highly competent silviculturist, but he, too, was depressed about the possibility of managing the local rainforests (Jolly, 1928): "*In fact, it seems certain that reliance must be placed largely upon the artificial regeneration of all valuable species without exception ... It seems ... that, if the economic difficulties in the way of raising the high-grade species are excessive, conversion into fast-growing exotic species is preferable to concentrating on non-descript species*." A small area of Hoop Pine had been planted at Mt. Pikapene S.F. in 1922, and following Jolly's paper further plantings were made into the cut-over dry rainforest (sometimes also with a eucalypt component), with a subsequent progressive removal of the "non-descript species." These provided the State's oldest Hoop Pine plantation, and represented the first recorded rainforest treatment since the Cedar plantings of the 1880s.

5.4 Recent Use

The 1930s seem to mark a break with the past in rainforest management - a reflection perhaps both of the traumatic effects of the Depression and of the arrival of E.H.F. Swain as Commissioner for Forests in 1935: during his period in Queensland Swain had initiated some of the work that ultimately developed into one of the world's most successful treatments of tropical rainforest. Despite this, however, the belief that rainforest in N.S.W. could not be managed persisted in Commission thinking into the 1950s, and among the public at large to the present.

An outline of rainforest timber production in the State, from 1928 to 1988, is given in Table 4. Note how, over the whole of this period (except for the insignificant final entry), most of the production has come from Crown sources even though in the pre-War period total timber production in N.S.W. was mostly from private sources: this reflects the fact that, following the earlier settlement period, most of the remaining rainforest was held in Crown tenures.

Table 4
N.S.W. RAINFOREST SAWLOG PRODUCTION 1928-1988: CUBIC METRES

Year	Crown			Total			
	Rainforest	Total	%RF	Rainforest	Total	%RF	RF:Crown/Total%
1928	42 200	239 400	17.6	56 400	N.A.	-	75
1936-37	71 200	399 000	17.8	133 900	N.A.	-	53
1942-43	123 923	721 155	17.8	141 268	1 056 480	13.4	88
1947-48	134 429	897 104	15.0	194 826	1 585 429	12.3	69
1949-50	106 897	902 912	11.8	142 314	1 580 744	9.0	75
1959-60	114 052	1 136 209	10.0	136 848	1 891 359	7.2	83
1969-70	126 649	1 319 327	9.6	138 425	2 014 669	6.9	91
1974-75	110 336	1 410 416	7.8	121 679	2 034 858	6.0	91
1979-80	67 645	1 611 958	4.2	71 977	2 132 177	3.4	94
1984-85	13 492	1 493 488	0.9	17 289	1 868 563	0.9	78
1987-88	1 875	1 529 440	0.12	4 441	1 917 315	0.23	42

In 1928 nearly 80 per cent of the rainforest production consisted of Hoop Pine; the rate of Pine production was much the same (around 35 000 m^3) in 1936-37, but by then it contributed only about 50 per cent of the rainforest cut. After that both the absolute and proportional yield of Hoop Pine fell sharply, though it remained at about 10 per cent of the rainforest cut through to 1970, when separate statistics on Hoop Pine production ceased. When the dissection of computer royalty accounts became possible in 1975-76, Coachwood was contributing about 20 per cent of the rainforest cut, a position it maintained until routine rainforest harvesting was phased out, with Yellow Carabeen and Sassafras both contributing over 10 per cent and with Black and White Booyong, Crabapple, Red Carabeen and Hoop Pine fairly consistently each making up more than 5 per cent of the total cut. Between them, these eight species provided from 65 to 80 per cent of the rainforest cut from Crown lands from the mid 1970s.

The war years and immediate post-war period saw a great increase in rainforest production, with Coachwood in particular being sought both as plywood used in the construction of Mosquito bombers and for rifle furniture. Subsequently Crown production remained fairly stable (though a diminishing proportion of total sawlog production) through to the mid-1970s, when there was a rapid fall, firstly in line with the Indigenous Forest Policy (Forestry Commission of N.S.W., 1976) and then following Government decisions in 1982. Over the same period the production of rainforest timbers from private sources diminished, so that from the 1960s only a small volume was coming from non-Crown sources.

The timber obtained from these operations was sawn at local mills or, from the 1930s, peeled in plymills. The number of mills involved decreased through mill amalgamations and through improved roading that allowed transport into more central locations, and by 1979 there were only 10 mills still obtaining significant volumes of rainforest timbers from Crown-timber lands.

The early enrichment planting of Hoop Pine at Mt. Pikapene was followed by further such planting on a small scale on the same forest up to 1935. Swain's arrival that year was followed by a spate of activity. D.A.N. Cramer, a recently graduated forester, was sent to Queensland to study Hoop Pine silviculture (Annual Report for 1935-36), and the next year plans were announced for Hoop Pine planting projects at Brooklana (Wild Cattle Creek S.F.) and in the Urbenville district - the latter at *least* in part prompted by local farmer agitation to have the cut-over rainforest on Acacia Plateau (Koreelah S.F.) thrown open for settlement. Nurseries were established and rainforest areas cleared, with the first plantings made in 1938. Other areas (Toonumbar, Mt. Pikapene, Mebbin) were subsequently brought into this programme, and small trial plantings of Hoop Pine were made in other sites as far south as Cumberland S.F. Some other species were also planted on a small scale, and on the eastern Dorrigo a few small studies on the growth and natural regeneration of Coachwood commenced.

War-time operations for Coachwood at Doyles River S.F. led to a further, short-lived programme of planting that species (see Section 7.3), while the crown die-back that developed on stems remaining after logging in these higher altitude forests did much to enhance the myth that N.S.W. rainforest could not be managed for continued timber production (see Section 9.2).

D.B. Dun was posted to Urbenville in 1946 as Divisional Officer, with responsibility for the technical aspects of silvicultural work, particularly Hoop Pine planting, in the Casino District, and he was appointed to head the new "North Coast Silvicultural Research Organisation" on its establishment at Coffs Harbour in 1951. From that time the silvicultural capabilities of rainforest started to be examined in a new and more objective manner, and under a series of research foresters various experiments investigating aspects of rainforest silviculture were established on the North Coast between the mid-1950s and the late 1960s.

These studies increasingly demonstrated the manageability of the N.S.W. rainforest stands, but external political pressure and internal desire for higher levels of productivity and for development meant that the actions, necessary to bring the local rainforests towards sustained yield management, were mostly delayed in their introduction.

* * * * * * *

Whilst rainforest occurs in some of the earlier areas set aside as what are now N.S.W. national parks, the presence of rainforest does not appear to have been a significant reason in the establishment of these parks (e.g. Royal, Blue Mountains). However immediately north of the State border there had been proposals voiced as early as 1896 to set aside the Lamington Plateau, in Queensland, as a national park, and the park was established, as an area almost totally covered by rainforest, in 1915 (Groom, 1949).

In N.S.W. the core of the present Dorrigo National Park was gazetted in 1927, of Mt. Warning N.P. in 1928, and of New England N.P. in 1935. Although in all cases general landform and scenery were probably the main reasons for their establishment, the presence of rainforest, contrasting with the more widespread eucalypt forest, must have been a major contributory reason: again the 1930s represent a break with the past, with people in the community starting to see rainforest in a new light, as something with interest and attraction in its own right.

Following improvements to the road linking Coffs Harbour with the Bucca settlements about 1932 there was agitation "*to have an area of this beautiful scrub scenery*" (i.e. rainforest in the Bucca Creek valley) reserved for all time, and in 1933 the Minister, who was also the local Member, directed that an appropriate area should be set aside as "Bruxner Park Reserve." Although delayed in notification until 1958 this subsequently became the Bruxner Park Flora Reserve. Similar moves, prompted by elements of the public rather than by a then strongly timber-oriented Forestry Commission, led to the notification of the first two gazetted Flora Reserves - F.R. No. 62253 (now Tooloom Scrub F.R. No. 1) in 1937 and F.R. No. 62278 (subsequently mostly absorbed into the Barrington Tops N.P.; the remnant piece is now Williams River F.R. No. 2) in 1940. Certainly in the case of the latter it was the presence of rainforest that was the cause of the Reserves being set aside: the Reserve boundary endeavoured to follow the limits of the rainforest along the Williams River. There is some evidence that, in these early Flora Reserve notifications, the Forestry Commission of the time was not unduly opposed to the reservation of rainforest, with its reputation for being unmanageable, whereas similar moves concerning eucalypt forest, with its more apparent potential for long term management, would have been much less acceptable.

It should perhaps be added that, whilst there was undoubtedly a growing appreciation of rainforest for itself, over much of this period a large number of local residents tended to value the rainforest primarily as a place to shoot pigeons and Brush Turkeys or to collect epiphytic ferns and orchids.

Some ecological studies involving rainforest had been carried out at Mt. Wilson in the 1920s (Brough et al., 1924; McLuckie and Petrie, 1926), but in the 1930s ecology started to come into its own and a number of projects involved areas of rainforest, including studies in the Bulli district (Davis, 1936, 1941), on the Central Coast (Pidgeon, 1937), in the Myall Lakes district (Osborn and Robertson, 1939), and the outstanding work of Fraser and Vickery (1937, 1938, 1939) in the Barrington Tops.

Again, rainforest was starting to be appreciated for values other than its land and its timbers.

* * * * * *

The 1960s saw the development of increasing interest in environmental matters. The National Parks and Wildlife Service was established in 1967, and by the early 1970s pressure, from various environmental groups acting alone or in conjunction, was mounting for different areas to be set aside as national park. Many of these involved State Forest, and inevitably it was not long before forests carrying rainforest were being singled out for attention - Wiangaree S.F. and Levers Plateau on Roseberry S.F., along the McPherson Range ("The Border Ranges"); Washpool S.F.; the forests of the Hastings catchment; Bellinger River S.F. and the Dorrigo escarpment; Terania Creek within Goonimbar S.F.; the Barrington Tops.

Not all areas involved routine rainforest logging, and where logging was involved the techniques varied. Along the McPherson Range selective logging with numerous environmental safeguards had been introduced in the early 1960s, but in the Hastings Catchment, which by the late 1970s was the other major centre of rainforest logging, the operations were to a much heavier intensity.

It was clear that in any case rainforest logging could not continue indefinitely at its present rate, and the Commission's reaction was to try and phase out routine rainforest logging with the least disruption to the established industries:

- The broad objective for all rainforest areas is to reduce harvesting to selective fellings for specialty (*sic*) logs, at a level low enough to maintain canopy and rainforest structure. This would require the phasing out of general-purpose timber harvesting in most rainforest areas. The rate of selective logging of specialty timbers would generally be too low to support mills now primarily dependent on rainforests.

- Where selection logging is successfully carried out without destroying the ecological viability of the rainforest, this may be continued to meet current market commitments. However, these commitments should be reduced where necessary in time to avoid the need for logging above the sustained yield level after the first cutting cycle. (Forestry Commission of N.S.W., 1976).

The various controversies were subjected to innumerable enquiries and studies, none of which satisfied the more vociferous demands. Finally, in 1982, the Government after long and apparently painful deliberation decided on a policy that involved:

* Conservation of rainforest areas in new national parks and nature reserves.

* Maintenance of employment levels consistent with those existing and predicted from the current management proposals of the Forestry Commission of N.S.W.

* Identification of alternative timber sources, the availability of which will be assured by Government.

* A 'Rainforest Fund' of $1 million will be established to promote and encourage the development of new technology and to assist affected industries during implementation of the Government policy.

* The principle of sustained yield was reaffirmed for hardwood forest management affected by the new rainforest parks and reserves. (Department of Environment and Planning, 1983).

The "conservation of rainforest areas" involved the transfer of nearly 100 000 ha of forested land from State Forest to national park; about a third of this area was actually rainforest. The second and third elements of the policy were hardly borne out in practice, and the effects of the policy, seen from a different angle, were:

- To accelerate the phasing out of routine rainforest harvesting;

- To reinforce the public belief that logging was equated with rainforest destruction, even though many of the logged stands were promptly accepted into the world heritage list;

- To cause the rapid closure of a number of mills, and a drop in employment in others;

- To create local problems in hardwood supply, since most of the transferred area carried high quality hardwood forest which could not be replaced from elsewhere;

- To make increasingly difficult any future efforts to manage rainforest on a sustainable basis for its supply of fine timbers;

- To make most people believe that all rainforest logging in N.S.W. had been banned.

Nonetheless, the decision was a public relations triumph, and even though its wisdom might well be queried on the basis of sound and wise landuse (e.g. see Hurditch, 1985), the previous history of rainforest logging in N.S.W., with its long failure to recognise the manageable nature of the stands, its over-commitment of a limited resource, its belated introduction of silvicultural practices, its usually far too low royalty rates, its use of many timbers for low value purposes, and sometimes its blindness to the other, non-material values of rainforest - these made the ultimate decision of 1982 almost inevitable, and certainly understandable.

* * * * * * *

Just as the 1930s marked a watershed in the history of rainforest use and management, so did the mid-1980s, with the logging of rainforest on State Forest reduced essentially to the salvage of logs along road lines or occurring beneath hardwood stands being logged, and of dead and dying trees. Only in one area (Washpool), as part of the 1982 decision, did a small-scale routine rainforest harvesting operation continue for any time.

In the inventories of rainforest in N.S.W (Pople and Cowley, 1981; Forestry Commission of N.S.W., 1985), the condition of each stand as a result of previous logging was assessed in four classes:

I Virtually undisturbed (unlogged, or very selective logging a long time ago).

II Structure retained (structure and general species composition retained after logging).

III Structure changed (substantial change, but structure, though incomplete, is still evident and in process of recovery).

IV Structure removed (basic structure lost; recovery occurring through regeneration).

Table 5

CONDITION OF N.S.W. STANDS
(Forestry Commission of N.S.W., 1935; % of total area in category)

Condition Class	I	II	III	IV
Structure	**Little Disturbed**	**Retained**	**Changed**	**Removed**
Category				
Subtropical	52	25	18	5
Warm Temperate	39	9	41	11
Cool Temperate	80	12	8	-
Dry	24	53	19	4
Depauperate	79	7	10	4
All Rainforest	**56**	**19**	**19**	**6**
Condition Class	**I**	**II**	**III**	**IV**
Structure	**Little Disturbed**	**Retained**	**Changed**	**Removed**
Multiple Use State Forest	54	21	19	6
National Park	72	20	8	-
Private Property	18	9	52	21

Table 6
CONDITION OF MULTIPLE-USE STATE FOREST STANDS
(Total area, 000 ha; % of area in Condition category bracketed)
(From Forestry Commission of N.S.W., 1985)

Condition Class	I	II	III	IV	Total
Structure	**Little Disturbed**	**Retained**	**Changed**	**Removed**	
Category					
Subtropical	25.1(47%)	15.4(29%)	10.6(20%)	2.6(5%)	53.7
Warm Temperate	5.0(26%)	1.3(7%)	9.7(50%)	3.4(18%)	19.4
Cool Temperate	7.9(82%)	1.4(15%)	0.2(2%)	0.1(1%)	9.7
Dry	3.1(25%)	7.1(57%)	2.1(17%)	0.2(2%)	12.5
Depauperate	30.1(83%)	2.8(8%)	2.4(7*)	0.8(2%)	36.1
Total	71.2(54%)	28.0(21%)	25.0(19%)	7.2(6%)	131.4

Table 5 summarises the condition classes of selected rainforest categories itemised in Table 1. Note the limited disturbance in the cool temperate and the largely non-commercial depauperate rainforest stands, and the heavy disturbance in the Coachwood-rich warm temperate rainforest. After the implementation of the Government decisions of 1982, national park lands carry a relatively large proportion of little disturbed rainforest, while private property areas are heavily disturbed, with multiple use State Forest closely parallelling the total area of rainforest in N.S.W. Details of the condition of the multiple use State Forest stands are given in Table 6, and indicate the nature of the rainforests that N.S.W foresters have to manage in the next few decades. For timber production purposes little of the depauperate rainforest would have productive capacity, reducing the total area to about 100 000 ha, while perhaps half of Condition Class I has not previously been logged and, realistically, is unlikely to be available for logging on political, if no other, grounds. This suggests a maximum area of about 75 000 ha that could be available and suitable for long-term management with timber as one of the benefits being sought.

6. NATURAL REGENERATION

6.1 Sources of Regeneration

In this section, emphasis will be given to the natural regeneration of tree species in the rainforest, and at the outset it should be realised that none of the 300 or so rainforest tree species in N.S.W. is likely to have precisely similar regeneration mechanisms: each species will have evolved its own characteristic strategies towards ensuring its regeneration and survival. Information on these strategies for almost all species is at best sketchy and, even were it more extensive, space is not available to detail it here, species by species: Taylor (1960), in his landmark volume on silviculture in Ghana, required 293 pages to describe the silvical characteristics of some 160 rainforest trees in that country, and it will remain for a future generation of foresters to document similar details for the N.S.W. rainforest trees. In these Notes, information about individual species will be used primarily to illustrate the ways in which N.S.W. rainforest trees regenerate.

Whilst **seed** provides the ultimate source of all regeneration, rainforest regrowth may have other, more direct origins.

Following disturbance much, and sometimes most, regeneration develops not from freshly germinated seed, but from **seedlings** which were present prior to the disturbance; which in some cases may be many years old; and which have the capacity to respond rapidly to the sudden creation of a gap. This behaviour will be examined further in Section 6.4.2.

As noted in Appendix 2, a number of N.S.W. species, mostly occurring in temperate rainforest, typically have sprouts or suckers growing from their base. Species showing this habit include Negrohead Beech, Sassafras. Southern Sassafras, Pinkwood and Ringwood. Though often only small, these **basal sprouts** may reach small pole size even where the original stem is still healthy and vigorous. Johnston and Lacey (1983) have examined this habit in Sassafras and Pinkwood on the South Coast, and observed that the older seedlings produced swollen bases apparently analogous to eucalypt lignotubers, and capable of giving rise both to shoots and, below the soil, to fine roots. In the areas where they worked, these two species typically occurred as clumps:

> *The clumps commonly consist of a central stem and subsidiary associated stems. The stages of clump development range from small shoots around the base of a central main stem that may be conspicuously swollen, to large clumps where the central stem is alive or dead but is surrounded by mature vigorous secondary stems. These often become successively smaller from the centre to the periphery of the clump. The most extreme examples of clump development consist of rough circles (up to 8m in diam.) of large stems, which may each have subsidiary stems, surrounding an area filled with rotted wood and sometimes the recognizable remnants of the original stem.*

Where this habit occurs, the sprouts are probably the main means of regeneration in Nature: this is indicated for Southern Sassafras in Tasmanian rainforests by Forestry Commission Tasmania (n.d.) and for Negrohead Beech in the New England N.P. (except at the stand margins) by Hore-Lacey (1963). The habit tends to grow in significance as species approach their limits of occurrence. Thus on the former Wiangaree S.F., where Negrohead Beech appeared as a relic of a different climatic regime, regeneration normally seemed to be entirely from basal sprouts. Nonetheless where artificial disturbance occurred, as on road batters, seedlings regularly appeared and developed: a theory that the tree had locally lost its capacity to reproduce by seed was proved untrue. Where present, the sprouts can be important in providing regrowth after logging.

The basal sprout habit of Negrohead Beech can lead to a large, gnarled section of basal stem, sometimes extending up the stem for several metres. In the past some observers (e.g. Bernard O'Reilly, in his book "Green Mountains") have interpreted this as the exposed central root of the tree, revealed by the erosion of soil from around the tree over the millennia. On this basis some remarkable (and incorrect) ages have been attributed to Negrohead Beech, which in reality is a relatively fast-growing tree for a N.S.W. rainforest species (see Section 8.3.2.) The myth of the "exposed root" still often appears in popular accounts of this tree, and received a mention in the 1965 edition of the Australian Encyclopaedia.

The habit of producing basal sprouts is closely linked with that of coppicing - which involves basal sprouts that only develop after the original stem has been removed.

Many rainforest trees will coppice, though the capacity varies between species and also with the size of the original stem. Porada (1980) examined the phenomenon, along with basal sprouting (he combined the two as coppice) in cool temperate rainforest at Mt. Boss S.F. Of the four main species present, Prickly Ash never showed any ability to sprout or coppice, but the suckering of the other three species, both as sprouts around living trees and as coppice on stumps, was high: see Table 7

SPROUT AND COPPICE FREQUENCY IN COOL TEMPERATE RAINFOREST
(Mt. Boss S.F.; after Porada, 1980)

	Frequency of Coppice under 10cm present (%)		
	Negrohead Beech	**Coachwood**	**Sassafras**
On trees over 10cm DBH	62	49	37
On trees over 25cm DBH	80	66	57
On logged stumps	78	100	29

On the Barrington Tops, Turner (1976) notes that Corkwood, Socketwood, Sassafras and Crabapple are fairly consistent coppicers, Negrohead Beech and Water Gum less consistent, and Yellow Persimmon, Rosewood and Prickly Ash seldom coppice, though by contrast in south Queensland, Tracey (1985) reports Rosewood (along with Yellow Carabeen) as a tree producing "*rapid growth of sucker shoots from surviving stumps to form a rainforest canopy*". Also in south Queensland, Dale (1933) notes that Bolwarra, Socketwood and Yellow Carabeen coppice freely.

Where small stems in the rainforest are smashed down - whether from a windthrow, log felling or snigging - they will often recover by coppice from the stump. Typically the growth of coppice, with its established root system, is much faster than that of seedlings, so that the dominant regrowth in such disturbed areas can to a large extent be of coppice origin. Borne and Mackowski (1987), in a study on the effects of different logging intensities on warm temperate rainforest at Moonpar S.F., reported about 700-800 large saplings per hectare (between 2.6 and 9.9cm DUB) as being of coppice origin, mostly from logging 28 years earlier, with about half of the Coachwood stems in this size range being of coppice origin. (The unlogged control plot showed a similar stocking of coppice saplings, though with a much lover proportion of potential overstorey species among them - 15 per cent as against about 60 per cent in the logged plots). In this study even large stumps of Coachwood, felled as logs, produced vigorous coppice. Similarly, in New Zealand Smale (1982) has noted the ability of Tawa to produce coppice shoots from even large stumps; the coppice grows relatively quickly, becomes functionally independent of the parent stump and can probably continue to develop indefinitely.

In North Queensland, Stocker (1981) observed that, of 82 tree species regenerating on a site that had been felled and burnt, 74 were represented by coppice; most of the genera, and some 19 of the species, occur also in N.S.W. rainforests. Stocker shows some surprise that so little reference is made to coppice in the rainforest literature, though as long ago as 1933 Symington, working in Malaya, had noted that *"after felling, coppice growth, if allowed to develop, will within a few years create a stand which, except for the absence of large trees and the presence of a few typical secondary growth species, shows little indication that the rainforest had been so recently cleared."*

Stocker's study also shoved that, of the 82 regenerating tree species, 10 originated from **root suckers** (most of these species were also represented by coppice). Again most of genera involved, and two of the species, occur in N.S.W. From south Queensland Tracey (1985) records Socketwood and Bolwarra as showing much suckering from roots. Root suckering does not appear to have been examined in N.S.W. and is probably only of minor significance, though Borne and Mackowski (1937) appear to believe it of some relevance at Moonpar S.F., for they specifically note that its extent was not recorded and therefore the extent of vegetative regeneration was probably underestimated.

One very minor source of regeneration can occur when a tree blows over while still alive, and with some roots still active. Some species may then produce a line of epicormic shoots from along the stem, and ultimately a line of trees. This phenomenon of "tree lines" is well recorded from tropical rainforest (e.g. Baur, 1968, p. 152) and is mentioned by Forestry Commission, Tasmania (n.d.) as a source of Leatherwood regeneration.

Seed, a reservoir of advanced seedlings, basal sprouts, coppice and root suckers: these are sources of regeneration in rainforest stands.

6.2 Flowering and Fruiting

Floyd (1976-1983) gives details of the flowering and fruiting of each of the species of rainforest trees occurring in N.S.W., and a summary from this, showing the months of flowering and fruiting and the nature of the fruit (fleshy, winged or other) for major rainforest families, is given in Appendix 7. Some features, partly but not entirely from Appendix 7, might be noted:

- Some flowering and fruiting is occurring throughout the year, but there is a clear pattern (repeated also within the major families) of a peak in flowering during the late spring and early summer, and in fruiting during the autumn and winter.

- While many species have protracted fruiting periods (e.g. *Mallotus philippinensis* from September to February; Giant Stinger from April to August), none of the trees will normally bear ripe fruit throughout the year: this is in contrast to many equatorial species, particularly from the lower tree storeys.

- About two thirds of the species have seed or fruit (or the associated arils, stalks, etc.) which are fleshy and which would appear to be distributed by birds, bats or other larger fauna. About half the remaining species have winged seeds, with the remainder showing various features.

- Three quarters of the species with winged seeds are typically trees of the uppermost storey of the rainforest, compared with only about one quarter of the species with fleshy seeds and a fifth of those with other seed types. Similarly, many of the climbers that reach the topmost canopy have winged seeds.

- Nonetheless, only about a third of the characteristic overstorey species have winged seeds. However this tends to underestimate the dominance of winged seeds in the rainforest overstorey: although only a third of the species may have them, these are the species that commonly tend to dominate the stands (e.g. Booyongs and Red Cedar in subtropical rainforest; Coachwood, Sassafras and Prickly Ash in warm temperate rainforest; Hoop Pine and **Flindersia** spp. in dry rainforest). The pattern, repeated in rainforest throughout the world, is for wind-distributed seeds to predominate in the top canopy where the effects of wind are most marked, and for other forms of dissemination, particularly by animals, to take over in the lower storeys.

Statistics such as these, while useful in pointing to patterns, can do a disservice in blinding us to the specific features of individual trees, with their mechanisms for pollination and dissemination and with the obvious long histories of co-evolution between the plants and various forms of animal life. Foresters managing rainforest should always try to be aware of these interactions, e.g. the pollination mechanisms of the various figs; the dependence of many of the native pigeons on the regular and sequential production of fleshy fruits in the rainforest. Maintaining such relationships should be an important part of rainforest management.

In rainforest of mixed composition there is evidence that seedlings germinating at some distance from seed trees of their species have a greater chance of success than those germinating beneath the seed tree crown (e.g. see Howe et al., 1985); similarly mortality tends to be greater among clumps of seedlings of one species than when the seedlings are more evenly distributed (e.g. Connell, 1971) working in the former Wiangaree S.F., Burgess et al. (1975) found:

- Generally most of the smaller regeneration tended to be clumped rather than well distributed over the transects. This was particularly noticeable with Booyong having fleshy winged seed and with Doughwood. The latter, while it has fine seed, tends to shed whole flowers that do not travel great distances. Fine seed of Corkwood and the dry winged seed of Red Carabeen were more widely spread. Also bird dissemination of seed (e.g. Pigeonberry Ash) resulted in a reasonable spread of regeneration. (Common names substituted)

Much winged seed in rainforest is in fact probably not very effectively distributed, and the best dissemination seems to belong to fleshy-fruited species eaten by the larger birds; small birds often tend to regurgitate the seed close to the parent tree.

Species with relatively poor means of dissemination are slow to invade new but favourable sites. On the West Coast of the South Island of New Zealand a marked discontinuity in the occurrence of the Beeches (**Nothofagus**), which have poorly winged nuts, is attributed to poor seed spread delaying their entry into areas exposed at the end of the Pleistocene Ice Age (P.J. McKelvey, pers. comm.); by contrast the bird-distributed podocarps rapidly colonised these previously glaciated sites. This points to real dangers of substantial extinction if forecasts of the rapid climatic change associated with the Greenhouse Effect prove correct, and the likely need for some human intervention if many rainforest communities showing reasonable biological diversity are to survive.

In several cases the means of seed dissemination appear to determine trees' ecological occurrence. In North Queensland the large fruits of Silver Quandong are eaten by cassowaries, and the tree is widely distributed through the rainforest; in N.S.W. no fauna capable of eating and regularly distributing the fruits is present, and gravity and water provide the normal means of seed distribution, so that the species is almost entirely confined to creek side and gully sites. Similarly the large seeds of Black Bean effectively, though not entirely, restrict this tree to riverain communities.

Whilst there is increasing interest and activity in the planting of rainforest species (see Section 7), little information on the associated collection and storage of seed of these species appears to have been documented. One exception relates to Hoop Pine, which until 1954 was being planted on a significant scale in N.S.W. Information on seeding and seed collection for this species (based largely on Queensland data) was presented by the Forestry Commission of N.S.W. (1950). Hoop Pine cones take about two years to ripen from the time of pollination, and a heavy crop of male cones, which are readily visible, is a reliable indicator of fertile seed two years later. The female cones are concentrated near the top of the tree; seed collected from green cones is infertile; and the cones break up and shed their seed shortly after they turn brown. Collection thus has to be in the narrow timeslot between cone browning and cone disintegration - a period that may only exist for one to two weeks. Seed from natural trees was collected by felling the trees and then drying the seeds prior to storage at sub-zero temperature.

Hoop Pine is an irregular seeder. Data from south Queensland showed seven moderate to heavy seed crops in the 18 years 1933-50. The period between reasonable seed crops varied from 2 to 4 years.

Similar irregularity in seeding appears a feature of many larger rainforest trees, even though some seed is probably produced in most years. Thus in Tasmania Hickey et al. (1982) reported 6 heavy, 3 moderate and 7 light seedfalls of Myrtle Beech over a period of 16 years, with rates varying from less than 0.1 g/m^2 in a poor year to 19.3 g/m^2 in a heavy seedfall; variations in the annual seedfall of Leatherwood and Southern Sassafras were less marked (0.1 to 1.9 g/m^2 and 0.4 to 2.6 g/m respectively), but nonetheless existed. Closer to home, Burgess (1973) records moderate to heavy falls (up to 100 000 seeds/ha) of Negrohead Beech at Mt. Boss S.F. in 1963/64, 1964/65 and 1965/66, a small fall (3 000/ha) in 1966/67, and no falls in 1961/62 or 1962/63; in the same area Coachwood produced small quantities of seed (40 000/ha) in 1965 and 1966, a few seeds in 1967, and none in the other years; while on Wild Cattle Creek there were heavy Coachwood falls in 1943 (about 300 kg/ha, equivalent to about 13 million seeds/ha), 1944 and 1946, and very light falls in 1942 and 1945 (Forrest, 1961).

6.3 Germination and Establishment

6.3.1 Patterns of Seedling Establishment

Again, the rich rainforest tree flora shows great diversity in the manner in which seedlings germinate and become established. Unlike the eucalypts, which essentially all require open conditions and mineral soil, and which germinate from recently fallen seed (though a pre-germination period may be required for some species), rainforest trees may require none of these conditions.

Seed longevity may range from a century or more in the case of some wattles (Gilbert, 1959, suggests that seed of Silver wattle may retain its viability for up to 400 years in the soil of Tasmanian temperate rainforest), to a matter of weeks - Coachwood seed loses its viability within a few weeks of ripening, and germination takes place almost immediately the seed reaches the ground.

Whilst some species germinate speedily and more or less automatically on reaching the ground, with others the germination tends to be delayed and, under artificial conditions, may be difficult to achieve. Evidence suggests that, with some animal-dispersed seed, passage through the animal provides a treatment that at least hastens germination. Floyd (1977b) reports seed of Silver Sycamore germinating after 3 months in the soil if eaten and excreted by pigeons, compared with 6 months for uneaten seeds, and he observes that 47 per cent of seeds of Small-leaved Water Gum germinated after 3 weeks after having been excreted by emus at Iluka N.R., whereas only 13 per cent of uneaten seed germinated in the same period.

Other species apparently require periodic exposure to high light intensity, or even to light of particular wavelengths; warmth above the level experienced on the shaded rainforest floor may trigger germination in some; still others may have a natural dormancy that disappears with time: this could be important in species where seedfall occurs at a time unsuitable for establishment, such as in the driest part of the year. Whitmore (1983) has provided an excellent review of this subject, concentrating on tropical pioneer species but nonetheless with more general application. Whilst little work has been done with N.S.W. species, many of the processes discussed by Whitmore appear to apply to rainforest trees in this State.

In the certain knowledge of making a gross oversimplification, three main patterns of tree seedling establishment can be recognised in rainforest:

1. Seed, mostly wind-dispersed, with relatively short viability and tending often to germinate prolifically following a good seed-year.

2. Seed, largely animal-dispersed, with longer viability and tending to create a soil seed bank where germination only occurs when conditions are suitable.

3. Seed, mostly relatively large and often with delayed germination, capable of establishing in the low light intensity of an undisturbed patch of rainforest.

It should, however, be realised that these classes are by no means clearcut and that in reality a great range of germination and establishment strategies exist.

Before looking at these classes in slightly more detail, two other observations are warranted.

Whilst seed will normally germinate and develop on the soil or on the remains of well-rotted logs, a few species of trees may germinate and grow on other plants. Strangling Figs are the most notable of these, their seeds animal-distributed and with germination often occurring high in a host-tree's crown. There is another group of trees which commonly establish on the trunks of Tree Ferns: on well developed trees, the remnants of this host can still often be seen near the base of the stems. Possumwood, Pinkwood and, in Tasmania, Southern Sassafras (Forestry Commission Tasmania, n.d.) all commonly establish in this way, which probably has benefits in raising the young seedlings above the level of wallaby browsing. The species involved here all have wind or gravity-dispersed seed. Epiphytes, including many fine-seeded (or spored orchids and ferns, also by definition grow on other plants.

Secondly, the rainforest floor is usually sufficiently open for most, or certainly many, seeds to find suitable sites where germination can occur and, if other factors permit, for the young seedlings to become established. However in some stands there may be extensive patches carrying a dense herb cover - usually of ground ferns; sometimes also of Smooth Nettle. Both warm and cool temperate rainforest types may exhibit this feature. Where it occurs germination may take place, but there is little or no chance of the germinates surviving on the ground, and this may reflect itself in regeneration deficiencies if the stand is subsequently logged.

6.3.2. Species with Short Viability Seed

The trees (and notably also vines) included here typically have wind-dispersed seed which may periodically appear in great profusion. Coachwood is an example with very short viability, and with seeds that appear almost impossible to store artificially (such seeds are sometimes called **recalcitrant**, as opposed to **orthodox**, storable seed). In most species the viability is rather longer in the field (possibly up to a year) and artificial storage for still longer periods is possible under appropriate conditions (e.g. at about -20^{0}C for Hoop Pine; dry storage at 2-5^{0}C for Red Cedar). Nonetheless germination usually occurs soon after seedfall, and in a good seed year there may be a dense cover or recently germinated seedlings around seed trees, often regardless of the nature of the overhead canopy.

- The numbers involved can be high: in southern Queensland dry rainforest Cameron (1953) reported falls of 10 to 40 million Hoop Pine seeds/ha, producing up to 800 000 germinates per ha; over two successive heavy Coachwood seedfalls on Wild Cattle Creek S.F. a total germination of 1.8 million seedlings/ha resulted (Baur, 1962); the equivalent of a quarter of a million germinates/ha around the seed trees followed a good seed fall of Red Cedar on Whian Whian S.F. (Baur, 1959).

- The germinative capacity of the seed varies considerably between species, and also from season to season within species (Hickey et al., 1982). In a seeding study at Unumgar S.F., Hoop Pine showed a GC of about 4 per cent (Forrest, 1962), whereas in the heavy 1943 seedfall of Coachwood at Wild Cattle Creek S.F., GC was 35 per cent (Forrest, 1961)

- The germination requirements of few species are known. Some, such as Coachwood, germinate promptly almost regardless of the conditions where they land. All are likely to require adequate moisture, but at least some may need the warmer (or brighter) conditions associated with gaps in order to germinate, while with others in moist, shaded situations, germination will proceed, but is likely to be equaled by the development of pre- or post-emergent damping off, so that germination is reduced and few germinates long survive: early survival tends generally to be better in less dense patches than under long-undisturbed rainforest with its dark, humid environment. Nonetheless seedlings of short-viability species undoubtedly do occur beneath little disturbed rainforest.

- The germinates appear not only on the soil, but also on patches of litter, decaying logs and the stems of Tree Ferns. In at least one N.S.W. study, seed bed preparation by raking made no significant difference to the presence of germinates (nor to subsequent establishment - Coachwood seeding study on Wild Cattle Creek S.F.; Forrest, 1961), though in less favourable environments this may not be so.

- The subsequent fate of the germinates depends on both environmental factors and the intrinsic features of the various species. Dry season mortality, browsing, insect damage, damping-off and rooting out by ground-feeding birds will all considerably reduce the stocking from the initial germination. Some examples, all from sites where the canopy was only slightly disturbed, are given in Table 8. In these cases a few only seedlings persisted for from slightly over 1 year to 4 or more years; most had disappeared within 12 months.

- By contrast the heavy 1943 and 1944 Coachwood seedfalls at Wild Cattle Creek S.F. were in a site where all merchantable trees had been recently removed, and 13 years later there were still 50-100 plants/ma present from these seedfalls, with heights up to 3m.

To summarise for this class of plants with typically wind-dispersed seeds of relatively short viability (a class including many vines as well as characteristically overstorey trees), for some species at least germination can occur prolifically under undisturbed or little disturbed rainforest conditions and the seedlings will persist for one or more years, though usually only in low numbers. Some species may require rather more open canopy conditions either to germinate or to survive beyond the germinate stage. Because of the usually speedy germination, seed predation may rarely be of much significance.

Table 8
EARLY SEEDLING MORTALITY

A. Hoop Pine - Unumgar S.F. (Forrest, 1962). Seedfall January, 1958.
Quadrats 0.84 m² (1 square yard); 1 600 quadrats.

Date	% quadrats stocked	Seedlings/ m²
February, 1958	27	1.04
June, 1958	8.3	0.18
December, 1958	1.8	0.023
June, 1961*	0.7	0.010

* In June 1961 there were also some additional seedlings from 1960 seedfall

B. Crows Ash - Unumgar S.F. (Forrest, 1962). Seedfall March, 1957.
Quadrats 0.84 m² (1 square yard); 61 quadrats.

Date	% quadrats stocked	Seedlings/ m²
April. 1957	62	1.39
July, 1957	54	1.08
October, 1957	30	0.47
June, 1958	3	0.04
June, 1961	0	0

C. Red cedar - Whian Whian S.F. (Baur. 1959). Seedfall Feb., 1957 Quadrats 0.84 m² (1 square yard); 48 quadrats.

Date	% quadrats stocked	Seedlings/ m²
March, 1957	98	25.4
April, 1957	85	8.5
May, 1957*	83	2.9
July, 1957'	74	2.7
October, 1957	42	2.0
December, 1957	25	0.5
December, 1959	Not Recorded	0.1
December, 1962	0	0

*Figures based on about half of total quadrats

6.3.3 Soil Seed Bank Species

For more than half a century it has been known that soil, collected from beneath rainforest, can germinate a large array of plants, including some not currently found close to where the soil was collected. The plants involved are typically the so-called pioneers - species that colonise disturbed sites, whether from natural gap formation or from human activity. The trees involved are mostly ones with seed dispersed by birds or fruit-bats, though they include some with wind-dispersed seed (e.g. Callicoma) and some, such as the wattles, where the seed largely just falls and lies, with possibly some insect or small mammal dispersal. Besides trees, many herbs, vines and some shrubby species are commonly present in the soil seed bank.

In reality two types of seed are probably involved in this group. One has seeds of at least relatively (and sometimes very) long viability, constituting a true long term soil seed bank, whilst the others are of relatively short viability (perhaps up to a year or so), but are being distributed to the area in a fairly continuous "seed rain". A collected soil sample is likely to contain both types, and there is still little understanding of the relative significance of the two (Whitmore, 1983)

The feature that unites these two types is the inability of the seeds to germinate in the absence of appropriate disturbance. At least in the short term all are part of the soil seed bank at any time, but in an undisturbed site the seeds will lose their viability at rates appropriate to each species, suffer fungal or insect attack, or perhaps be eaten and destroyed by other animals: even the longest surviving seeds presumably have some upper limit to their longevity in the soil.

However if the site is opened up, by logging, natural tree-fall or other causes, germination will start to occur.

Burgess (1965) collected soil samples from three subtropical rainforest sites in northern N.S.W. and exposed them to partial or complete light. Species subsequently germinating included various Asteraceae (Compositae - mostly exotic herbs), several grasses (mostly exotic, but including the rainforest grasses, **Oplismenus** spp.), Inkweed, Bleeding Heart, Duboisia and Red Ash. Apart perhaps from **Oplismenus**, all are typical pioneers in disturbed rainforest sites.

In the Lamington N.P. of southern Queensland, Abdulhadi and Lamb (1988) collected soil from under 6 subtropical rainforest sites - 2 undisturbed, and the others disturbed from 2 to 59 years previously. A total of 143 species (106 genera, 51 families) were recorded germinating from the soil seed banks at these sites; of these, 95 species were native and 48 exotic. (The number of exotic species, represented almost equally as well in undisturbed as in disturbed sites, was regarded as unusually high and was attributed to the proximity of agricultural land within 2 km of all sites). Most of the native species were trees (32 per cent) or vines (20 per cent); most exotics were herbs (74 per cent). One hundred and fifteen species germinated within 6 weeks of the soil's collection; most pioneer or secondary species, including Giant Stinger, Duboisia, Bleeding Heart, Poison Peach and Corkwood germinated quickly, though Blackwood and Red Ash continued to germinate over 36 weeks. The number of viable seeds in the soil bank was about 600 per m^2 for the undisturbed sites, 345/ m^2 at the 2 years old site, rose to over 2 000/ m^2 20 years after disturbance, and then decreased with age. Herbs were the most common life-form at all sites, and Abdulhadi and Lamb suggest, not altogether convincingly, that on average herb seed can remain viable for about 50 years in the soil. They also suggest that *Rubus rosifolius* seed may persist for up to 40 years, but that the life of much of the seed of secondary tree species was limited to a few years. (A number of tropical workers believe that relatively few species have prolonged storage (Whitmore, 1983).

Whilst the numbers of seeds are large, and these can be germinated under optimal greenhouse conditions, in the field - and more specifically, in the rainforest gap - seed mortality is high. In a North Queensland study Hopkins and Graham (1984) found that at best about a quarter of the soil seed bank germinated successfully; more than half either lost viability or died immediately after germination (presumably in both cases mostly from damping-off); the remainder continued to be dormant in the soil.

What triggers the germination of seed in the soil seed bank? The review by Whitmore (1983) makes clear the vital role of gap microclimate in promoting the germination of the soil seed store. He states that light appears as the most important germination stimulus, followed by temperature. Thus many species remain dormant in low light intensities (even where interspersed with brief sunflecks) or in green, filtered light; others have temperature-sensitive seeds, and need the higher temperatures experienced in a gap or clearing on a warm, sunny day in order to germinate. In some cases rupture of the seed testa may trigger germination: this can occur during snigging.

The germination triggering mechanisms apply not only to seed held in the soil, but to seed subsequently entering a cleared area: while, the conditions associated with an opening persist, seed of this class can continue to germinate. Thus herbs may go through several generations, and in the process leave behind a high soil seed bank, in the first year or so following the creation of an opening, before woody species are sufficiently well established to shade out further growth of pioneer herbs (Webb et al., 1972).

Germination occurs speedily following the creation of an opening, but the seed store may continue to germinate for a year or more. The woody species (including vines) resulting from this germination are typically fast-growing; many are also short-lived, though this is certainly not always the case - Giant Stinger, some wattles, Corkwood and many vines are among the relatively long lived species; the Basswoods appear to occupy an intermediate position.

Most studies relevant to N.S.W. have concerned subtropical rainforest, and the picture obtained here probably broadly fits dry rainforest, also. For warm temperate rainforest it seems that some other species are commonly involved in the soil seed bank, with Tickbush, Wattles and Callicoma among the more common: none of these are normally animal-dispersed.

The study of foliage nutrients by Lambert and Turner (1986) suggests that at least some of the pioneers on disturbed subtropical rainforest sites tend to accumulate nutrients at a relatively high rate.

6.3.4 Seed Establishing in Low Light Intensities

The third major germination class includes species that tend to have relatively large seeds with good food reserves. Most are probably animal-distributed, some are non-specific, and a few may be wind-dispersed. The seed may have a natural dormancy (in some cases reduced by passage through an animal), but it has the capacity to germinate on the forest floor in low light intensities. (Overseas experience suggests that some species may be incapable of germinating at high light intensities; see e.g. Jones (1955-56), quoting G. Gilbert.) In contrast to the first group (short viability seed), the species rarely produce masses of regeneration around seed trees (though the seed trees may produce occasional bumper seed crops), and predation or disease of seed is probably high. Also, once established, the seedlings tend to survive for longer periods and possibly even to make slow growth at very low light intensities.

Unlike the other two groups there appears to have been little Australian study of this seedling mechanism, though it takes in a large number of rainforest trees (including most Lauraceae and fleshy-fruited Myrtaceae) and most of the characteristic understorey shrubs. Webb et al (1972) touch on it in their study of subtropical rainforest regeneration at Mt. Glorious, in southern Queensland, when they refer to the dense regeneration of Giant Water Gum and, to a less extent, of Sour Cherry in the vicinity of seed trees and to a broader scatter of Olivers Sassafras regeneration through the study plot. In the case of the Giant Water Gum the behaviour shows some similarity to that of species with short viability seed, constraining the authors to write: *"... nowhere in the subtropical rainforest of South Queensland has this species been recorded as attaining local dominance: it behaves **...** as a typical non-gregarious species, and self-thinning of the seedlings must be very intense."*

In general, however, species in this group tend to produce more scattered and less numerous seedlings, which show considerable shade-tolerance - as indeed do the parent trees.

6.4 Regeneration Behaviour

6.4.1 Reprise

As seen, regeneration may develop vegetatively, from basal sprouts, coppice or root suckers, or from seedling establishment. Seedlings, in broad and simplistic terms, largely establish in one of three ways:

- Mostly wind-dispersed and with short seed viability; often periodic heavy seed crops giving rise to dense regeneration which tends to suffer heavy mortality though some seedlings may survive for a number of years.
- Largely animal-dispersed, of moderate to long seed viability and creating a soil seed bank; unable to germinate except under conditions associated with stand disturbance.
- Mostly animal-dispersed and with good food reserves; moderate seed viability but probably heavy predation, germinating over a period even under heavy shade.

These groups are not as clear-cut as has been suggested, and to some extent they merge into each other. Nonetheless, they provide a range of opportunities for rainforest to regenerate, based on the differing silvical characteristics of different species, and on the opportunities available to them.

6.4.2 Undisturbed Patch

In a long-undisturbed patch of rainforest, with its low light intensities at the ground, there will be various established stems that are capable of coppicing if damaged. In the soil will be a seed bank of pioneer species, supplemented from the seed rain, but also losing seeds as they are destroyed by natural agencies or as their viability is exhausted. On the ground there may be some seedlings of short viability species surviving from the last seed fall - numbers may be high if the fall was recent, or very low if it preceded the last dry season. Also there usually are some seedlings of more shade-enduring species. Mortality among the seedlings, of whatever type, will generally be high, but there are always likely to be a few individuals capable of surviving rather longer than their colleagues, by virtue of the luck of their seed placement and perhaps of having a slightly larger seed with better reserves.

If the patch remains undisturbed, all the seedlings will ultimately die, but new seedlings, of the same or different species, germinating from the seed rain, will also replace them.

Very slight disturbance - the death of a tree branch or of a nearby shrub, for example - may be enough to improve the chances of survival of a few seedlings. These are more likely to be shade-endurers, though certainly some of the short-viability species have the capacity to persist, with very low rates of growth, for long periods under quite heavy shade. Hoop Pine, Coachwood, Prickly

Ash, once their seedlings are well established, are ones with this capacity. The longevity of these seedlings, once reasonably established, can be remarkably high: in New Zealand Smale and Kimberley (1986) recorded mortality rates of about 1 per cent a year for dominated seedlings of Tawa and several podocarps: *"these species maintain slowly-turning-over banks of slow-growing established seedlings in the understorey, surviving on average for about 100 years…"* The significance of this behaviour is to allow the build-up of advanced growth that can respond if further disturbance occurs.

The extent of this advanced growth "pool" varies between different types of rainforest and between different sites:

- In undisturbed Coachwood-dominated rainforest on Moonpar S.F., 75 per cent of $4m^2$ (milliacre) quadrats carried useful saplings (3.6m high to 10cm DBH), 66 per cent of them with Coachwood saplings. About 15 per cent of the 25 m^2 quadrats carried Hoop Pine saplings, and 9 per cent of the smaller quadrats carried Hoop Pine seedlings (Baur, 1962; McCann, 1970). A later assessment on the unlogged plot in this particular area showed the presence of 20 800 seedlings/ha under 30cm tall (5 900/ha of commercial species); 6 100 (2 600) seedlings between 30cm and 130cm tall; 3 900 (2 100) saplings under 2.5cm DBH and 1 400 (810) saplings between 2.5 and 9.9cm DBH (Horne and Mackowski, 1937).

Table 9

REGENERATION IN UNLOGGED COOL TEMPERATE RAINFOREST
(Mt. Boss S.F. - after Porada, 1980)

Type	**Seedlings** (under 60cm height) **(% 4 m² quadrats stocked)**	**Saplings** (60cm height to 10cm DBH) **(% total stocking)**
Negrohead Beech	10	9
Coachwood	26	25
Sassafras	31	26
Prickly Ash	52	3
others	-	37
All species	81	100
Stems/ha	-	830

- In Negrohead Beech-Coachwood type on Mt. Boss S.F., Porada (1980) recorded the stockings in undisturbed sites shown in Table 9 81 per cent of 4 m^2 quadrats carried seedlings of the four main species, which also contributed about 520 stems of advanced growth per hectare.

- Subtropical rainforest on the former Wiangaree S.F. was less well stocked, with only 34 per cent of quadrats carrying regeneration from 30cm in height to 10cm DBH, and with 12 per cent of these quadrats regarded as having "useless" regrowth (Baur, 1962). Assessment of seedlings under 30cm would undoubtedly have increased the stocking, though the comparison with the temperate rainforest stands remains striking, Similarly the advanced regeneration present in undisturbed dry rainforest stands is usually low.

- In subtropical rainforest in south Queensland, Dale (1983) records a stocking of 662 stems/ha between 3 to 6m in unlogged rainforest, with 151 of these stems being of the main commercial species, including Sassafras, Prickly Ash, Yellow Carabeen, Rosewood, Pigeonberry Ash and Black Booyong.

6.4.3 The Gap Phenomenon

More significant disturbance can range from the relatively small opening that follows the death of a standing tree through to the massive disturbance accompanying cyclone damage or a heavy logging operation.

The death of a standing tree may in fact do little more than give some seedlings a respite from otherwise certain death and allow the more advanced regeneration to grow more actively for a short while. It may well be insufficient to trigger germination in the soil seed bank. However a larger opening will promote germination, as in the chablis of a large, fallen tree, whether windblown or felled for timber:

- Some existing, advanced regeneration will be smashed down, but many of the broken stems will coppice and may provide some of the fastest developing regrowth.

- Undamaged advanced regrowth will also respond - indeed the ability of what may appear as weak, suppressed saplings to respond to sudden opening is a striking feature of rainforest. Hoop Pine again provides an excellent example, though quantitative data on the response are lacking. However in New Zealand Kirkland (1961) recorded the response of a stem of Red Beech that had a stump diameter of 8cm and was (by subsequent ring count) over 100 years old; in the next 12 years after release it grew another 14cm. Porada (1980) refers to the response of Negrohead Beech after release.

- Seedlings on the floor of the gap will also respond, whether they be short-viability species or shade-enduring species (Webb et al., 1972, infer that the shade-endurers may suffer from sudden exposure in a gap, and require a shelter crop in order to develop. Certainly individual seedlings, developing in the shaded understorey, may suffer if suddenly exposed to full light. However, apart from some typical understorey species, it is probably most unusual for any rainforest tree species to grow better under shelter than in the open: see also below and Section 7).

- The exposure of the floor to increased light and warmth will promote the germination of seeds in the soil seed bank.

- At a greater height, trees around the edge of the gap will also be responding as branches (and vines) take advantage of the opening, and grow in towards its centre.

The result is a burst of growth in the gap, tapering off as one proceeds into the undisturbed area. A thicket of regrowth (again, including vines) develops, with probably the occasional stems of larger surviving advance growth above it.

In North Queensland G.C. Stocker (1984, 1985, also pers. comm.) has closely studied gap regeneration. In particular tree seeds of different apparent light requirements were sown and germinated in gaps of different sizes:

- Some species (e.g. Brown Sal Wattle, Alphitonia) survived only in large gaps, where they grew very rapidly.

- In the smallest gaps, shade-enduring species (e.g. some Proteaceae) survived best, though their growth was slow: these species grew faster in larger gaps, though other, more light-demanding species grew faster again (and often considerably faster).

- In gaps of intermediate size, where light intensity was too low for the species that develop best in the largest gaps, yet other species (e.g. Red Cedar) showed the maximum response.
- As the gaps diminished in size by growth at the higher levels, there was often a change in dominance, as the species previously showing maximum response faltered, and in some cases started to deteriorate, and as the species requiring lesser light intensities benefited.

For simplicity, Stocker refers to “large gap” and “small gap” species, but in reality there is a spectrum of species, from those capable of responding in the smallest gaps, i.e. species with a high level of shade tolerance, through to those pioneer species that require the largest gaps.

Stocker makes several other points:

1. Whereas in the tropics even a small gap will receive overhead light at some times of the year, in forests beyond the tropics small gaps may only ever receive indirect light and sunflecks, suitable for the growth of tolerant species.
2. An ability to grow, albeit slowly, or at least to survive, at restricted light levels is a prerequisite for many (Stocker says most) rainforest species.
3. “Large gap” species survive only in large gaps
4. “Small gap” species survive well in large gaps, but grow very slowly compared with “large gap” species.
5. Even “small gap” species grow more rapidly in big gaps than in small gaps.

In Nature, most rainforest regeneration develops as a result of gaps. They are one of the most fundamental features of the rainforest life cycle.

The extent of gap formation in rainforest is surprisingly high. In southern Mexico, using a common small palm whose habit can be used to record damage from falling trees, Martinez-Ramos et al. (1988) have shown that more than 50 per cent of 25m quadrats had received treefall damage in the past 30 years, and that 28 per cent had been damaged more than once in 70 years. At the opposite climatic extreme, Read and Hill (1988) suggest that in the Tasmanian temperate rainforests, dominance by the more shade tolerant species (e.g. Southern Sassafras) *“is infrequent because of the slow rate of replacement relative to the frequency of catastrophic disturbance.”*

The average gap, which most typically seems to result from the windfall of an individual tree, will vary in size in different types of forest. In N.S.W. the largest single-tree gaps occur in subtropical rainforest, with its tall height and its component of large-crowned species, such as Figs and Yellow Carabeen. Warm temperate rainforest, with its characteristically rather narrow-crowned trees (e.g. Coachwood), will tend to have smaller gaps, though even here large gaps are hardly unknown - an old Crabapple may have a wide crown, while the existence of veteran eucalypts, as in the Norman W. Jolly F.R., can produce most substantial gaps in the warm temperate rainforest below.

In small gaps, regeneration growth and development is a start-stop affair, but in large gaps it will continue for a much longer period. As seen, the gap is typified by a thicket of growth whose composition and development alters with time.

Initially the pioneer herbs tend to dominate, but within a year these are normally overtaken by longer living pioneers - Basswoods, Poison Peach, Duboisia, Bleeding Heart, Giant Stinger, Callicoma, Tickbush, Blanket-leaf and others, including vines. Most of these are relatively short-lived (perhaps 20 years or so at most), though some live much longer - Callicoma and Blanket-leaf, and particularly Giant Stinger (which can possibly live for over 200 years) and some of the larger growing vines. Growing with the thicket are some of the shade-enduring species, present before the gap was created and now plugging along in the (for them) improved conditions, and also probably some of the short-viability-seed species, a bit slower than the pioneers but poised to assume dominance in the gap as the pioneers reach the ends of their lives.

Whilst this pattern fits most natural gap formation in rainforest, in large gaps at high altitude in N.S.W. the development may be deflected. Particularly where tree seedling development has been delayed (e.g. by the existence of compacted soil or a dense fern cover), the larger gaps (e.g. from cyclone damage or heavy logging) may develop frost-hollow characteristics that tend to favour grass and fern growth. Small, open, fern-dominated patches amid successful regrowth are not uncommon in larger logging openings in the higher altitude N.S.W. rainforests, and are specifically discussed by King and Chapman (1983) in their study in warm temperate rainforest at Doyles River S.F. (650-700m altitude). As surrounding vegetation develops these patches slowly shrink and ultimately disappear, though in the Doyles River case openings with a maximum area of about 0.2 ha are still evident more than 30 years after logging, and at a guess could continue to be evident for another 20 years or so. Though rarely of major significance, such patches do reduce the overall productivity of the site.

Deflection or delay in the development of the gap thicket may occur through other reasons. In dry rainforest the introduced Lantana can form dense patches that can long hinder the development of the native species; it is rarely a significant problem in other types. Some gully areas may develop dense vine growth (particularly of Native Grapes) that again can delay further development: this is a problem that appears to warrant some study. Vine patches can also be perpetuated in sites subject to frequent disturbance, as in regular storm paths (Webb, 1958). Browsing, probably by wallabies and possums, may sometimes also delay regeneration establishment in openings (e.g. former log dumps in Washpool S.F.).

6.4.4 Clearings

Regeneration development in clearings has been subject to greater study in Australia than has smaller gap regeneration (e.g. Webb et al., 1972; Stocker, 1981; Tracey, 1985), but essentially the processes are the same. Tracey and Webb and his colleagues both reported on a study at Mt. Glorious, in south Queensland, where an opening was bull-dozed in subtropical rainforest: the treatment was thus more extreme than would naturally be experienced and most pre-existing seedlings were eliminated. As described by Tracey:

> *Massive germination of Inkweed, **Rubus rosifolius**, Gooseberry appeared within three weeks. Several species of **Solanum** germinated in this early stage. The Inkweed, Gooseberries and some Solanums completed their life cycle within two years as did many other annual weeds. Tobacco Bush and Bleeding Heart closed canopy at about 3m at this time and formed a "natural bush house" in which recently arrived canopy tree species thrived Lantana germinated over the whole plot, but survived and became dominant only in one corner that received sunlight throughout the year. Some canopy species established under the Lantana, but many failed to survive. Stumps of many species coppiced, and where present these tended to form the new rainforest canopy.*

When reviewed by Webb et al. (1972), 12 years after the opening was created, seedlings of other than pioneer species predominated in the regrowth below the height of about 2m, while above this height were the pioneer trees and the coppice. Up to that age little natural thinning or mortality had occurred among the regrowth of more long-lived species.

Tracey (1985) also referred to regeneration in North Queensland on to pastureland. Here the underlying geology determined the nature of the succession. On metamorphics, wattles and several other pioneer trees appear first, followed by other light-demanding trees to form islands which coalesce into larger clumps. At this stage the future canopy trees start to appear, mostly brought in as seeds by birds.

By contrast on basalt Tobacco Bush and Bleeding Heart appear early, with some longer-lived trees (including Red and White Cedar) also appearing at an early stage. Lantana and aggressive vines may hold the regeneration development back, and canopy species appear as seedlings below the first wave of trees.

Horne et al. (1981; Fig. 2.2) have provided graphic aerial photographs of the redevelopment of subtropical rainforest on to former farmland adjacent to Terania Creek. The land had been cleared and sown to pasture about 1921, and the 1942 photograph shows it still cleared and partially under cultivation. By 1959 the site had been invaded by wattle, lantana and rainforest species, and by 1972 the site was fully forested. A survey about 1980, reported by Horne and his colleagues, showed a composition typical of the Booyong-Coachwood type, with some 70 tree species present, 30 of these being representative of undisturbed rainforest patches.

In former warm temperate rainforest sites on the eastern Dorrigo Plateau, Tickbush often dominates early succession on pastureland (and also in much disturbed and compacted sites, as on log dumps or tractor-cleared sites). The Tickbush thickets can be long-lasting, but other species enter, including wattles, Callicoma, Hoop Pine (if a seed source in vicinity) and subsequently Coachwood and Sassafras. “Islands” that 40 or so years ago appeared as wattle or Callicoma thickets are today often dominated by Hoop Pine, with other commercial species well represented.

6.4.5 Regeneration in Logged Stands

Logging creates gaps, and the intensity of logging determines the size of the gaps. The processes are essentially identical with those associated with natural treefall gaps, except that snigging may lead to some local compacting of soil and also to some loss of established seedlings and saplings: Dale (1983), from subtropical rainforest in south Queensland, observes that in sites where snigging effects are apparent, *‘‘regeneration is less dense and restricted mainly to pioneer or ephemeral species”,* with some coppice regrowth of other species broken off during logging. Log dumps are often slow to regenerate after use, apparently primarily due to compaction and sometimes also to browsing pressure. Old bullock tracks have persisted as “tunnels” through the rainforest for decades after bullock haulage ceased: again compaction appears to have been the cause. On the other hand snig tracks and minor logging roads will sometimes support very dense regeneration of the more prolifically seeding species, such as Coachwood and Prickly Ash. As noted above (Section 6.4.3), at the higher altitudes local open, fern patches may develop and persist, apparently due to frost.

Data are absent for dry rainforest areas, but the overall impression is that regeneration is often deficient in logged areas, though dense patches of useful regeneration (notably Hoop Pine) may be encountered in some areas.

In other N.S.W. rainforest types the general results following logging tend to be the reverse, with regeneration of commercial species usually plentiful, and tending to match the original stand in composition - Appendix 8 summarises some of the recorded information from regeneration assessment in logged areas. Whilst few of the figures are strictly comparable, the general picture is one of abundant regeneration, almost regardless of the nature of the logging operation. Contrary to the earlier common belief, N.S.W. rainforest types normally do regenerate after logging.

6.4.6 Growth of Regeneration

Some indications of the size of regeneration are given in parts of Appendix 8 and elsewhere in the earlier discussions on regeneration.

However it should by now be appreciated that, with most rainforest trees other than the light-demanding pioneers, figures for regeneration mean little. The plants have the capacity for stop-start growth and, once well established, many can survive with very slow growth in low light intensities for many years, and then respond rapidly when conditions improve. It is a feature that warrants more study, but it should be realised that many small rainforest saplings may be many decades old, yet retain the ability to resume active growth, while in a nearby area stems of similar size may be less than 10 years of age.

Some indications of optimum growth rates will be considered in relation to artificial regeneration, in Section 7.

6.5 Regeneration Damage

A large array of agencies can - and does - damage or destroy regeneration. Only a minute proportion of the seeds that reach the rainforest floor will ever produce an established seedling, and few of those will ultimately develop into a mature tree.

Damping-off in the dark, humid understorey is probably the major cause of loss, both before and immediately after germination. Seed insects appear to cause much seed to be aborted and, whilst many species rely on animals for seed dispersal, predation by animals also causes heavy loss: in North Queensland, the Queensland Department of Forestry (1983) observes:

> "... *major cause of reduced germination was seed destruction by both vertebrate and invertebrate animals, e.g. one trial recorded rodent destruction of 25 per cent of Kauri seed, while termites and other insects, wallabies and possibly possums and birds were regarded as important predators. Seed of Red Cedar appeared to be almost immune to attack, possibly as a result of its size being too small to attract mammals, and too large to attract seed-eating ants."*

Once germinated, the seedlings face other problems, though in the understorey insect attack rarely seems to be significantly one of these. Notwithstanding the humid conditions of the forest floor, the dry season takes its toll of young germinates (see Table 8): casual observations suggest that seasonal drying may be very important for young seedlings, especially in undisturbed forest where the litter layer delays root penetration into the soil. Animals also continue as a major cause of seedling loss - some by browsing and others, probably more importantly, being uprooted by birds such as Brush Turkeys and Lyrebirds, scratching in the litter for insects.

Physiological factors cause other loss, e.g. low light intensity. Litterfall physically kills some; in other cases litter may release chemicals antagonistic to the growth of some species, though the significance of this in field conditions is still rather uncertain.

In open conditions various insects can become major agents of damage. Thus young Giant Stinger and Duboisia can be almost defoliated by leaf-eating beetles; some of the Lilly Pilly relatives develop leaf abnormalities probably caused by sap-sucking insects; most notably Red Cedar can be attacked by the Tip Moth, which can effectively prevent its ever developing a stem of commercial quality.

If fire is able to burn into the rainforest (see Section 2.4.6), this will destroy existing regeneration.

Logging can cause substantial damage to existing regrowth. McCann (1970), referring to Coachwood treatment plots on Moonpar S.F., states:

> *"... it is clear* ***...*** *that the number of useful saplings present has been reduced in all the logged blocks. There has been a reduction of 50 per cent in Coachwood saplings in the most heavily logged block. (Forestry Commission files) recorded in 1951 that this was very obvious in the field and was due to damage sustained during logging when long logs (on occasions up to 20m in length) were swung around behind the tractor, smashing many smaller stems in their path. Hoop Pine saplings were also present before logging ... After logging none was present in the (heavily logged blocks), though they were still found in block B (lightly logged)."*

In this case many of the smashed stems (though not Hoop Pine) recovered by coppicing, but the moral is clearly for care in logging to minimise damage of this type.

7. ARTIFICIAL REGENERATION

7.1 Role of Artificial Regeneration

Artificial regeneration, involving the planting of established seedlings, has been used in two ways in the silviculture of rainforests: firstly for the establishment of open plantings (occasionally, and for experimental purposes only, with some subsequent underplanting), and secondly for the enrichment of areas of logged rainforest. Both of these approaches will be examined rather briefly below. In addition, of course, many rainforest plants, of all life forms, are regularly used for ornamental purposes: this is not considered here, but many details will be found in such publications as Jones (1986) and Wrigley (1979). Macadamia (for nuts) and Duboisia (for alkaloids) are also sometimes planted commercially, and are not considered further here.

7.2 Planting Stock

Rainforest trees planted by the Forestry Commission in the past have almost invariably been raised from seed (occasionally from wildings transplanted from the forest), and grown in containers. However many rainforest trees, including Sassafras and Pinkwood, can be readily grown from cuttings (Wrigley, 1979), and where seed is awkward to collect this can offer a ready means of building up a supply of planting stock. Cuttings should be obtained from half-hardened wood, cut cleanly, kept moist, and established in soil that is well drained, but maintained in a moist condition, after treatment of the cuttings with a root-promoting compound.

Wildings have been used on a relatively small scale in the past, though the earlier Hoop Pine plantings at Mt. Pikapene S.F. (1922 and later), the 1945 planting of Coachwood at Doyles River S.F., and the small White Beech planting on Way Way S.F. (1951) were all reputedly established using natural seedlings from the nearby rainforest. Particularly where a heavy seedfall has resulted in massive germination, large numbers of wildings can be readily obtained and, with care, transplanted into containers to develop as normal seedlings for later planting.

However most planting stock has been of seedlings, germinated in a nursery and subsequently transplanted into suitable containers from which they are ultimately planted out in the field. Because rainforest seedlings typically need to be larger than eucalypts for field planting, the small peat-pots favoured for eucalypts are not appropriate for rainforest species and instead tubes or larger plastic containers are usually employed.

As noted previously (Section 6.3), rainforest seed has various germination mechanisms, and some may prove refractory to germinate, or need special pre-sowing treatment. Species that are, or have been, regularly raised by the Forestry Commission either for amenity or management use do not receive such special treatments: most have wind-dispersed seeds that tend to germinate readily, and the others appear to germinate satisfactorily, even though some pre-treatment might hasten germination. Some of the North Coast commercial nurseries, that in recent years have tended to concentrate on raising rainforest species, have developed suitable treatments for some of the more difficult species, but details have yet to be documented.

Some species, such as White Beech and Silver Quandong, have seed that may germinate over a period of a year or more. In such cases it is usual to leave the seed in a suitable, but out of the way, place for germination, check the seed at intervals, and transplant the germinates into containers as they appear. A similar approach was taken with Bunya Pine when it was being routinely planted.

The rainforest species planted on the largest scale by the Forestry Commission in the past has been Hoop Pine. The technique developed, based fairly directly on Queensland practice, never appears to have been published in N.S.W., though a summary of the process was included in an unpublished review by Baur (1960). Seed, dusted with a fungicide, was sown on to nursery beds under 50 per cent shade in late spring or early summer, at a rate calculated to yield about 200 seedlings/m^2, and then covered with a layer of sawdust. Germination occurred over a period of a fortnight to several months. Beds were kept well watered and weeded. About 21 months after sowing (August to October of second year), when the seedlings were 20-25cm tall, the young plants were transplanted into metal tubes (about 20cm long by 4cm diameter) - seedlings were lain in the soil-filled, open tubes, which were then clamped shut. Earlier (autumn) tubing was practiced in some of the higher altitude nurseries. Tubing was meant to be completed at least 8 weeks prior to planting, but not so early that the seedlings became root bound. Planting normally occurred in late spring and early summer, after the seedlings had spent about two years in the nursery. The nursery technique was expensive, and was a significant factor in the 1954 decision to cease routine Hoop Pine plantation establishment. However recent Queensland work (Anon., 1987) suggests that improved practice could raise Hoop Pine seedlings to planting size in about 11 months.

The Coachwood plantings at Doyles River S.F. were documented by Burgess (1962). The plantings were made irregularly from 1945 to 1955, the two largest plantings (1947, 8 ha; 1949, 11 ha) being complete failures. Seed was sown in beds under shade immediately after seedfall (viability fell off within 7 days) in February or March, and the seedlings tubed in September-October when 8-20cm tall, for planting during the following wet summer, i.e. 10-12 months after seedfall.

Species dealt with by Wrigley (1979) and listed in Appendix 1 are marked in the Appendix - but note that Wrigley also refers to many other rainforest species which are not listed in Appendix 1.

7.3 Open Plantings

Former rainforest sites in N.S.W. have been used for planting with exotic conifers (notably *Pinus taeda* and *P. elliottii*) and with eucalypts. These are not considered here, but some aspects of such eucalypt planting are dealt with in other Silvicultural Notes in this series, particularly No. 7 (Flooded Gum type).

Most Forestry Commission effort on open plantings involving rainforest species has been concentrated on Hoop Pine and, to a lesser extent, on the Queensland Bunya Pine. Coachwood was planted at Doyles River S.F. on a small scale shortly after World War II, and pure stands of a number of other species, including Queensland Kauri, Red Cedar, Silky Oak and White Beech, have been planted on any experimental scale. Of those tried, only the conifers have proved satisfactory in pure plantation stands:

- Red Cedar plantings are invariably attacked and badly deformed by Tip Moth, though in the long run some good stems have developed (e.g. Strickland S.F.: stem with DBH of 48cm and a height of 34m at age about 80 years). With younger plantings the pattern has been for stems to reach a height of 10-15m by about age 11 years, Tip Moth damage being well evident by age 4-5 years, with resultant crooked stems.

- After early rapid growth and good form the Silky Oak plantings (Mt. Pikapene and Toonumbar S.Fs.) became very unhealthy looking, with slowed growth and dead crowns: similar features are often seen in Silky Oak planted for amenity purposes, and may be a reflection of the autotoxicity factor noted by Webb et al. (1967) for Silky Oak seedlings.

- Coachwood seedlings developed multiple leaders and a very branchy habit, often with sharply angled branches. At Doyles River the larger plantings developed into frost hollows where all seedlings were wiped out, and elsewhere wallaby browsing was heavy and the young plants were attacked by a moth larva (*Charaga* sp.) causing top death, multiple leaders and stem damage (Burgess, 1962). Such poor form and damage is typical of planted Coachwood, while in any case natural regeneration at Doyles River tended to be plentiful.

- White Beech on Way Way S.F. was slow growing and heavily branched, though of the non-conifers planted on any scale it probably had the most promise of success.

- Brown Pine, in the arboretum at Cumberland S.F., grew slowly with most stems multi-leadered and very branchy.

Growth details from plots established in the Coachwood and White Beech plantings are shown in Table 10, both at age 33 years. The Coachwood planting was made beneath a similar aged overwood of the pioneer species, White Basswood, which not unexpectedly has shown the better early development though probably now nearing the end of its period of significant growth.

Nonetheless there are some broadleaved rainforest species that appear worthy of further trial in pure stands. These include some of the larger growing pioneer species, which often regenerate naturally in pure stands, and also some of the species of rapid or moderately rapid growth with a strongly monopodial growth habit, such as Silver Quandong (which would undoubtedly need pruning) and Sassafras. Among the pioneer species, Blackwood has been planted on a small scale in Tasmania and rather more widely in New Zealand and South Africa (Borough, 1988; Hickey and Borough, 1988): like some of the other larger and longer-lived wattles, it warrants some planting trial in N.S.W.

GROWTH OF PLANTED RAINFOREST SPECIES IN PLOTS

State Forest	Species	Age	Stems/ha	Mean DBH (cm)	Largest DBH (cm)	M.Dom. Ht (m)	BA/ha (m^2)
Doyles River	Coachwood	33	2564	7.3	15.4	-	13.2
	White Basswood	33	1026	14.0	24.1	-	18.4
	Total		**3675**			**17.0**	**35.5**
Way Way	White Beech	33	923	16.3	32.5	19.6	22.1

Plantings of the **Araucaria** spp. cover about 1500 ha in N.S.W., mostly established between 1938 and 1956, with only spasmodic and small additions since that time. All were established on sites that previously carried rainforest, usually with a Hoop Pine component (though certainly on Acacia Plateau [Koreelah S.F.] this component was very small). Three main rainforest forms were involved: dry rainforest (Mt. Pikapene, Toonumbar and Mebbin S.F.s); subtropical (Tooloom and Beaury Plantations on Beaury S.F.; Acacia Plateau) and warm temperate (Bo Bo (or Brooklana) Plantation on Wild Cattle Creek S.F.). Again a summary of the technique used, derived from that developed in Queensland, has been given by Baur (1960). Sites to be planted (typically heavily cut-over rainforest) were cleared (hand felling) in the winter, and the debris, lying broadcast as it fell, was left to dry out during the spring. Belts of rainforest, about 100m wide, were retained as green breaks around planting areas. The debris was burnt in late spring to early summer (mid-October to mid-

December), choosing a day of low humidity and reasonably high temperature, and planting followed immediately, to get as much planted as possible before weed growth appeared. Planting was thus occurring in the dry season, though the tubed plants, with their retained cylinder of soil, were usually able to cope with this with minimal mortality. Optimal seedling size was 25-40cm: larger plants were liable to heavy losses during extended dry periods after planting; smaller ones were more prone to weed competition.

Weed control became a major task once the first weeds appeared, and its costs, probably more than any other factor, ultimately led to the cessation of routine Hoop Pine planting. Weeds usually appeared following the first rains after the burn, and unless controlled could overwhelm the young plantings within 3 months. Thus repeated chipping and grubbing were needed for the next 3 or 4 years, by which time the conifers were exerting their own control on the weeds (except for lantana at Mt. Pikapene S.F.). In some recent plantings the use of weedicides has greatly eased the problem of weed control.

Damage to the young plantings came from a number of sources:

- Even light fire would destroy the young conifers.

- Particularly at the higher altitudes, low-lying sites developed as frost-hollows, where the Hoop Pine was killed or repeatedly cut back. The use of the more frost-tolerant Bunya Pine reduced this damage at Acacia Plateau, but some frosted sites still developed and were ultimately planted up with **Pinus** spp.

- Wallabies, and to a lesser extent rabbits, caused some damage by nibbling the tops of seedlings.

- More significant damage followed a rat plague on Acacia Plateau (probably Eastern Swamp Rat, *Rattus lutreolus*), with about 80 ha of young (up to 6-7 years) Bunya Pine being destroyed by ringbarking near ground level: see Fig. 15 in Baur (1962). Inadequate weed control was thought to have contributed to the severity of this attack.

Table 11

HOOP PINE PLANTATION GROWTH - GREVILLIA MANAGEMENT AREA

Age (yrs)	Mean Dom. Ht (m)	BA (m^2/ha)	Tot.Vol. (m^3 /ha)	Vol. PAI (m^3/ha)	Vol. MAI (m^3/ha)
10	14	18	64	13.6	6.4
20	23	36	200	18.0	10.0
30	29	54	380	19.5	12.7
40	33	71	575	18.0	14.4
50	34	89	755	13.7	15.1
60	34	107	892		14.9

In successfully established Hoop Pine plantings the seedlings tended to develop slowly for the first couple of years, and then speed up. In the better sites mean dominant height reached 10-14m at age 10 years, and on the poorer sites 5-8m. Table 11 summarises data on the growth of Hoop in plantations in the Grevillia Management Area of northern N.S.W., obtained (and slightly extrapolated) from regression equations using data from plantation inventory plots, and Table 12 gives some specific plot data, in one case (Wedding Bells S.F.) from a small, but rather fine, planting on a former banana plantation, and in the other two cases from the State's oldest Hoop Pine plantings, both initially established as enrichment plantings (see Section 7.4).

Table 12

HOOP PINE GROWTH IN SELECTED PLANTATION PLOTS

State Forest	Age (yrs)	Stems/ha	Mean DBH (cm)	M.Dom.Ht. (m)	BA/ha (m^2/ha)	Vol/ha (m^3/ha)	PAI (m^3/ha)	MAI (m^3/ha)
Wedding Bells	45	484	37.4	37.7	55.7	756.2	24.4	16.8
Mt. Pikapene	53	408	40.3	35.3	53.2	615.9	3.7	12.8
Mt. Pikapene	61	324	50.0	34.1	71.4	828.2	15.7	13.6

As noted above, the plantings considered so far all involved the use of a single species on sites from which the rainforest had been cleared away and burnt immediately prior to planting. More recent developments have seen plantings on pasturelands and the use of mixed species plantings.

The pioneering work on pasture plantings appears to have been done in Queensland. Previously it was impossible to plant Hoop Pine into grass cover - the seedlings turned a poor colour, made little growth and were swamped by pasture. However by eliminating grass from around the seedlings, by keeping the immediate vicinity free of grass, and by fertilising with N and P. Hoop Pine has been successfully established in former pasture. Grazing is usually incorporated into this system once the seedlings are sufficiently established. The procedure has also been found successful for planting a large range of mixed rainforest species into grass or other pasture (Forestry Commission of N.S.W, 1988). Glyphosate (Round up, Zero, etc) is generally used, with an area of about 2m diameter being sprayed around the intended planting spot 2-3 weeks ahead of planting. (This time allows the grass to die; the dead grass forms useful mulch). Follow-up grass control is essential until the seedlings are capable of controlling the grass themselves - a period that may be only 2 years for some species and more than 4 years for others on the Far North Coast. Spraying is needed 3 to 4 times in the first year, and usually less frequently thereafter; mulching helps reduce weed competition, and appears to have additional benefits in keeping the seedling's surface roots cool and moist.

Seedlings for such plantings are typically container plants, with a height of about 40cm: under 30cm they are liable to be overwhelmed by grass and weeds; over 60cm they often suffer wind damage and are slow to start growth. Planting can be at any season, but avoidance of late winter and early spring, with its following dry season, is advisable.

Plantings of mixed species have to date been carried out primarily with a view to recreating a rainforest stand, rather than with timber production in view. Most work has been done under private sponsorship in the Tweed district, usually under the guidance of a local enthusiast, Mr. B. Chick, though the Forestry Commission has used the technique on the Big Scrub F.R. with the intent of extending the rainforest out to the Reserve boundaries. (Prior to its notification as a Flora Reserve, this "panhandle" section of Whian Whian S.F. had suffered some contraction due to grazing encroachment from neighbouring properties.)

In reviewing mixed plantings, the Forestry Commission of N.S.W. (1988) notes that, contrary to popular myth, most rainforest trees are not particularly fragile, and they do not normally require the shelter of more hardy species to become established. (Away from the Far North Coast, and particularly at the higher altitudes, some initial shelter may be necessary in order to minimise wind and frost damage.)

Some species will grow much faster than others: among the faster are Silver Quandong, Silky Oak and Native Tamarind. Among the slower growing are many of the laurels, many of the Lilly Pilly relatives (including Cherries and other Myrtles), and Brown Pine: these slower species often develop a rather stunted, many-leadered, shrubby form, and they seem to benefit from the side shelter (not overheaded shading) provided by their faster-growing neighbours. A rough listing of the speed of growth of some planted rainforest trees is given in Table 13.

The Commission, on the basis of little practical experience, suggests that for such rainforest plantings a spacing of about 3.5 x 3.5m (800 per ha) is desirable with the faster-growing species widely spaced (say every 5th tree in every 5th row) and a mixture of other species used for the bulk of the planting. Thicket conditions, on the Far North Coast, could be expected within 5-6 years, and at that stage additional, shade-requiring understorey species can be introduced into the planting, if sought.

Plantings of this nature were in many respects foreshadowed half a century earlier by the very successful arboretal plantings on Cumberland S.F., where a large number of rainforest species were planted in almost random manner along some of the gullies running through the property, that was acquired about 1933 and largely planted up over the next four years. At the time of planting most of the site was cleared with scattered remnant trees; originally it would have been dominated by Blackbutt and Sydney Blue Gum, and it would not have carried any rainforest species. The measurements of the largest surviving stems from some of these plantings are given in Appendix 9.

Such planting should be capable of providing commercial timber in due course, though it is suspected that its economics would be dubious at best. It is more likely to be attractive to the enthusiast tree-planter or to people seeking, for various reasons other than wood production, to create a new rainforest (Baur, 1984).

Table 13
ROUGH GRADING OF GROWTH RATES FOR A FEW FAR NORTH COAST RAINFOREST TREES IN PLANTATION

Very Fast (to 5-7m high at age 3 years, 20m at 15 years)

White Basswood	Silver Quandong
Silky Oak	Wattles

Fast

Queensland Maple	Native Tamarind
Hoop Pine	

Moderate to Fast (to 2-3m high at age 3 years, 4 to 8m at 7 years)

Red Ash	Red Cedar
Silver Ash	Queensland Kauri
Red Carabeen	Pepperberry
Onion Cedar	Tulipwood

Moderate

Bennett's Ash	Flametree
Crow's Ash	Rosewood
Prickly Ash	Silver Sycamore
Black Bean	Yellowwood
Red Bean	Deep Yellowwood

Slow to Moderate (to 3 to 4m at 7 years)

Black Apple	White Beech

Slow

Laurels generally	Lilly Pilly relatives
Brown Pine	

7.4 Enrichment Planting

The other main way in which artificial regeneration has been used in N.S.W. is for the enrichment of areas of logged rainforest.

Enrichment planting has a long history in N.S.W., although the name itself is of moderately recent origin (an early review of the technique in the tropics was given by Brasnett, 1949). Detailed records are lacking, but it is almost certain that the Red Cedar plantings at Dorrigo and elsewhere in the 1880s were what today would be termed enrichment, and certainly the first Hoop Pine plantings at Mt. Pikapene S.F. in 1922 and again in the early 1930s were enrichment into the low understorey of the dry rainforest, followed by intensive cleaning to produce what in effect was an open plantation (see Table 12).

The technique lapsed during the era of open Hoop Pine plantations, but was resurrected experimentally in the 1950s and subsequently used on a limited, but routine, scale in two main circumstances, one being to establish Hoop Pine into dry rainforest stands where regeneration of the conifer was deficient, and the other to revegetate log dumps and snig track openings with desirable species (most commonly Hoop Pine and Red Cedar) in subtropical rainforest.

The results of the research in the 1950s were summarised by Baur (1962), and a few general conclusions can be drawn from this and other work:

- Growth tended to be directly related to the amount of overhead opening. Plants that were overtopped might survive for a long period, but growth was negligible, whereas plants established in an opening tended to show strong growth from an early stage. Some figures from dry rainforest at Unumgar S.F. are given in Table 14: note that in all cases the “best stem” was growing in an open site. Dale (1983) gives two graphic illustrations (Plates 1 & 2) of the same effect in subtropical rainforest in southern Queensland: at age 936 years Hoop Pine under open conditions (0-10 per cent canopy density) had a mean height of 7.6m; under dense canopy (75 per cent +) it was only 1.5m.

Table 14
GROWTH FROM ENRICHMENT PLANTING, UNUMGAR S.F.
(from Baur, 1962)

Species	Age	In Opening (m)	Under Canopy (m)	Best Stem (m)
HoopPine	5	1.2	0.8	2.4
Silky Oak	5	1.8	1.0	2.9
Red Cedar	2	0.8	0.6	1.1
Yellowwood	2	0.3	0.25	0.5
Crows Ash	2	0.4	0.4	0.6

- Larger plants tended to show better survival and subsequent growth than small plants: the disappointing results from Crows Ash and Yellowwood in Table 14 are partly the result of having planted too-small seedlings. As with the open plantings discussed above, a seedling height of 40cm, or even slightly more, is desirable.

- Damage levels are variable. Baur notes that in dry rainforest Silky Oak and Red Cedar showed heavy losses during the dry winter/spring season, whereas Hoop Pine had a high survival rate and wallaby attack was of negligible proportions. On the other hand some (but not all) trial plantings of Hoop Pine in warm temperate rainforest suffered substantial wallaby and rat attack (see Fig. 25, in Baur, 1962). In the high altitude (mostly over 1 000m) subtropical rainforest enrichment reported by Dale, some of the Hoop Pine, as it grew to larger size, was subjected to repeated attack by the Fawn-footed Melomys, an arboreal native rat.

- In large openings weed growth, and in smaller openings the closing in of the adjacent taller trees, are almost certain to lead to the restriction of growth of enrichment planted stock. Release will allow growth to be maintained (though sometimes with some reduced survival because of damage where taller trees are poisoned: see Dale, 1983). However usually the expense of further treatment cannot be justified, and the planted seedlings thereafter will behave like well-established natural advance growth, with its stop-start behaviour as conditions locally and periodically alter. Growth restriction by the closing in of the gap from above is likely to be more long lasting than restriction by weed growth, and this points to the desirability of planting in relatively large openings if follow-up treatment is unlikely to be available.

- In most cases there is obviously little point in enrichment if there is already adequate regeneration or advance growth present. However even in these circumstances enrichment may be justified in order to build up the stocking of some of the less common, but high value, species or to introduce species not naturally present, such as Queensland Maple (which appears as one of the most successful species for enrichment) or some of the more important commercial species, such as Hoop Pine and the **Flindersia** spp., into some of the more southerly dry rainforest stands.

Enrichment planting is a useful tool in rainforest management, but needs to be used with commonsense and some discretion. It is probably best applied by the planting of a group of seedlings in appropriate openings, if necessary after treatment to remove or reduce existing weed growth, and although subsequent release treatments will rarely be an available option for State Forest plantings, they are nonetheless desirable to maintain unrestricted growth for as long as possible.

The technique is particularly useful in bringing patches of viney scrub and other regrowth rainforest areas to a potentially more productive state, and has been used by Waring (1985) in the rehabilitation of rainforest regenerating on former pastoral land in the Robertson district.

7.5 Underplanting

Dale (1983) uses the term “underplanting” in the sense of enrichment planting - that is undoubtedly one form of planting beneath an existing stand. However in the sense intended here it refers more specifically to the planting of rainforest seedlings beneath an existing plantation of trees.

It has only ever been used experimentally in N.S.W., with results that were summarised by Baur (1962). Reasons for underplanting have included:

- Establishment of Hoop Pine on high altitude frost hollow sites, using Pinus as a cover crop (e.g. Bo Bo Plantation; Chapmans Plain plantings on Clouds Creek S.F.).

- Efforts to minimise Tip-moth damage on Red Cedar (e.g. plantings beneath Hoop Pine on Toonumbar S.F., Flooded Gum on Pine Creek S.F., and Silky Oak on Mt. Pikapene S.F.).

- Establishing mixed rainforest species under Flooded Gum, before it was appreciated that most of the species would grow and survive better in the open (e.g. on Woolgoolga Nursery site).

Two main conclusions can be drawn from these studies:

1. As with enrichment, underplantings need to be in an opening if growth is to be achieved. In the case of Red Cedar at Toonumbar S.F., seedlings under shade, but near an opening, developed sigmoidally curved stems as they aimed towards the gap.

2. Heavy damage to the underplantings can be expected in any harvesting (or even poisoning) of the cover crop.

Underplanting appears to have only limited application, though it may have a role in reestablishing rainforest in some of the higher altitude, frosty sites from which it was originally cleared. In such cases, and because of the damage from harvesting, it would probably be best to use a relatively small and short-lived species as the cover crop, such as wattle or possibly Teatree. (In New Zealand various species have been successfully planted into native Teatree (Manuka) scrub: Anon., 1983).

8. Growth And Yield

8.1 Rainforest Stand Dynamics

A considerable number of growth plots have been established in rainforest stands in N.S.W., but unfortunately only in relatively few cases have analyses of the results been carried out.

In considering the information that is available, several points should be noted:

- In a patch of virgin rainforest growth is constantly occurring in the individual trees and other plants, but over a period of years this growth is balanced by the mortality that is also occurring: G.G.K. Setten, former Director of the Forest Research Institute, Kepong (Malaysia), described the process as “dynamic stagnation”. (In like manner, the vast rainforests of the Amazon basin and elsewhere are unlikely to be either nett producers or nett absorbers of atmospheric CO_2: the absorption during growth is balanced by the subsequent production of $C0_2$ during decay.)

- The mortality does not occur regularly (nor, for that matter, does the growth), but will be high some years and then may be negligible for a run of years: the process (related to stand BA) is diagrammatically portrayed by Horne and Gwalter (1982; Fig. 2), and their specific examples, from unlogged plots in subtropical rainforest measured over a period of 14 years, are reproduced here as Table 15. (Years of high mortality probably often coincide with periods of unusually strong winds or low rainfall).

Table 15
FLUCTUATING BA (M^2/HA) IN VIRGIN SUBTROPICAL RAINFOREST
(from Horne and Gwalter, 1982; data from former Wiangaree S.F.)

Year	Plot 1	Plot 2	Plot 3	Plot 4
1966	40.1	31.9	21.4	31.2
1910	39.1	34.2	26.8	33.5
1973	*31.7*	34.1	26.4	32.1
1975	*38.1*	34.5	27.4	33.5
1980	36.1	33.7	28.2	32.9
Mean	**38.6**	**33.7**	**26.0**	**32.8**

- The stop-start nature of regeneration growth has already been noted (Section 6.4), and this carries through to the larger stems. A complete cessation of growth probably never occurs except when the tree is about to die, but growth can be maintained at low levels for a long period, and then accelerate when the growing conditions are suddenly improved. For example Porada (1980) examined growth ring patterns in Negrohead Beech at Mt. Boss S.F., and reported:

  "… while pole sized stems or advanced coppice growth may have been suppressed by the overwood for relatively long periods (c. 20 years in one sample) , once the canopy has been removed response is very rapid. For one sample MAI since overwood removal (15 years) has been 0.3cm, with a maximum annual increment of 1.1cm. A similar response was recorded for mature trees even after long periods of intense competition (c. 20 years in a number of samples). In one case growth rings tended to merge together before release from competition. After release there was an almost immediate growth response. (MAI recorded for all samples since logging was 0.6cm)."

  This coincides, albeit less extremely, with the findings of Kirkland (1961) for Red Beech in New Zealand (see Section 6.4.3), and parallels common experience with a large number of rainforest trees, few of which produce usable growth rings.

- On the other band, trees kept free from suppression can maintain relatively rapid rates for growth for long periods, as shown, for example, by Hoop Pine in plantations, by the older mixed planting growth rates quoted in Table 13, and by the rainforest trees planted in the not entirely favourable environs (for rainforest growth) of the arboretum on Cumberland S.F. (Appendix 9).

- As trees survive through to enter the upper rainforest canopy, the likelihood of severe suppression is lessened and the trees can be expected to show less impeded growth rates[6]. However, as in any forest stand, these taller trees still face competition from their neighbours, and the growth rate of comparably sized trees in logged stands tends regularly to be greater than in the denser, unlogged stands.

8.2 Growth in Even-aged Stands

Even-aged stands of any extent are unusual in rainforest, though certainly not unknown. Even though the gap, or chablis, is a basic unit *of* most rainforest stands, these are rarely truly even-aged because of the existence of advance growth, and unless of large size their identity tends in time to be lost amid the development of the adjoining older trees: the mosaic pattern, evident with relatively young gaps, becomes increasingly obscure with time.

More evident even-aged stands occur where larger tracts have been destroyed by storm, occasionally by fire, or more commonly where heavy logging has substantially opened up the stand, though in all cases scattered larger trees typically remain and much of the regrowth comes from advance growth, probably often of considerable age, present prior to the disturbance (in the case of fire, via coppice growth: see Sections 6.1 and 6.4.4). In such regrowth stands the differential growth rates of different species typically tend to produce a relatively greater array of size classes than one might tend to expect in, say, an even-aged eucalypt stand.

[6] In some tropical rainforests, assessments of certain commercially significant species (e.g. African Mahogany, ***Khaya ivorensis***) consistently show a deficiency in the middle range of size classes. There is evidence to suggest that this is often due to the accelerated growth of stems in these size classes, comparative to the smaller and larger sizes (Baur, 1968, pp. 143-150).

Table 16
RELATIVELY EVEN-AGED RAINFOREST REGROWTH

Site (see note below)	1	2	3	4
Approx. age (years)	25	30	45	40
Stocking /ha	1 360	1 200	1 640	530
BA (m^2/ha)	9.9	19.7	22.2	25.9
Diam. of Mean BA (cm)	9.9	14.3	13.1	25.0
Coachwood - stems/ha	350	340	-	-
- Mean diam (cm)	8.0	15.5	-	-
Brush Box - stems/ha	910	-	245	-
- Mean diam (cm)	10.0	-	17.0	-
Hoop Pine - stems/ha	-	86	235	530
- Mean diam (cm)	-	23.9	15.3	25.0

Note: **Site 1**: Coachwood type; Wild Cattle Creek S.F. (Forrest, 1961).

Site 2: Coachwood type; Wild Cattle Creek S.F. (Forrest, 1961). (Little Nymboida).

Site 3: Hoop Pine type; Mt. Pikapene S.F. (Forrest, 1962).

Site 4: Hoop Pine type: Unumgar S.F. (Forrest, 1962)

Table 16 give summaries of four such plots, two each in Coachwood type on the eastern Dorrigo Plateau and in Hoop Pine type further north, at ages from about 25 to 45 years after disturbance (logging in sites 1, 2 and probably 4; fire in site 3). Sites 1, 2 and 3 have received no treatment; site 4 was culled and thinned at about age 25 years to leave only Hoop Pine. As can be seen, growth has generally not been rapid, but with the most interesting feature shown by site 4: when treated, the remaining Hoop Pine stand had a BA of 3.7 m/ha and a mean diameter of 9.5cm; 14 years later BA had increased to 25.9 m^2/ha (PAI 1.6 m^2/ha/y) and diameter to 25.1cm (PAI 1.1cm/y). The growth in this plot since treatment has been comparable with that of plantation Hoop Pine at a similar stage of development, demonstrating once more the capacity of many rainforest trees to respond rapidly to release. The two Coachwood sites, which appear typical of much heavily logged warm temperate rainforest, are developing in different ways. At Little Nymboida the stand contains many relatively short-lived pioneer species (e.g. wattles, Callicoma) that can be expected to reduce in growth and numbers, leaving Coachwood dominant. By contrast, at Cascade the Coachwood is likely to develop more slowly beneath a Brush Box overstorey. In the Little Nymboida site (No. 2), BA at the time of measurement was from a third to a half the level commonly encountered in virgin Coachwood stands (45-55 m^2/ha).

Plantations also provide examples of even-aged stands of rainforest species: see Section 7.3 and Tables 10, 11 and 12 for information on the growth of such stands.

8.3 Growth in Uneven-aged Stands

8.3.1 Data

As previously noted, although records exist for a considerable number of growth plots established in rainforest stands of various types and histories, only a few of these plots, and a small amount of the total data, have been subject to detailed or critical analysis.

For the most part, only those data that have been more fully worked over are considered in the following discussion, which will deal with each of the four major forms.

8.3.2 Cool Temperate Rainforest

Both Burgess (1973) and Porada (1980) have examined growth trends in Negrohead Beech-dominated stands. Basal area is consistently very high - Burgess records BAs from 77 to 97 m^2/ha in virgin stands, and Porada 84 to 111 m^2/ha. These are substantially above the levels found in other rainforest types, and appear to be the highest BAs of any N.S.W. native forest types. Beech commonly contributes half or more of the total BA, with usually more numerous, but generally smaller, stems of a limited range of other tree species making up the rest.

In one series of treatment plots, Burgess records DBH PAIs over 10 years of 0.2 to 0.8cm for Beech, 0.1 to 0.3cm for Coachwood and a little over 0.1cm for other species. These increments, which are averages for all stems of the relevant species in each plot, bore no obvious relationship to the intensity of logging treatment. Growth over 9 years in another series of plots is shown in Table 17. Here again it is difficult to relate growth to treatment: in commenting on this study, Porada notes that the limited response in Coachwood tended to support his observation from Coachwood growth rings that it is rather more uniform in growth than other associated species. Perhaps the most notable features from both these series of plots are the relatively high (for a rainforest species) increments shown by Negrohead Beech, and its ability to maintain these increments on large diameter stems.

Porada, working like Burgess in Mt. Boss S.F., examined growth rings to elucidate growth in these Negrohead Beech-dominated stands. In these high altitude (over 750m) stands, the rings produced in the wood probably approximate annual rings fairly closely, and on this basis Porada demonstrated:

1. The stop/start nature of Beech growth (see Section 8.1).

2. Relatively rapid Beech growth, with one PAI of 0.8cm following release, and a maximum annual increment of 1.1cm; increment after release on all samples averaged 0.6cm.

3. Slower growth in Sassafras, with a maximum increment of 0.4cm and an average of 0.2cm over 155 years (1 sample).

4. Intermediate growth rates for Coachwood: maximum 0.6 and average 0.3cm. Whilst Coachwood showed a marked capacity to persist under extreme competition, to maintain slow growth beneath the canopy for long periods and to respond rapidly when released, it showed (from ring growth) less extreme stop/start growth than the other two species.

Table 17
GROWTH IN COOL TEMPERATE RAINFOREST TREATMENT PLOTS
(Mt. Boss S.F.: from Burgess, 1973)
Period of measurement: 9 years.

Plot	Species	Stems/ha	BA (m^2lha)		Mean DBH (cm)	
			Last Measure	PAI	Last Measure	PAI
A	Coachwood	204	24.6	0.3	36.6	0.4
	Others	74	3.9	0.95	24.6	0.3
B	Coachwood	75	10.6	0.15	38.2	0.4
	Beech	25	19.5	0.4	90.2	1.3
	Others	229	18.8	0.3	28.9	0.3
C	Coachwood	25	3.7	0.5	41.8	0.6
	Beech	99	15.0	0.4	41.9	0.5
	Others	247	21.2	0.2	30.5	0.2

D	Coachwood	55	6.3	0.1	33.9	0.4
	Beech	56	21.4	0.3	65.7	0.6
	Others	142	12.2	0.2	29.2	0.3

Note: **Plot A**: remove all species except Coachwood 22 m^2/ha; to reduce BA to 22 m^2/ha

Plot B: reduce BA as in A, but maintain species proportions;

Plot C: as for A, but seek BA halfway between virgin and 22 m^2/ha;

Plot D: as for B, but BA level as in C.

8.3.3 WarmTemperate Rainforest

(a) Bo Bo Plot

Following selective logging which removed virtually all stems larger than 50cm DBH and which reduced stand BA to about 36 m^2/ha, a growth plot was established in a pure stand of Coachwood near Bo Bo plantation (Wild Cattle Creek S.F.) in 1945. The plot was in a particularly healthy condition, with ample advance growth present and no signs of crown dieback evident by 1957 (and not recorded earlier). After regular remeasurement over 12 years, the growth to date was analysed by Baur (1963). The analysis showed several things:

1. The relatively slow growth of Coachwood: the time for an average stem to grow from 5 to 50cm DBH was estimated to be about 220 years, giving an average PAI of 0.2cm.

2. The great variation in growth rates between trees. Out of 175 trees measured over 12 years, one stem showed no growth and 17 stems grew less than 0.25cm (i.e. 0.02cm a year). At the other extreme one stem grew 7cm (about 0.6cm a year), 8 stems grew more than 5cm (0.4cm a year) and 54 stems grew more than 2.5cm (0.2cm a year).

3. The stems with the better growth rates were distributed through all diameter classes, but were proportionally more numerous in the larger classes.

4. Such stems occurred under good light conditions and had well developed crowns. The more rapidly growing stems of less than 8cm DBH, not yet reaching into the main canopy, were typically associated with a marked opening in the canopy above.

5. Based on the diameter growth of the faster trees in each size class, one tree in seven could grow to 50cm DBH in 130 years, and occasional stems could reach this size in 100 years - always assuming these growth rates could be maintained without impediment.

6. Growth rates tended to diminish over the period of measurement:

Years 1 - 4	Mean DBH PAI (cm)	0.19
5 - 8		0.17
9 - 12		0.14

Over the same period BA increased from 36 to 46 m^2/ha, and the fall in diameter increment was probably associated with increasing competition in the stand. This fall continued in subsequent measurements, and a recalculation by Forrest (1961) indicated that the period to grow the average stem to 50cm had in consequence increased to 256 years.

7. BA PAI over the 12 years was 0.78 m^2/ha/y. Small trees contributed proportionally more to the BA increment, in relation to their contribution to the total BA, than did the larger stems.

8. A harvesting operation to reduce BA to about 33 m^2/ha (believed to be an appropriate lower level for Coachwood type in this district) would, if concentrated solely on the removal of the larger stems, have removed all trees down to about 33cm DBH. About 30 years would then elapse before BA returned to about 45 m^2/ha, and a logging at that time would have removed all stems to about 35cm. (In reality, such logging should retain some of the larger trees and take a proportion of the small trees.)

9. As would be expected, a general relationship between DBH and tree height existed. The graphically harmonised relationship is shown in Table 18. In comparison with a height of about 30m for a tree of 50cm DBH at Bo Bo, a similar study at Moonpar S.F. gave a height of about 33m, presumably reflecting a somewhat better site at Moonpar.

Table 18
COACHWOOD DBH-HEIGHT RELATIONSHIP, BO BO
(from Baur, 1963)

DBH (cm)	Tree Height (m)
5	8.8
10	14.3
20	20.7
30	25.6
40	28.3
50	30.2

10. A volume table for stems over 25cm DBH was developed, and by application to the measurement records suggested a volume of about 200 m^3/ha remaining after the 1945 logging operation, increasing to 265 m^3/ha 12 years later. This suggests a volume increment of over 5 m^3/ha/y, but this would be an inflated figure due to the substantial recruitment of 25cm stems over the period. The suggested harvesting (item B above) was estimated to yield about 140 m^3/ha.

Apart from the decidedly misleading figures provided by Hay (1913), this study appears to have been the first effort to analyse rainforest growth in N.S.W. Although based on only one growth plot, the stand was considered typical of much selectively logged Coachwood type on the eastern Dorrigo Plateau. It highlighted the slow growth of Coachwood, and also the very variable growth and the need for crown freedom if reasonable growth was to be maintained.

(b) Styx River Plot

A growth plot was established in undisturbed Coachwood-dominated rainforest on Styx River S.F. in 1944. Unfortunately not all stems were measured, but remeasurement 14 years later allowed some analysis based on the 104 stems common to both measurements (Forestry Commission of N.S.W. Expt. D1.8). At the second measurement the plot carried an extremely high stocking of 950 stems/ha larger than 10cm DBH and a BA of 74 m^2/ha.

DBH growth generally resembled that at Bo Bo, but was somewhat slower in all size classes, and particularly under 20cm DBH, where average PAI was below 0.1cm/y. The report on the study suggests that this was due to the much denser stocking and to these smaller trees all being below the main canopy; at Bo Bo many similarly sized trees were growing in canopy gaps.

The value of this plot was chiefly to confirm the low diameter increments shown at Bo Bo.

(c) Moonpar Plots

One of the factors that had led to the belief that it was not possible to manage rainforest, and that, in the early years of silvicultural research into the N.S.W. rainforests, was identified as a major issue in any management, was the development of crown dieback (see Section 9.2). This was particularly significant in the temperate rainforest stands, and there was early recognition that the intensity of dieback increased with the intensity of logging. In an effort to examine this further, four plots were established on Moonpar S.F. in 1957 - one retained unlogged, and with logging in the others aiming to remove 20, 40 and 60 per cent of the original BA (about 55 m^2/ha over whole experimental area). The subsequent development of these plots has been reported by McCann (1970), Horne and Gwalter (1987) and Horne and Mackowski (1987).

Major findings from these studies include:

1. Coachwood clearly dominated the original stand, though the larger stems (over 75cm DBH) in the area were mostly of Crabapple. Other larger species present included Sassafras and Silver Sycamore.

2. In the treatment plots as a whole BA reduction was essentially as planned, but in the smaller growth plots it was 0, 25, 65 and 75 per cent reduction respectively.

3. Three years after logging dieback affected 7.5 per cent of trees in the unlogged plot, and 36, 46 and 75 per cent respectively in the logged plots. Coachwood was proportionately more affected than other species.

4. Three phases were recognised during the 27 years following logging:

   i Slow-growth phase. Logging to year 5: Little mortality, but growth slower than in later periods. Nett BA increment of overstorey trees in logged plots averaged O.32m^2/ha/y.

   ii High-mortality phase. Years 5-16: Mortality in logged plots high (21 trees per thousand per year). BA growth of survivors doubled in comparison with phase i, but because of mortality nett BA increment fell to 0.22 m^2/ha/y.

   iii Recovery phase. After year 16: Mortality reduced to a low level (average 2 trees/ 1 000/year); BA increment remained high, with nett BA increment averaging 0.41 m^2/ha/y.

   Horne and Mackowski suggest that the slow-growth phase coincided with the development of a high level of crown dieback; subsequently in the high mortality phase *"it was a forest made up of a small but conspicuous number of dead and dying trees among many other trees that, although still showing the visual symptoms of crown dieback, were by then growing vigorously*."

5. Trees with crowns forming part of the overstorey accounted for 73 per cent of the total pre-logging BA; i.e. about 40 m^2/ha. DBH of about 37cm coincided with stems forming part of the overstorey.

6. Horne and Gwalter estimated that, following the levels of logging (BA removal), periods ranging from under 60 years for the most lightly logged plot to over 100 years for the most heavily logged plot would be needed to restore the overstorey BA to its pre-logging levels. Whilst species composition generally was expected to remain unchanged, the frequency of Coachwood was estimated to increase at the expense of Crabapple and Silver Sycamore. At restoration the largest diameter tree in the overstorey would be about 80cm, in contrast to the pre-logging stand which had 2.3 trees/ha larger than 100cm DBH: a major reason for the size reduction is the predicted increased Coachwood predominance: this species rarely exceeds 90cm DBH.

7. McCann examined the growth during the 11 years following treatment - a period that included the 5 years of the slow-growth phase. Over this period Coachwood averaged 0.25cm a year DBH PAI in the logged plots, against 0.17cm in the unlogged plot. Best growth was in the 40 per cent BA reduction treatment, where DBH PAI was 0.32cm.

8. Coachwood generally showed somewhat faster growth rates than the other species present.

9. Diameter growth showed a fair and direct correlation with annual rainfall.

10. DBH PAI for the other species averaged 0.11cm in the unlogged plot and 0.24cm in the logged plots, with the highest value (0.29cm) in the most heavily logged plot: McCann attributed this difference from Coachwood (PAI in most heavily logged plot only 0.25cm) to the more severe logging putting Coachwood at a competitive disadvantage.

11. In the unlogged plot there was a reasonable and direct correlation between PAI and diameter class, with the larger trees having the greater increments. No such correlation existed in the logged plots where, instead, the smaller stems tended to show the higher increments.

12. The proportion of fast growing trees (over 0.23cm/year) in any size class increased with the intensity of logging. A few trees in all plots showed DBH PAIs in excess of 0.46cm/y, with most (16 per cent of stems) in the 40 per cent BA removal and least (2.4 per cent) in the unlogged plot.

The analyses of these plots have proved particularly useful in revealing the pattern of growth recovery experienced in these Coachwood stands following logging; in allowing modelling to project the restoration of the overstorey; and in demonstrating the growth response in logged stands. Coachwood growth in general was of a similar order to that found in the Bo Bo plot and also in the cool temperate rainforest stands studied by Burgess and Porada (see Section 8.3.2.)

8.3.4 Subtropical Rainforest

Again various growth plots exist in subtropical rainforest stands subjected to various past treatments, but detailed analysis has been largely restricted to a series of treatment plots established on the former Wiangaree S.F. in 1965. Data from these plots have been used in papers by Burgess et al. (1975), Shugart et al. (1980) and Horne and Gwalter (1982). However some information from southern Queensland is also relevant and has been discussed by Dale (1983).

Dale's studies involved stands occurring along the Great Divide generally north from Koreelah S.F. and included both logged and unlogged plots measured over a period of 13 years. Among the more significant of Dale's findings:

1. Diameter increment increased markedly in logged plots, particularly in the smaller size classes: over the 13 years the average DBH PAl of the main commercial species[7] in the logged plots showed an increase of 260 per cent over that in the unlogged plots for stems in the 10-20cm DBH class, but the increase dropped to only 9 per cent for trees in the 50-60cm class. In virgin stands the DBH PAl of the main commercial species increased from about 0.1cm/y in the 10-20cm DBH class to about 0.30 to 0.35cm at about 50-60cm; beyond this diameter the increment tended to plateau, possibly declining in very large trees. By comparison PAl in the logged plots was at about 0.36cm/y through all sizes up to 60m. In commenting on the response of the 10-20cm class, Dale notes that individual crowns in this class had entered the lower stratum of the canopy, and were best able to benefit from competition reduction resulting from the partial opening of the canopy.

2. BA in the unlogged plots ranged from 53 to 58 m^2/ha over the 13 years of measurement. In the logged stand BA had been reduced to 28 m^2/ha and increased to 42 m^2/ha over the 13 years - an increment of about 1 m^2/ha/y.

3. Smaller stems showed proportionately greater BA increment than the larger stems; and about 60 per cent of the BA increment was contributed by the main commercial species.

4. Dale’s study did not include volume estimates, but based on the BA increment of the main species he suggests that gross volume increment should “substantially” exceed the figure of 1-3 m^3/ha/y that had been suggested as the average sustained merchantable volume production of similar stands by Richards (1976).

The original intent of the Wiangaree plots was to examine the response of local subtropical rainforest to a variety of treatment schedules, including a number in use overseas. For various reasons the full sequence of treatments was not carried through, but the initial work resulted in a series of plots logged to different intensities, resulting in the removal of from 26 to 77 per cent of the pine-logging BA, together with 3 unlogged plots. Original BA averaged about 45 m^2/ha (range 37-58 between plots), with an average of 284 stems/ha larger than 20cm DBH (range 227-363). Some 44 species larger than 20cm DBH occurred, with 9 of these contributing more than two thirds of total BA and of stems larger than 20cm: these species were, in descending order of frequency, Corkwood, the two Booyongs, Red Carabeen, Sassafras, Yellow Carabeen, Olivers Sassafras, Prickly Ash and Black Apple. Further details of the stand are given by Burgess et al. (1975).

The early analysis by Burgess and his colleagues, after 7 years, demonstrated again the growth response following logging, with trees in treated plots averaging about 0.3cm DBH PAl, compared with 0.1cm for the unlogged plots. Olivers Sassafras, with individual PAIs of 1.2 to 1.5cm, showed fastest growth.

Shugart et al. (1980) used later data from these plots both in developing and demonstrating a computer model for the development of a patch of subtropical rainforest. Whilst the model appears to provide an unexpectedly realistic simulation of the way such a stand grows and responds to disturbance, much of data used seems highly theoretical or extrapolated from rather weak bases.

Horne and Gwalter (1982) presented an innovative paper looking primarily at the restoration of the overstorey following logging: the overstorey was considered to consist of trees of over 46cm DBH, and based on the average of the unlogged plots the overstorey was restored to its pre-logging level when the BA of the overstorey trees reached 33 m^2/ha.

[7] The “main commercial species” in this study included Black Booyong, Bollywood, Giant Water Gum, Yellow Carabeen, Pigeonberry Ash, Prickly Ash, Sassafras, Olivers Sassafras, Socketwood and Rosewood.

Table 19

DBH GROWTH IN LOGGED AND UNLOGGED SUBTROPICAL RAINFOREST
(from Horne and Gwalter, 1982)

Species	Unlogged			Logged		
	Mean DBH (cm)	No. Trees	DBH PAI (cm/y)	Mean DBH (cm)	No. Trees	DBH PAI (cm/y)
Corkwood	34.5	106	0.16	34.2	68	0.24
Sassafras	19.9	54	0.08	28.0	48	0.31
White Booyong	41.3	33	0.15	37.8	28	0.36
Red Carabeen	47.4	33	0.21	36.9	42	0.26
Prickly Ash	33.6	25	0.22	31.8	13	0.44
Slack Apple	37.0	15	0.06	26.4	13	0.16
Yellow Carabeen	45.7	14	0.14	44.1	28	0.28
Olivers Sassafras	31.1	12	0.30	29.9	27	0.53
Black Booyong	25.9	5	0.11	54.1	16	0.15

Once more the improved growth obtained in the logged plots was evident. Table 19 shows the average response for 9 major overstorey species, and Table 20, for these same species together, shows the variation in response with size class.

Table 20

DBH GROWTH OF MAJOR OVERSTOREY SPECIES BY SIZE CLASSES
(from Horne and Gwalter, 1982)

DBHClass (cm)	DBH PAI, 14 years (cm/yr)	
	Unlogged	Logged
9.5 - 20.4	0.08	0.27
20.5 - 30.4	0.18	0.39
30.4 - 46.4	0.18	0.33
46.5 - 60.4	0.20	0.27
60.5 +	0.17	0.10
Weighted Mean	**0.15**	**0.31**

Horne and Gwalter note that Olivers Sassafras was the fastest growing species in both logged and unlogged stands, and together with Sassafras and Prickly Ash showed the greatest DBH growth increase following logging. The drop in increment in the 60.5cm+ trees after logging can be attributed to such trees usually being ones considered unsuitable for commercial use, often being overmature and in poor health. The retention of such stems can be rationalised on environmental grounds, but undoubtedly represents a cost in terms of the growth of usable wood.

Although Table 20 shows some relationship between diameter class and increment, Horne and Gwalter observe that the growth rate of individual trees bears little or no relationship to the trees' diameter. Although not followed up in this study, it would be expected that a relationship would exist between the growth rate and both the health of the trees' crowns and their position in relation to canopy gaps.

The growth rates determined by Horne and Gwalter correspond closely with those in the study of Dale (1983)

Table 21

FASTEST DBH GROWTH IN SUBTROPICAL RAINFOREST
(from Mackowski, 1980)
DBH PAI: Fastest stem in class

DBH Class	10-30 cm	30-50 cm	50-80 cm	80cm +
Corkwood	1.60 (117)	0.75 (61)	0.75 (34)	0.55(2)
Yellow Carabeen	0.85 (25)	1.75 (36)	0.65 (13)	0.00(8)
Sassafras	1.95 (91)	0.75 (19)	0.30 (2)	-
Olivers Sassafras	1.85 (44)	0.90 (17)	0.70 (3)	-
White Booyong	2.50 (55)	1.55 (25)	1.20 (18)	0.00(7)
Black Booyong	0.70 (6)	0.90 (2)	0.60 (2)	0.00(1)
Prickly Ash	1.00 (21)	1.10 (17)	0.65 (8)	-
Red Carabeen	0.90 (41)	1.25 (31)	1.20 (20)	0.00(3)
Black Apple	0.50 (16)	0.44 (16)	1.55 (4)	-

(Bracketed figures indicate number of stems in class)

Using this same Wiangaree data, Mackowski (1980) records the best diameter PAIs for the 9 major species. These are shown in Table 21, and in contrast with the figures in Table 20 they suggest that, under the conditions of most favourable growth, the smaller stems will, not unexpectedly, show the fastest growth rates.

In contrast with their study of Coachwood growth at Moonpar S.F. (see Section 8.3.3), Borne and Gwalter recorded little crown dieback in the Wiangaree stand, and there was no slow-growth phase, nor any apparent high-mortality phase. Time for the restoration of the complete canopy was estimated to be between 30 and 60 years where 33 per cent of the overstorey BA was removed in logging; under 100 years where half the BA was removed; and from about 100 to 220 years where 78 per cent of the BA was removed. Some shift in the relative frequency of the major overstorey species was expected as a result of logging, notably with some decrease in the proportion of Corkwood and an increase in the faster-growing Sassafras and Olivers Sassafras: a result also predicted in the study by Shugart and his colleagues.

8.3.5 Dry Rainforest

Growth in various plots established in dry rainforest (typically Hoop Pine type) stands was briefly reviewed by Forrest (1962): at the time many of the plots involved were of relatively recent origin, and no subsequent analysis of the data has been carried out.

Much of the information related to Hoop Pine growth, including well established trees standing above the typically dense understorey: such stems (average DBH about 50cm) may show DBH PAIs of up to 1cm a year. From these data Forrest suggested that the following increments would not be unrealistic for final crop trees:

DBH Class (cm)	PAI (cm)
-10	0.38
10-25	0.51
25-40	0.63
40-60	0.76
60-70	0.63

Data for other species were most limited, but the following indicative increments were suggested:

Species	DBH range (cm)	PAI (cm/y)
Crows Ash	40-70	0.14-0.45
Yellowwood	12	0.26
Ivorywood	10-35	0.05-0.06
Yellow Boxwood	25	0.02

Whilst the larger overstorey trees, such as the **Flindersia** spp. appear to show growth rates comparable with those in other rainforest types, the PAI of the species more typically associated with the understorey seems extremely slow.

As with the other rainforest types, a more critical review of the growth data relating to dry rainforest is long overdue.

8.3.6 Patterns in Rainforest Growth

The very patchy information outlined above nonetheless allows some general patterns in the growth of rainforest trees and stands to be discerned:

1. There is considerable range in the growth rates both of different species and of individuals of any particular species.

2. The average growth rate of smaller stems in undisturbed rainforest is slow, but increases as the stems enter and become part of the overstorey.

3. These stems mostly retain the capacity to increase their growth rate markedly if the stand is opened up and conditions improve.

4. The smaller stems inevitably benefit from such improved conditions more than the larger ones.

5. A few species have the capacity to maintain diameter PAIs of 1cm a year or more, but most species have rates below this, even under the most favourable conditions, with rates of about 0.2 to 0.4cm/y fairly characteristic in logged stands.

6. Although not included in the preceding review many of the pioneer species have particularly fast growth rates while developing in large gaps or openings, and the early rates shown in Table 13 for White Basswood and Red Ash are probably quite applicable to naturally regenerated trees. (See also White Basswood in Table 10, from a marginal (cold) site.) Such species are, however, usually highly intolerant of competition.

7. The little information on volume growth suggests gross increments well in excess of 1 m^3/ha/y, but in the absence of further data yield expectations should not be pitched above 1 m^3/ha.

8.4 Size, Longevity and Mortality

Details of the size of some of the more outstanding specimens of rainforest trees recorded from N.S.W. are given in Appendix 10. This does not include all the trees maintained on the Forestry Commission's register of large trees, but it includes the larger specimens recorded generally, and also the largest specimens of species of commercial interest. In many cases larger specimens undoubtedly exist, but have not to date been measured.

Although there are some notable exceptions, most of the species do not attain massive size, and if strangler Figs and a few other species are excluded, few N.S.W. rainforest species exceed 1 to 1.5m in DBH: as noted in Appendix 2, the overall impression in rainforest tends to be of tall, slender trees. Nonetheless the sizes listed in Appendix 10 are in all but a few cases larger, and often substantially larger, than the maximum sizes (DMAX and HMAX) used by Shugart et al. (1980).

The ages of these larger trees are rarely known. The calculations for Coachwood by Baur (1963) suggest an age of about 250 years for a tree of 50m, but the variation in growth rates means that a tree might reach this size in less than half that period, or possibly in more than twice it. By ring count Porada (1980) dated what was apparently a 31cm (underbark) Sassafras at 155 years, and another ring count from Wauchope district gave an age of 196 years for a 50cm Negrohead Beech.

Carbon dating of several trees from the Terania Creek area gave the following ages:

Species	Diameter (cm)	Age (years)
White Booyong	95	850 BC
Red Carabeen	62	Under 100
Crows Ash	?	350

Brush Box trees, standing above rainforest in the same area, had ages up to 1 300 years for a 165cm diameter tree - but a Brush Box from Wauchope registered only 350 years for a stem of 190cm diameter: the variable growth rates obviously apply not only to rainforest trees. A radio report in the 1950s attributed an age of 1 800 years, presumably determined by ring count, to a large Red Cedar felled in the Ewingar area.

Little pattern is apparent from these almost random figures. For a large tree, like Red Cedar, with light, durable timber, a lengthy life expectancy is not unrealistic, and the unauthenticated radio report might indeed have been in the right order. On the other hand numerous Figs, planted in parks only a century or so ago, are now massive trees: one at Narrandera, probably about 120 years old, has a diameter above buttress of 2.06m and a crown diameter of 55m.

The fast pioneer species, such as Red Ash and the Basswoods, probably rarely exceed about 50 years, through Giant Stinger, which can develop into one of the larger rainforest trees, may have a longevity of 2 centuries or more. For a large number of trees of the rainforest, including Coachwood and Hoop Pine, the maximum life expectancy is possibly in the order of 500 years. Others, including possibly Negrohead Beech[8] and, from the Terania Creek figures the Booyongs, may approach 1 000 years, and probably only a few, but including Red Cedar, White Beech and Rosewood, exceed a millennium in their maximum life spans. These, it should be noted, are maximum figures; most stems of these species, including very large ones, will be substantially less.

Closely related to growth and longevity is the mortality occurring in the forest. Mortality as a result of logging will be examined in Section 9, but a brief comment on mortality in natural stands is warranted here.

As previously noted (Section 8.1), over a period growth in the virgin rainforest is balanced by mortality, but the process is hardly regular: periods of growth, with an increase in stocking and BA, will be followed by some event causing a number of stems to die, so that BA plotted over time shows a sawtooth formation, oscillating about some mean value characteristic of the site (Horne and Gwalter, 1982). Horne and Gwalter comment that, as tree mortality is a sporadic occurrence, the 14 years measurement period available to them was inadequate for a survey of the phenomenon. It is hard to disagree.

[8] The popular accounts attributing very great ages (up to 10 000 years) for Negrohead Beech in the McPherson Range area have been discussed in Section 6.1. Ironically, and because of the suckering habit of Beech, it is likely that many plants of this species in the McPherson Range are clones of seedlings that did in fact appear over a thousand years ago, though the current stems are themselves much younger.

The information that is available suggests rather low average mortality rates, as might be expected to balance the rather low growth rates:

- In the Bo Bo growth plot (not virgin, and therefore probably a greater likelihood of survival), 0.32 per cent of measured trees per year died over a period of 12 years. All of these were under 10cm DBH.

- Over 14 years in the Coachwood plot at Styx River S.F, mortality averaged 0.51 per cent per year (0.33 per cent for Coachwood).

- McCann (1970) records an average annual BA mortality of 0.095 per cent in the Moonpar control plot, represented by 2 stems/ha/y, over 11 years.

- A higher value was recorded by Burgess (1973) for cool temperate rainforest at Mt. Boss S.F., where 2.5 per cent per year of Coachwood BA died over a period of 10 years.

- A BA mortality rate of 0.33 per cent a year is given by Dale (1983) for subtropical rainforest in southern Queensland. Most of this appears to have been attributed to small, non-commercial species.

While these values (except for the Mt. Boss site) are low, a drought or a period of strong winds could produce a much higher value.

9. DAMAGE TO OLDER STANDS

9.1 Damage Agencies

The continued existence of rainforest on the Australian continent for close to 100 million years suggests a certain degree of resilience in the rainforest communities, with an ability to rebound from the numerous damage agencies that undoubtedly can affect the stands.

Most of these agencies have already been mentioned, and will be touched on very briefly here; rather greater attention will be paid to crown dieback and to logging damage.

Climatic influences, as well as generally determining both the occurrence and limits of rainforest, can cause damage in various ways. Strong winds represent probably the major natural cause for mortality of large trees, and occasionally substantial areas will be effectively felled by a cyclonic storm (see Section 2.4.2). Repeated gales may result in continual disturbance and the formation of stands with no potential for commercial wood production, though more usually the blowing over of an old tree, and the resultant chablis, is a vital part in maintaining a healthily dynamic rainforest stand.

At higher altitudes frost can hinder the reestablishment of rainforest in openings of any size. In the normal cycle of the rainforest this is probably no problem, but where a large opening has been created, as perhaps by cyclone and then subsequent fire, regrowth of the rainforest may be long delayed (see Section 2.6).

Fire can severely damage or destroy rainforest (see Section 2.4.6). Normally undisturbed rainforest will not burn, but under extreme drought conditions, or more commonly after significant stand opening from storm or logging, so that the microclimate is altered and a heavy fuel load is on the ground, fire may burn through the stand. Particularly where the debris is plentiful the fire may be extremely destructive so that most trees are killed, and repeated fires may then convert the area from rainforest to eucalypt forest, or occasionally to grassland. However fire in less disturbed rainforest is generally less damaging, though smaller trees (particularly if thin-barked) and undergrowth may be killed, along with some larger stems where branch material or other slow-burning debris has piled up around their bases. Little disturbed rainforest, however, more usually serves as an effective firebreak.

Some of the heavier rainforest soils, especially those derived from basalt, can be subject to **movement** on steep slopes, and in such situations it is not unusual to find stands of trees with bows in their lower stems resulting from past soil creep and the subsequent resumption of vertical growth by the affected trees (e.g. parts of Mallanganee F.R.). Sometimes significant **landslides** may occur on the steeper slopes. One such slip, covering some hectares of virgin subtropical rainforest in the former Gradys Creek F.R. (former Wiangaree S.F.) and occurring about 1977, led one prominent environmental activist, who had sighted it from an aircraft, to accuse the Forestry Commission of practising clearfelling in the Reserve! Another slip, of much earlier origin, appears to have been responsible for the creation of Burraga Swamp, in the cool temperate rainforest on a former part of Chichester S.F.

Evolution has produced a great number of organisms that depend upon the rainforest plants for their existence. Some are browsers, though these are rarely significant damage agencies in the mixed rainforest stands. Nonetheless Lawman (1985) has found that insect herbivore in the canopy of subtropical rainforest results in an annual loss of about 15 per cent of the leaf area. More important are the numerous wood-destroying **insects** and **fungi**. While most of these are saprophytes, and play an important part in the breakdown of litter, some speedily attack logs on the ground, necessitating rapid extraction after felling, and many can enter bark wounds to cause damage to growing trees. Inevitably the risk of this damage increases after logging.

In one area of North Queens land, *Phytophthora cinnamomi* has been identified as a cause of localised tree deaths in rainforest.

Mistletoe, though common in many rainforest stands, does not appear to be a significant damage agency. Possibly more important are vines, which interfere with the growth of trees when their crowns are in competition, which at times can malform stems, and which may lace adjoining tree crowns together, creating problems (and dangers) in felling; **epiphytes**, which occasionally develop as huge masses whose weight can cause large branches to break; and most of all **strangling Figs** which can prematurely kill large trees and whose crowns, often of immense size, must have a most restrictive effect on neighbouring trees. Despite their biological interest and their importance as a food source for much wildlife, too many Figs are bad news in areas being managed for timber. Trials on Toonumbar S.F. in the 1950s showed that strangling Figs could be fairly readily killed by applying various plant poisons to their aerial roots (Forrest, 1963).

9.2 Crown Dieback

Crown dieback has proved a serious problem in temperate rainforest stands, and to a less extent in some of the higher altitude subtropical rainforests. It is not normally of significance in dry rainforests or lower altitude subtropical rainforest, but it is of particular concern in stands carrying Coachwood.

Dieback has been described as *"the general shrinking of tree crowns away from branch tips towards the trunk, leaving dead branches and twig ends exposed*" (Forestry Commission of N.S.W., 1981). It was closely examined in environmental impact studies concerning rainforest logging in the Hastings catchment (ibid), with the main findings being stated as follows

1. There was considerable crown dieback in the unlogged stands. This dieback, however, was not readily apparent to an observer because of the normally close proximity of the tree crowns. The dieback in the unlogged overstorey was variable and averaged 20% of the total trees for the unlogged stands, but only 2% showed severe dieback.

2. Following logging, areas in which dieback was present were generally extended, and the severity of dieback on individual trees increased in the short term. However, viewed over a longer time scale, forest assessment has shown that there were low levels of dieback in forests logged over 13 years ago, as compared with

areas logged more recently. For example, the incidence of dieback in forests logged less than 9 years ago averaged 42 per cent of the residual overstorey trees, with 10 per cent showing severe dieback symptoms. In comparison, assessment of forests logged more than 13 years ago showed that 9 per cent of the overstorey trees had symptoms of dieback, but that no trees showed severe dieback symptoms.

3. In order to determine whether or not dieback ultimately causes mortality of affected trees, the number of standing dead trees were counted for all stands sampled. Within the unlogged forest, an average of three dead trees/ha were recorded in comparison to two dead trees/ha in the logged stands. This is not sufficient evidence to deny that mortality, as a result of dieback, does occur following logging. Trees susceptible to dieback may have been removed during logging. Alternatively, mortality may be attributable to causes other than dieback. However, the data do suggest that mortality, as a result of dieback in logged stands, may be considerably less than the visual impact suggests.

The incidence of dieback is variable, sometimes being barely evident after heavy logging and elsewhere severe after only moderate disturbance. Nevertheless in broad terms it tends to occur in proportion to the degree of disturbance.

In early reports on the Moonpar treatment plots [see Section 8.3.3 (c)] it was concluded that Coachwood was particularly susceptible, that dieback had greater incidence in the larger size classes, and that its incidence increased with increasing canopy and site disturbance. Some trees undoubtedly die, though as noted above these often may be ones where other causes, such as logging damage, may also be major contributing causes of mortality. However most trees affected by dieback ultimately recover, with the shrunken crown firming up and then expanding. Where the crown was only lightly affected, so that only small branches die, the dead branches soon fall and the visual signs of dieback disappear; with heavier damage larger branches will die, and these may remain evident for a longer period. Thus, after a period when dieback is very evident, its symptoms become progressively less as the dead material in the crowns falls and decays.

This progression in dieback symptoms is paralleled by the growth response in logged stands, as reported by Borne and Mackowski (1987) from Moonpar S.F. There, logging was followed by about 5 years of slow growth, coinciding with the onset of dieback and its peak development; then followed a period of relatively high mortality, as the more severely affected trees succumbed, but at the same time trees which were now recovering, even though their crowns still showed signs of dieback, assumed vigorous growth. Finally, tree mortality returned to a low level and stand growth continued at (for these stands) a high level, with overstorey BA growth of 0.41 m^2/ha/y, compared with 0.26 m^2/ha/y in the unlogged plot.

In cool temperate rainforest stands, Porada (1980) found that Negrohead Beech was even more susceptible to dieback than Coachwood. In a series of plots, mostly logged, 21 per cent of all Beech stems showed dieback, as against about 8 per cent for Coachwood and 5 per cent for both Sassafras and Prickly Ash.

The causes of dieback are not known, but appear to be essentially exposure effects as crowns, previously sheltered by their neighbours, are suddenly exposed to increased insolation and wind, and to reduced humidity levels. There is probably some similarity with what happens when a seedling, raised in a sheltered, shaded nursery bed, is suddenly transferred to open conditions. Certainly there can be a considerable difference between the leaves in naturally exposed parts of the crown of a rainforest tree and those developing in the sheltered conditions of the lower crown, which can be exposed by logging or other disturbance. Thus Baur (1968, p.70) notes that shade leaves of Coachwood may have up to four times the surface area of sun leaves from the same tree; the sun leaves also tended to be much more coriaceous. Such shade leaves would not be well adapted to withstand sudden exposure.

However the causes appear rather more complex than this, Porada noting that the incidence in cool temperate rainforest was most severe on poor, shallow, yellow-grey podsolic soils, and he suggested that dieback may be accentuated by microclimate alteration, a high degree of disturbance to the soil surface, soil compaction, physical damage to residual trees and possibly invasion of pioneer and weed species. Once again, this is a field where further study is required.

These various studies suggest that crown dieback, though undoubtedly a significant problem in the logging of temperate rainforest is a less serious problem than was earlier believed and than its initial visual symptoms suggest. Nevertheless anything that can be done to reduce its incidence should be done and this basically amounts to keeping stand disturbance to a relatively low level by selective operations, and to exercising considerable care in logging, since other stem damage appears to exacerbate its effects and probably increases mortality.

9.3 Logging Damage

Besides its influence on the development of dieback in the temperate rainforest stands, logging can lead to physical damage to the remaining trees in the stand (and also to regeneration and advance growth: see Section 6.5).

The most detailed study on the damage resulting from rainforest logging in N.S.W. was reported by Burgess et al. (1975) for subtropical rainforest in the Wiangaree treatment plots (see Section 8.3.4). As logging in each block was completed, the damage status of each stem was assessed into one of 12 categories; where damage occurred in two categories, the more serious was recorded. These categories were:

1. No damage - good form
2. No damage - bad form.
3. Bark damage - less than 0.3 lineal metres of wood surface showing.
4. Bark damage - between 0.3m and 1.5m of wood surface showing.
5. Bark damage - between 1.5m and 3m of wood surface showing.
6. Bark damage - between 3m and 6m of wood surface showing.
7. Bark damage - over 6m of wood surface showing.
8. Crown damage - less than 25% of crown damaged.
9. Crown damage - 25-50% of crown damaged.
10. Crown damage - 50-75% of crown damaged.
11. Crown damage - 75-99% of crown damaged.
12. Broken off below crown.

Efforts were also made to assess whether the damage was caused by felling or by tractors during extraction. A summarised indication of the results is given in Table 22:

Table 22

DAMAGE RESULTING FROM LOGGING - WIANGAREE
(from Burgess et al., 1975)

Block	% BA	Damage Classes % BA retaining					Cause	
		Nil (1-2)	Slight Bark (3-4)	Severe Bark (5-7)	Slight Crown (8-9)	Severe Crown (10-12)	Felling	Tractor
1	32	34	18	6	17	25	55	45
5	56	36	22	7	10	24	46	54
6	36	57	16	5	11	11	62	38
7	26	41	20	9	10	20	48	52
8	47	37	21	12	10	20	56	44

(Damage categories 1-12 as described in text)

In general over half the BA remaining had been damaged to some extent, and the authors note that this was not thought to be exceptional as the logging operators were very experienced and were probably rather more careful than normal in this experimental area. Bark categories 5-7 and crown categories 10-12 were considered to represent severe damage, believed likely to lead to protracted loss of growth or even death, and this basis about a third of the remaining stand had received severe damage, except in treatment 6 (a group selection treatment) where the severe damage was reduced to 16 per cent. Felling and extraction each accounted for about half the damage.

The longer-term effects of this damage have yet to be assessed. Horne and Gwalter (1987), in comparing this study with the one in warm temperate rainforest at Moonpar, note that at Wiangaree there was "no evidence of lesser growth or greater mortality following logging", though it is inevitable that severe crown damage, at least, must temporarily reduce the growth of the affected stem, while severe bark damage renders the trees more liable to fungal or borer attack. Against this, stands that have been relogged (usually following a relatively light first logging) do not appear to have shown significantly higher levels of log defect than unlogged stands, and the effects are probably much less serious than was at first suspected.

McCann (1970) notes that the extent of butt damage after logging was recorded in the warm temperate rainforest plots at Moonpar S.F. Here the damage (expressed as a percentage of the number of trees damaged) seemed fairly directly related to the extent of logging:

Percent BA removed	0	16	43	60
Percent trees with butt damage	0	3	8	23

Again the long-term effects of this damage have not been, but should be, assessed.

Some damage from logging operations must always be expected, and it undoubtedly will have some, though on the evidence to date not major, effect on growth, timber quality and mortality of remaining trees. Anything that can be done to minimise the extent of this damage represents a positive contribution to the management of the stand.

10. SILVICULTURAL TREATMENTS

10.1 Explanation

Because these Notes are intended to summarise experience and knowledge about the silvicultural treatment of rainforest in N.S.W., this brief section is included to cover information about some of the main forms of treatment that have been applied to the State's rainforests, and to serve as an introduction to the equally brief consideration of the environmental effects of these treatments in Section 11.

10.2 Subtropical Rainforest

Prior to World War II logging in the subtropical rainforests was generally fairly selective, but during and after the war markets for most species developed, and there was potential for very intensive logging. Where the longer-term management intent was to convert the stands to Hoop Pine plantation (e.g. the Coxs Road area of Toonumbar S.F.), this intensive logging was realised.

As the capacity for the stands to be managed as rainforest was realised, operations again became more selective, and in the former Casino Forestry Region (notably the current Urbenville Forestry District) a fairly routine treatment, aiming at retaining a 50 per cent canopy cover, was introduced. This treatment was described in a background paper dealing with management policy in the Border Ranges area (Interdepartmental Committee, 1977), and the following description is taken largely from this paper; the prescriptions for the treatment were also given in the 1979 management plan for the Kyogle M.A.

Before logging took place in the subtropical rainforest stands, all trees intended for removal were marked by experienced Forestry Commission staff, either a local forester or more usually a forest foreman with long experience in working in these forests.

The marking was carried out with several requirements in mind

- At the conclusion of logging the upper forest storeys should still maintain at least a 50 per cent canopy cover. In places where the upper canopy was already sparse, e.g. as a result of storm damage or earlier logging, from which the canopy had not yet fully recovered, few or no trees were marked for removal.

- Allowance was made for the fact that there would inevitably be some damage to remaining trees during felling. Marking was somewhat lighter than was theoretically necessary to maintain a 50 per cent canopy cover for this reason.

- The canopy trees remaining after logging should, as far as practicable, be evenly dispersed. Efforts were deliberately made to avoid removing a number of trees growing close together, since this would result in the creation of large openings in the canopy.

The species marked should as far as practicable constitute a representative sample of the composition of the local stand, but with the less common species in general being retained in the forest. There was also a tendency to favour the retention of trees such as Pigeonberry Ash, known to be important sources of food for birds.

Particularly large and heavy crowned trees, such as many Yellow Carabeens, tended to create excessively large openings when they were felled, as a result both of the spread of the tree's crown and of the damage such a large crown will cause to neighbouring stems as it falls, and there was an increasing tendency to retain such trees.

In any areas where there was an overstorey component of Hoop Pine, any Hoop Pine stems considered capable of making significant further growth would be retained for a later cutting cycle.

It was for a period also usual in the former Kyogle M.A. for Commission staff to indicate, during their marking, the direction in which individual trees should be felled with a view to minimising any damage to the remaining stand.

The operations were accompanied by standard environmental protection measures (e.g. erosion mitigation conditions), and resulted in stands where significant areas received no logging.

Profile diagrams of a transect (7.5m wide) in one of the Wiangaree treatment plots, before and after receiving a somewhat heavier version of the routine practice, was given by Burgess at al. (1975) and is reproduced as Figure 4.

Similar treatment was applied to the subtropical rainforest in other North Coast districts.

10.3 Dry Rainforest

Most accessible stands of dry rainforest of commercial quality (i.e. Hoop Pine type) had been well and truly logged for their main commercial species before serious thought was given to their long-term management. It was in these stands that enrichment planting with Hoop Pine occurred in the 1920s and ‘30s. By World War II the dry rainforest stands on accessible State Forest usually carried little in the way of merchantable timber, though some Hoop Pine, Crows Ash and other stems that were submerchantable at the original logging may have grown on to merchantable size in the meantime, and the understorey often had many specialty species, such as Ivorywood and Yellow Boxwood, still present: many such stems were salvaged in later plantation clearing at Toonumbar and Mt. Pikapene S.Fs.

Hoop Pine regrowth was often scattered though the stands, sometimes in considerable quantity, as at Mebbin S.F. and in the stand treated for its dense Hoop Pine on Unumgar S.F. (see Section 8.2). Snig tracks and old openings resulting from past logging tended to remain evident in these drier stands longer than in other rainforest types, and also unlike other rainforest types lantana often became established in and persisted in these local openings.

Some harvesting has continued in these stands, usually for the thinning of Hoop Pine or to obtain some of the surviving larger trees: the operations have always been highly selective. Such logging, during the late 1950s and on into the 1970s, was often followed by enrichment with Hoop Pine in sites where the Pine regeneration was deficient: parts of Unumgar and Koreelah S.Fs were treated in this way. Planting was confined to the more open patches, where the seedlings could develop for a lengthy period without impediment from the overhead canopy.

Although never attempted, many of the non-commercial areas of dry rainforest, e.g. in the Gloucester district, would seem to lend themselves for enrichment with Hoop Pine and other commercial species if some longer term production from these stands were intended.

10.4 Warm Temperate Rainforest

Because of their usual domination by the relatively valuable species, Coachwood, there has been a tendency for warm temperate rainforest to have been logged more heavily than other rainforest types in N.S.W.: see Tables 5 and 6.

Where selective logging was practised, with a limit on the extent of stand opening, the stands are typically healthy and well stocked with advance growth: the Bo Bo growth plot [see Section 8.3.3 (a)] and the Moonpar plots [Section 8.3.3 (b)] provide good examples of stands of this type. Fig. 5 (from McCann, 1970) is the profile diagram of a transect through the 40 per cent BA removal treatment at Moonpar, about 12 years after treatment: McCann notes that the main canopy is discontinuous, and within the gaps a lower canopy stratum does not necessarily occur, although fairly dense regeneration under 18m high may be present (and by 1986 certainly was). Some symptoms of crown dieback still existed at the time of McCann’s study.

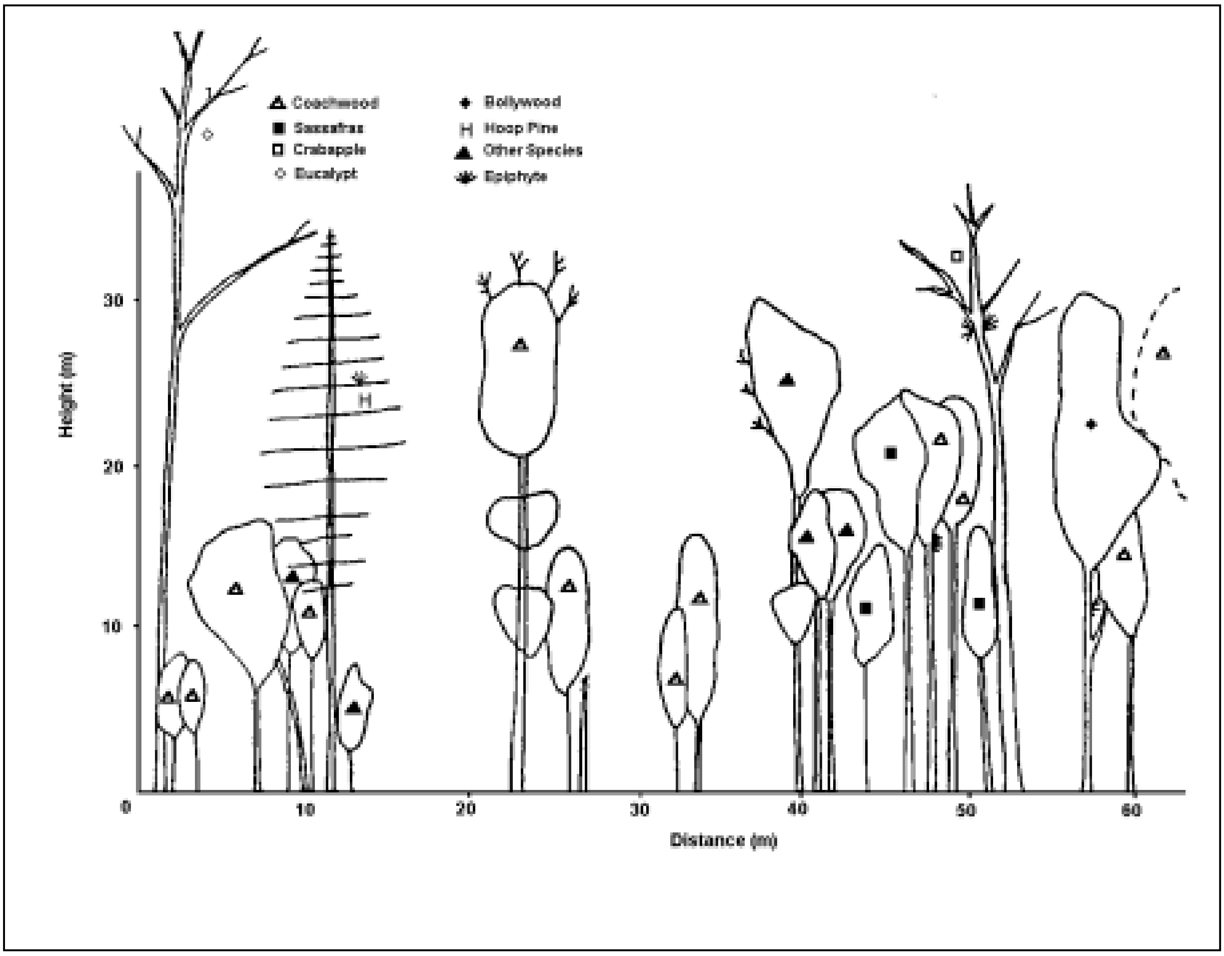


Figure 5: Profile Diagram of Warm Temperate Rainforest
(40 percent BA reduction: 12 years after treatment. From McCann 1970)

Most logging was much heavier than this, in both the Dorrigo and Hastings centres of warm temperate rainforest occurrence. At Dorrigo (Wild Cattle Creek S.F.) some such stands were subsequently converted to eucalypt plantation, until the amount of useful regrowth (particularly Coachwood and Hoop Pine) being destroyed in the process was realised. Often the logging was effectively clearfelling, or perhaps rather the final felling in a uniform system, releasing the regrowth already present in the understorey. Generally such logged stands are well stocked with useful regrowth, though old log dumps and other compacted sites frequently develop as Tickbush thickets, with tree regeneration slow to appear. These stands are developing back towards rainforest structure, though in most cases a long period must elapse before they again can produce logs. An exception to this occurs in some of the older, heavily logged stands on the eastern Dorrigo, where the Hoop Pine component, now present as an overstorey above the Coachwood and other species, is approaching the stage where it would benefit from a commercial thinning.

It was long appreciated that, although this heavy logging treatment did not destroy the rainforest, it was environmentally undesirable, and in the environmental impact statement on rainforest logging in the Hastings district, the Forestry Commission of N.S.W. (1981) proposed that future logging should retain sufficient trees to provide a canopy cover at least 50 per cent (30 per cent in the essentially subtropical “mixed” rainforest) (see also 1978 management plan for the Wauchope M.A., section 2.3.3). This treatment, which resembled that applied in the subtropical rainforest stands further north, was only applied for a short while before routine rainforest logging in the area was phased out.

10.5 Cool Temperate Rainforest

Negrohead Beech has never been a particularly favoured timber species, despite considerable efforts by the Forestry Commission in the 1960s to develop utilisation methods for it and to assist in its marketing. The tree is often faulty, and logging was typically selective. At Mt. Boss S.F. in the 1960s a prescription based on the retention of 50 per cent canopy was introduced, with both Beech and the associated understorey species (Coachwood, Sassafras, Prickly Ash) being harvested. Burgess (1973) reports that this treatment in practice removed about 20-30 per cent of the BA, mostly as Beech.

Beech continued to be somewhat less than popular with industry as a timber, and combined with the emotional aura that gathered around this “Antarctic” species this led the Commission to alter its harvesting prescriptions for the Wauchope area. As described in the 1978 management plan for the Wauchope M.A., and as rephrased by Porada (1980), these later prescriptions required that:

- no Beech be removed unless removal is required for road construction purposes or the tree is damaged as a consequence of roading or logging;
- sufficient trees be retained to provide a canopy cover of at least 50 per cent;
- trees to be removed are marked by the forester or his deputy;
- trees judged incapable of yielding quota logs at the time of logging shall be retained. Where these retained trees will not provide the canopy cover prescribed, the additional trees shall generally be:
    - smaller diameter trees with future realisable growth potential and lowest present value, and/or
    - trees, the felling of which would cause excessive damage to the remaining stand;
- as far as practicable log dumps should be located outside the Beech forest; and
- tree marking and supervision shall be directed towards minimising damage to the residual stand.

Figure 6, redrawn from Porada’s thesis, portrays a transect through a stand logged in this way two years previously. The logging removed some 80 stems/ha, with a total BA of about 20 m^2/ha; remaining BA was still high, at over 100 m^2/ha.

It is interesting to note that not dissimilar operations had occurred much earlier. During World War II operations in cool temperate rainforest along Paddys Creek on Wandella S.F. had harvested the Sassafras from beneath the associated Lilly Pilly and Pinkwood; today the stands are dominated by the unlogged species, with much coppice regrowth of Sassafras below. Elsewhere on the South Coast Pinkwood was not uncommonly harvested: its properties in many respects resemble those of Coachwood.

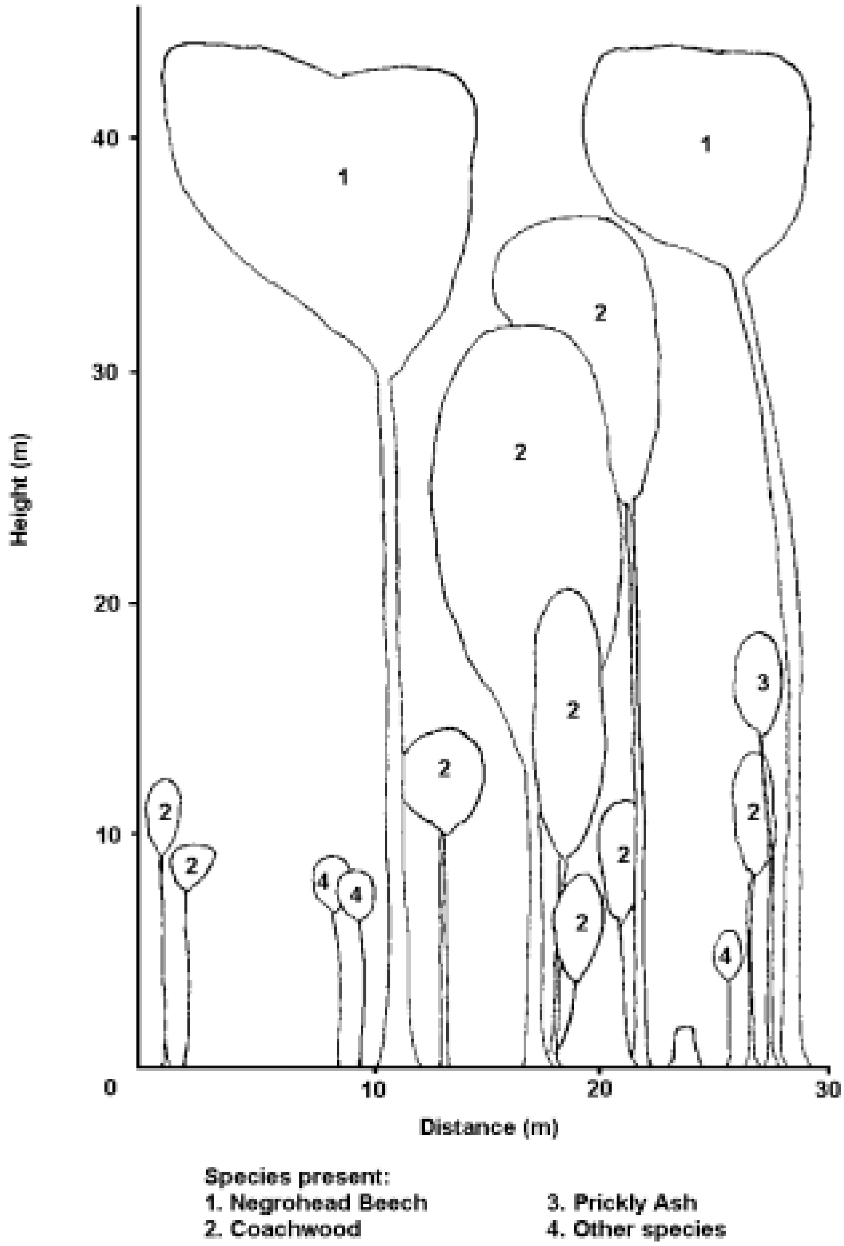


Figure 6 Profile Diagram of Cool Temperate Rainforest

(Understorey removal. From Porada, 1980)

10.6 Perspective

By the early 1980s fairly well defined harvesting prescriptions were in force in all districts where routine rainforest logging was still under way and these were detailed in the relevant management plans. These prescriptions had evolved over a period of some decades, and they aimed to retain the essential features of the rainforest stands, or to allow these features to be restored over a relatively short period. Unlike earlier times, when the rainforest was harvested with a view, if anything, towards its conversion to some other form of land use, there was recognition that rainforest could be, and should be, managed as rainforest. The practice was of a sufficient order that many stands so logged were subsequently included, apparently with little question, in the world heritage list.

Nonetheless two major deficiencies persisting up to the 1980s should be recognised.

One was managerial. The Commission's policy clearly stated in 1976, was to phase out routine rainforest logging, and considerable progress had already been made towards this end prior to the Government's 1982 decision, which accelerated the process. However in no case had serious efforts been made to reduce the annual cut to something resembling a sustainable yield. Instead, where logging continued, it was at rates that would have seen the exhaustion of the available rainforest resource within a couple of decades, with an ensuing hiatus until the previously logged stands could again support commercial operations. The Government's decision merely hastened the inevitable, though by its transfer of some of the best logged areas to national park[9] it made much more difficult for any establishment of a future sustained yield industry.

The second deficiency was silvicultural. Whilst the operations left the stands in good environmental shape, and with ample regeneration usually present, they could also lead to a build up of useless or otherwise refractory stems (e.g. those with very large crowns) in the stand. Whilst some of these could be rationalised as habitat trees or similar, the numbers sometimes appeared excessive if long term timber production from the stand was intended. In some areas a limited degree of culling would ultimately have been desirable.

11. ENVIRONMENTAL EFFECTS OF RAINFOREST TREATMENT

Since the early 1970s rainforest conservation (in various meanings of the word) has became a matter of major environmental concern both in Australia and on the global scale (e.g. Working Group on Rainforest Conservation, 1985; Seddon, 1985; Simon, 1986), with management for timber often being portrayed as a major villain leading to the destruction of rainforest or the loss of its special values.

These Notes are not the place for a detailed examination of the effects of rainforest treatment on the environment, but because of the dominance that environmental matters have achieved in recent rainforest considerations it seems necessary to include a few comments. More comprehensive reviews are given elsewhere, e.g. Interdepartmental Committee (1977) and Forestry Commission of N.S.W. (1981). However some points of relevance are:

- Rainforest logging operations in the recent past on State Forests in N.S.W. have all aimed at maintaining a viable rainforest community: the stands were sustainable, even if the yield was not.
- Any tract subject to logging operations will contain substantial areas excluded from logging – creek side strips, roadside belts, areas inaccessible because of slope or stoniness, areas currently with low volumes (or, where canopy retention systems apply, with existing open canopy), preserved areas.
- Rainforest in N.S.W., both generally and in respect to individual types, already has an extremely high conservation status (see Section 12)
- Operations are carried out under guidelines or specifications (e.g. erosion mitigation conditions) aimed at minimising adverse environmental effects.
- Logging clearly causes disturbance to the rainforest structure, but such disturbance, though usually on a more limited scale, is an essential feature of the dynamics of most if not all rainforest stands.

[9] Including, most regrettably, the valuable Wiangaree treatment plots, which are now (but for other reasons) part of the World Heritage!

- Because of species or lack of merchantability, some of the larger rainforest trees are typically retained during logging.

- The general structure of the undisturbed patch of rainforest is restored after logging, on a time scale fairly directly related to the extent of the disturbance (Horne and Gwalter, 1982, 1987)

- Stands under sustained management for timber will tend to be retained at rather less than the density (BA, stocking of larger trees) of an unlogged stand.

- The study of King and Chapman (1983) suggests that even with heavy logging in the apparently fragile warm temperate rainforest, all plant species present before logging are still present subsequently, though the proportion of some of the larger tree species may alter following even selective logging (Shugart et al. 1980; Horne and Gwalter, 1982, 1987)

- Shields et al. (1985) suggest that, while some species are encouraged and some discouraged by rainforest logging, the overall impact on bird populations has not been great while, as the time since logging increases, populations increasingly resemble those of the unlogged stands. This tends to agree with the studies of Pattemore and Kikkawa (1974) at Wiangaree, of Shields and Binns (1983) on Yabbra S.F., both papers dealing with birds, of Barnes (1983) on small mammals at Wiangaree and of Webb (1983) on the Southern Angle-headed Dragon. Whilst Winter (1983) indicates that the tropical Herbert River and Lemuroid Ringtail Possums are noticeably affected by partial logging, Warburton Goudberg (1983), studying those same species, used as her study site an area of rainforest *“last logged about 15 years ago”* and as her main transect *“a one kilometre section of an old snig track”.*

- The invertebrate rainforest fauna is generally less known, but often far more specific to rainforest, than the vertebrate fauna. In discussing the conservation of insects, Hill and Michaelis (1988) state:

  “The Drosophilidae is one of the 80-90 families of flies in Australia and exemplifies the difficulties of a species oriented approach to the conservation of Australian insects. One respondent supplied a list of 56 drosophilid species which are possibly rare or otherwise threatened. These species share both the same general habitat (wet forest, especially subtropical and tropical) and threats (clearing, fragmentation and degradation of habitat) but occupy a variety of very specific microhabitats within these forest ecosystems, e.g. one species relies on decaying flowers of native Hibiscus plants. Currently, the 56 species have been recorded at only one or a few localities each and often only a small number of specimens have been collected for each species. No specific ecological information is available for most of the 56 species. Another respondent provided an account of Australian rainforest Drosophila stressing their sensitivity to environmental change and suggesting their use as biological indicators of habitat disturbance and hence of species eliminations generally.”

- Selective logging, with appropriate existing safeguards and with its similarity to natural rainforest dynamics, would appear generally compatible with the conservation of such species.

- Whilst introduced plants are common in the rainforest soil seed bank (see Section 6.3.3), these are typically ephemeral species with no lasting impact on the rainforest community. Former rainforest lands converted to agricultural use may carry a large array of longer-lived weeds, but only one of these appears to have been of any significance in the rainforest communities. This is lantana that, apart from being a major weed in some plantations, is commonly present in openings in dry rainforest and may be relatively long present in some large openings in lower altitude subtropical rainforest (see Section 6.4.4). It does not survive once the rainforest canopy is reestablished, and at worst it will delay the development of rainforest regrowth in the affected sites.

- Logging operations almost invariably result in increased stream turbidity, though the increase may not be great. The Forestry Commission of N.S.W. (1983) records the following figures from adjacent and similar catchments on the former Wiangaree S.F. (units in Nephelometric Turbidity Units):

Treatment	**Unlogged**	**75% logged**
Mean	1.5	2.3
Range	0.0-7.3	0.2-17.0
Median	1.5	2.0
% Greater than 5 NTU	0.5	4.0
% Greater than 25 NTU	0	0

- Much of this logged catchment had in fact been harvested prior to the introduction of the Standard Erosion Mitigation Conditions, so the turbidity levels probably represent the upper end of the range likely to be experienced on these krasnozem soils. However, some other soils would tend to show greater effect.

- Except for some major ones, snig tracks usually regenerate rapidly after logging, but log dumps may be evident for much longer periods, and in the case of temperate rainforest often develop into long-lasting Tickbush thickets. Appropriate levelling, ripping and topsoil spreading after use normally speeds restoration; planting may assist in establishing more valuable species.

- Enrichment planting may be criticised for establishing non-local seed sources and species. If the forecasts of fairly rapid climatic change due to the greenhouse effect prove correct, such criticism loses much point: rainforest (and native vegetation generally) is likely to need considerable assistance if significant species impoverishment is not to occur.

- The visual restoration of rainforest following disturbance can occur speedily. Selective logging may be hardly noticeable 12-24 months later, when the more obvious signs of logging (open snig tracks, heads of felled trees) have largely disappeared. The aerial photographs provided by Horne and Gwalter (1982; Fig. 5) show that even shortly after logging the more selectively logged blocks (4 and 7) show few signs of disturbance; 15 years later they seem indistinguishable from adjacent unlogged rainforest, while even the more heavily logged blocks are well revegetated.

Ultimately it is for the community, through democratic processes, to determine whether the continued access to its fine timbers and other products from selected rainforest areas warrant the environmental impact that any timber harvesting operation brings about. In the case of selective rainforest harvesting this environmental impact - the environmental cost of obtaining the timber - is low.

12. PRESERVATION

12.1 Preserved Areas

As shown in Table 1 (Section 3), 37 per cent of the State's rainforest area is in Crown tenures, with about 28 per cent in national park and nature reserve and 53 per cent in State Forest, including Flora Reserves and Forest Preserves. This gives rainforest in N.S.W. a particularly high conservation status.

Most national parks and a large number of nature reserves in the coastal and escarpment districts carry some rainforest. Among the more significant national parks with respect to rainforest are Apsley Gorge, Barrington Tops, Blue Mountains, Border Ranges, Dorrigo, Gibraltar Range, Macquarie Pass, Morton, Mt. Warning, New England, Nightcap, Washpool, Werrikimbe, Woko and Wollemi. Some others, though containing relatively little rainforest, preserve otherwise rare communities. Nature reserves of particular significance for rainforest preservation include Boorgana, Brunswick Heads, Cedar Brush, Coramba, Davis Scrub, Iluka, Limeburners Creek, Limpinwood, Mt. Hyland, Mt. Seaview, Numinbah, Stotts Is. and Victoria Park.

The first Flora Reserves established in N.S.W. were sites with significant rainforest occurrence (see Section 5.4), and rainforest has continued to feature prominently - perhaps disproportionately so - in preserved areas on State Forest since that time. Appendix 11 lists Flora Reserves and Forest Preserves with significant occurrences of rainforest. In many, and possibly most, of these the rainforest is incidental to the main purpose in creating the specific preserved area, and this tends in itself to emphasise the widespread, though often small scale, occurrence of rainforest throughout the coastal and escarpment districts of the State. However a large number of included sites have been set aside deliberately to preserve rainforest stands, and particularly in the light of a series of excellent reports on rainforest in different parts of the State by A.G. Floyd, and his subsequent overview of their conservation status (Floyd, 1984), the Forestry Commission has taken specific action to preserve communities that are of particular botanical interest and that previously had an inadequate conservation status. This contrasts with the approach embodied in the Government decision of 1932 when, as Floyd (1984) states, *“the effect of a 153.6% increase in the rainforest area within the National Parks system has only been to reduce the number of inadequately conserved suballiances from 31 to 23.”*

The Commission’s preserved rainforest areas, listed in Appendix 11, include 82 Flora Reserves, with a total area of about 21 600 ha, and 19 Forest Preserves, totalling 3 600 ha. In all, about half the preserved areas within State Forests include rainforest, and these sites comprise rather more than half the total area of Flora Reserves and Forest Preserves. However rainforest itself makes up only part of this area, and the estimate of 10 200 ha given in Table 1 is of the right order.

Many of the sites listed in Appendix 11 are of relatively small size, and might be criticised on the grounds that such size is inadequate, especially for the “fragile” rainforest. To this several points should be made:

1. In many cases the small patch of rainforest is all that exists and is available: the dominant pattern of rainforest occurrence in 11.5.1. is of numerous but small patches.

2. The preserved areas typically exist within the matrix of much larger tracts of State Forest where the general pattern of native vegetation is retained, notwithstanding occasional disturbance (such as logging) in the course of normal management.

3. Even small, isolated rainforest patches can be extremely valuable in preserving rainforest features, and Corlett (1988) has provided a study of such a reserve in Singapore where, after 130 years of isolation and considerable disturbance, the 71 ha Bukit Timah Hill Reserve still retains most of its original botanical diversity, although many birds and mammals have been lost.

12.2 Rare and Threatened Species

The Commonwealth list of rare or threatened plants (Briggs and Leigh, 1988) includes over 70 N.S.W. rainforest species. This appears to be a decrease from the earlier (1981) list, which contained such common species as Negrohead Beech and Pinkwood, even though the new list includes a number of generally localised undescribed species. The list contains about 39 rainforest trees and 34 other forms, and of these 16 species (11 trees, 5 others) are classified as endangered (E). The Forestry Commission maintains a watching brief on these species generally, most of those (in all three categories, endangered, vulnerable and rare) that are known to occur in State Forests being present in at least one preserved area, and with particular attention paid to the endangered species.

Most of these rare or threatened species appear to have been naturally rare and of limited occurrence prior to European settlement, and in most cases it was subsequent land clearing for agriculture that brought the currently endangered species to their present status. However this is not always so, and two cases involving endangered species are of particular interest.

Onion Cedar *(Owenia cepiodora)* was effectively confined to the Richmond and Tweed valleys and neighbouring areas in Queensland, but was apparently common within this limited area: Maiden (1917) quotes a report from Forester Pope *"... .plentiful in the Richmond River district. Found scattered about in nearly all the brush forests of the Tweed, whenever the soil is inclined to be rich".* The timber was regarded as a substitute for Red Cedar, its initially offensive smell of rotten onions being only transitory. Once the large Cedars had mostly disappeared this species was favoured in their place, and combined with a limited natural range and the widespread clearing of much of this range, the species effectively ceased to exist as a large tree, though it is now known that regrowth occurs in parts of the still forested sites of its earlier occurrence. This appears to be one of the rare examples where logging has significantly contributed to the endangerment of a tree in Australia. In the late 1970s the Forestry Commission organised an initial collection of seed and raising of plants of this species, and today Onion Cedar is almost an obligatory inclusion in rainforest tree planting schemes in the Richmond-Tweed district, where its seedlings show a moderate to fast growth rate (see Table 13).

Olearia flocktoniae, a daisy-bush restricted to parts of the Dorrigo Plateau, was listed as extinct in the detailed case histories of extinct and endangered plants prepared by Leigh et al. (1984) on the basis of the earlier Commonwealth list, and it was the only extinct species included where forestry was named as a contributing cause. Subsequently living examples of the plant have been found in several places on State Forests on the eastern Dorrigo Plateau - along road edges, in a former quarry, and in logging openings. It would appear to be a soil seed bank species of very limited natural occurrence, requiring disturbed sites in which to regenerate and live out its relatively brief existence. In this case strict preservation would seem to contribute nothing to its survival: periodic disturbance in the sites where it occurs, and inclusion in living collections of native plants (e.g. in botanical gardens), would achieve much more.

Where not already growing in preserved areas, most of the very large specimens, listed in Appendix 10 and occurring on State Forest, have been identified under the Commissions' Preferred Management Priority classification to live out their natural lives.

12.3 The Global Perspective

The whole question of rainforest conservation in Australia has become closely interwoven with that of rainforest on the global scene -a subject that has become highly emotional and replete with such matters as multinational companies, absentee landowners, dispossessed native tribes, greenhouse effect, et al. Whilst the reality of apparently unwise management and landuse policies in many tropical rainforest areas cannot be denied, it is desirable that these should be seen in context. Simon (1986) has made a valuable contribution to this in relation to species extinction, and Roche (1982), in the course of a book review, has critically examined the forecasts of the disappearing tropical forest - *"the entire biome of 9 000 000 sq. km will disappear within only 37 years", "there will remain only isolated fragments at the end of the century except in some eastern Andean foothills and in the seasonal forests of the Congo",...* As Roche notes, much of the tropical forest that is disrupted and disturbed becomes secondary forest, and there is much evidence that secondary forest, with protection, can progress ecologically to the species richness of primary forest. Using FAO estimates of both forest area and the rate of destruction - estimates that are the most objective and factual available - Roche indicates that the actual position with the "*tropical closed hardwood forests*" is more likely to be:

Region	1975 Area (ha)	Est. 2000 Area (ha)	Loss (ha)
Central, S. America	641 000 000	575 000 000	66 000 000
Africa	202 000 000	187 000 000	15 000 000
Asia, Far East	291 000 000	243 000 000	48 000 000

The total estimated loss, of 129 million hectares, is equivalent to about 5 million ha a year, compared with estimates of 20-25 million ha a year in the publications to which Roche was objecting. Whilst the rate of destruction is great - more than twice the total area of Australian rainforest disappearing each year - the outcome is much less calamitous than is usually portrayed in the media or even in apparently reputable publications.

Roche particularly objects to the tropical forests being described as "*a nonrenewable resource*" (the title of one much quoted article), and this matter is discussed by Lanley in the quotation that opens these Notes; it is also reviewed, on economic grounds, by Leslie (1987) on the basis of his long experience as a senior officer of FAO.

It should be stressed that the loss of rainforest in the tropics is not due to logging **per se**, but to what happens to the site after logging, with the real loss occurring as a result of the subsequent development of the land, legally or illegally, for farmland, pasture or other purposes.

The desirability of managing tropical forests for, among other purposes, timber production is urged in the World Conservation Strategy and has been stressed in a recent special report on tropical forest conservation by the International Union for the Conservation of Nature and Natural Resources (1989):

> *"Tropical moist forests managed for sustained timber production are potentially highly significant elements in the overall effort to conserve the maximum species diversity, providing valuable extensions of near-natural vegetation as buffers around protected areas and conserving a wide spectrum of species and ecological processes across the broader landscape.*
>
> *Several studies have indicated that most vertebrate species survive selective logging by persisting in unlogged pockets from which they subsequently recolonise adjacent areas as these regenerate. A mosaic of logged and primary forest would appear to provide the optimum compromise between extractive land uses and the needs of biological diversity conservation, providing that the forest is subject to protection and post-logging management so as to discourage agricultural encroachment."*

13. MANAGEMENT ASPECTS

13.1 Objectives of Management

And so, by circuitous and verbose paths, these Notes reach the stage where it is necessary to interpret the silvicultural information that is available in terms of the future management of the rainforests that occur on State Forest.

The Commission's policy on rainforest management, enunciated in 1976, has already been quoted in Section 5.4. The events of 6 years later made most of this policy outdated, though the first sentence still appears relevant:

> *"The broad objective for all rainforest areas is to reduce harvesting to selective fellings for speciality (sic) logs, at a level low enough to maintain canopy and rainforest structure."*

In practice, and in the prescriptions for most relevant forest management plans, this has tended to translate into a general restriction on rainforest logging except for salvage-type operations or selective logging of specialty timbers, again largely on a salvage basis. The prescription in the 1984 Coffs Harbour management plan (section 2.2.4.3 (10)) is fairly typical:

> *"Harvesting in Rainforest types, except as required to salvage trees damaged or likely to be damaged by road construction, adjacent hardwood logging or other injury, shall be limited to the selective logging of mature, overmature or damaged trees at an intensity low enough to maintain rainforest structure and only as necessary to fulfil community demand for specialty purpose timbers which cannot reasonably be satisfied by purchase elsewhere or from timber made available under the other harvesting prescriptions*."

Such prescriptions are reflected in the minute Crown yield of rainforest timbers in recent years (1875 m^3 in 1987-88). (As a result of earlier commitments, continued in the 1982 Government decision, part of this yield came from a small rainforest harvesting operation in the Casino district and with some of the timber coming from previously unlogged stands. The commitment is a terminating one).

Prescriptions of this nature are adequate as a holding measure: they avoid the wastage of stems that would otherwise die or become degraded as a result of other operations (e.g. road construction, logging of hardwoods occurring above scattered rainforest stems), and they allow for the limited supply of specialty woods, typically to maintain a few small industries. They lie towards one end of a spectrum of possible approaches to rainforest management, only one or two steps removed from a total embargo on all rainforest harvesting.

They also have to be accepted as a possible long-term approach to rainforest management, though it must be hoped that such a policy and its consequent prescriptions and guidelines would only be adopted with a full realisation of their consequences. Perhaps the most valid reason for the effort in compiling these Notes is to provide information that can assist in this realisation, and in the evaluation of possible alternative approaches to rainforest management.

13.2 Management Options

Table 23

RAINFOREST ON STATE FOREST POTENTIALLY AVAILABLE FOR WOOD PRODUCTION
(based on Table 6; see text for details)
('000 ha)

Condition Class	I	II	II	IV	Total
Subtropical	12.6	15.4	10.6	2.6	41.2
Warm Temperate	2.5	1.3	9.7	3.4	16.9
Cool Temperate	3.9	1.4	0.2	0.1	5.6
Dry	1.5	7.1	2.1	0.2	10.9
Total	**20.5**	**25.2**	**22.6**	**6.3**	**74.6**

In Section 5.4 it is suggested that there may be about 75 000 ha of rainforest occurring on State Forest and available for long-term management with timber as one of the benefits being obtained from management. Effectively all of this area has been previously logged, with its condition ranging from structure little disturbed (category I, Table 6) to structure removed (category IV). A break up of the potentially manageable rainforest on multiple use State Forests is given in Table 23: it is based on Table 6 with the exclusion of depauperate rainforest and of half the area in category I (on the assumption that half of category I has not previously been logged, and should not be logged now).

In determining what may be feasible and acceptable for the management of all or part of these stands (and for that matter for some the depauperate rainforest also, as enrichment could convert some such stands to a potentially productive state), certain premises seem to be relevant:

1. While public attitudes do change, sometimes rapidly and drastically, it is hard to envisage activities that appear to damage rainforest stands significantly, or even to destroy them, being again accepted by the community generally. On the other hand operations where damage is deliberately minimised, allowing relatively speedy restoration of the rainforest structure, for the purpose of producing a sustainable yield of mostly high value timbers, may well prove quite acceptable to a majority in the community and to Governments.

2. The justification for continuing to harvest rainforest timbers was well summarised by Bootle (1983):

   "In the battle for protection of the remaining rainforests it is to be hoped that a reasonable compromise can be found that will permit woodcraft to continue to show the wealth of beauty and variety produced by this renewable resource."

   Nor is it just beauty and variety, for as Bootle himself points out, some of the timbers have values and uses that are almost unique to those timbers. As a corollary of this, royalties on such timbers should reflect their value as a relatively rare and precious commodity. As a further corollary, it has been argued on behalf of Australian woodworkers that a timber resources centre should be established for the stocking and retailing of wide variety of craft timbers (Williams, 1978; Woodworkers of N.S.W., 1979)

3. In any future management of rainforest on State Forest, the non-material benefits that the stands provide should be positively acknowledged: the visual integrity of the stands should be maintained at a high level; disruptions to wildlife food supplies should be avoided; a full range of microenvironments should be retained within the rainforest; and so on.

4. The natural dynamics of rainforest stands, as described within these Notes, should be appreciated. Disturbance is a regular part of the rainforest life cycle, and the rainforest has a high degree of resilience that is familiar to those who work with and in it, but that is often disregarded in popular accounts of rainforest. Westoby (1986) put it into context in the 2nd. Michael D. Sabath Memorial Lecture at Griffith University:

   "We should stop wittering about ecosystems being fragile. Rainforests are fragile, deserts are fragile. sclerophyll forests are fragile, the open ocean is fragile; I have yet to hear the media describe any ecosystem as anything but fragile. It is perfectly true that some of the worlds ecosystems are being destroyed at an unprecedented rate . But it is dangerously misleading to suggest that this is happening because the ecosystems are fragile. The tropical forests are contracting in area not because they are susceptible to subtle ecological side-effects which our scientific knowledge has been unable to anticipate, but because huge amounts of labour power and fossil energy are being systematically devoted to felling and removing the structuring species, which make those forests what they are."

5. The selective harvesting of a few high value species only can be a recipe for creaming the forest. Such operations need to be carried out in the knowledge that replacements for the harvested trees will be - or are - present in the future stands. Similarly, in rainforest stands where timber production is one of the objectives of

management, care is needed that the harvesting does not result in a continued build up of unmerchantable stems: at times a limited amount of culling may be necessary to release potentially merchantable stems of the higher value species.

6. In some areas, including northern dry rainforest stands and some heavily cut over warm temperate rainforest on the eastern Dorrigo Plateau, well stocked regrowth of Hoop Pine is present. Much of this would benefit - productively and visually - from periodic thinning. This possibility was not covered in the 1976 Indigenous Forestry Policy, but has been sanctioned by subsequent decisions.

7. And, to stress the first point, any operations need to be carried out with the utmost environmental awareness.

Several senior and experienced Commission officers contributed an internal debate on future rainforest harvesting in 1986 and 1987, partly sparked with a view to obtaining opinions and ideas for use in these Notes. All agreed on the need to avoid any substantial operations in the near future in rainforest, and to ensure that in the longer run a very conservative approach is required. John Bruce (Regional Forester, Coffs Harbour) contributed “a few thoughts” on appropriate measures, and these appeared to represent a general consensus of those who participated. Whilst they make no claim to represent a new policy, they usefully serve to summarise the factors involved in determining such a policy in at least the short term:

1. We need to provide for thinning of natural regeneration of Hoop Pine at Mebbin and elsewhere, even if we can’t find a specialty market for the product.

2. In the short term, in all other situations, we need to be very conservative in order to regain the confidence of the public and to begin to convince them that there is a genuine need to log some rainforest timbers and that we can do this responsibly and without long-term damage. (Another officer has suggested that the need will only arise when the specialist users of high value rainforest timbers start to complain about their scarcity of supply).

3. This will involve small volumes, low-intensity, low-impact logging, and high royalties.

4. The public may accept that we should supply a wood-turner. They will not wear a manufacturer of marine ply.

5. Supply should generally be restricted to craftsmen (wood-turners, wood-carvers, and makers of fine furniture) - and perhaps they should be registered with a Crafts Board.

6. Obvious sources of supply are from road-line logging and from understorey trees that would otherwise be destroyed in hardwood logging.

7. Next priority should be the salvage of windthrows and dead and dying trees.

8. This would logically involve helicopter snigging, which may sound futuristic, but which is established practice for high-value products in the USA and NZ. It would eliminate the roading and snigging disturbance that the vast shortsighted majority finds so offensive.

9. At the other end of the scale, the use of bullocks as a combined tourism/extraction venture may have a place in a few specific areas.

10. I would expect that these avenues would just about meet short-term requirements of true specialty wood. If not, a very light selective logging for individual species on demand could be carried out, always keeping in mind the need to retain something like the original species composition of each stand.

11. At present, "specialty timbers" still means Red Cedar and Rosewood, with the odd request for a bit of White Beech, Crows Ash, Silky Oak, etc. I expect that this will change with time. For example, I can't imagine why, when Tasmanian crafters sell heaps of articles made from Tasmanian Sassafras and Nothofagus, our people couldn't be bothered with equivalent N.S.W. species.

12. After we have had this system running smoothly for some time, and after the public has come to realise that there is a need for rainforest timbers and that we can supply them without devastating the forests, then we can think about broadening the scale of operations.

The Forestry Commission of N.S.W. (1984) contributed a paper on rainforest use and preservation to a Commonwealth-convened conference on rainforests, held at Cairns. The recommendations of this paper can perhaps be regarded as providing the basis for a longer-term policy on the management of rainforests in N.S.W.:

1. That, in the development of its policy on the conservation of rainforest, the Commonwealth should adopt the definition of conservation used in the World Conservation Strategy and subsequently accepted in the proposed National Conservation strategy for Australia.

2. That recognition is given that rainforest is indeed a renewable resource.

3. That there is a need to ensure that adequate representation of rainforest, in all its forms, occurs in preserved areas.

4. That efforts should be made to restrict further clearing of rainforest for agricultural, pastoral, urban or similar purposes, unless the clearing proposal has previously been approved following rigorous environmental impact study.

5. That the special values and uses of many of the timbers derived from rainforest trees, their heritage value and their historical significance in the development of eastern Australia be recognised and acknowledged.

6. That recognition be given to the fact that rainforests can be successfully managed for timber production, with low environmental impact.

7. That harvesting of timber or other plant products should be permitted in rainforest stands not specifically set aside as preserved areas, provided:

    (a) Levels of production are at or below that which can be indefinitely sustained;

    (b) Harvesting of trees is by a selection system, maintaining the general structure and character of the stand;

    (c) Royalties (stumpages) reflect the true worth of the products being obtained;

    (d) Adequate monitoring of logged areas is carried out, so as to ensure the continued well-being of the stand and of its associated plant and animal communities.

8. That any effort to define rainforest, or to curtail its commercial use, should recognise the often intimate association of rainforest elements in and with the generally more widespread forest communities dominated by eucalypts and related trees, and the usually very dynamic nature of the rainforest.

13.3 Guidelines

Most previous Notes in this series have included a section listing the main silvicultural points that need to be considered in the management of the relevant forest communities.

In this case such a listing is not provided. The management of the State's rainforests is currently in a state of quiescence, following a rather turbulent period. Whilst a large range of silvicultural options are theoretically available, in reality the future approaches can only be dimly discerned, though they are likely to lie within a relatively narrow range of options which give considerable emphasis to the maintenance of non-material values and much less emphasis -certainly than often was the case in the not too distant past - to wood supplies. When the future approaches can be more clearly defined, then will the listing of guidance points be necessary. In the meantime some of the premises suggested in Section 13.2 highlight the factors that currently need to be given special consideration in rainforest management.

These Notes touch on a large number of matters relating to the silviculture of rainforest stands in N.S.W. The table of contents is quite comprehensive, and at various stages in the text summaries of particular sections have been provided. To the extent that more specific guidance points than are provided in Section 13.2 may be needed, these should suffice.

13.4 Future Research

In communities as varied and complex as rainforest, research will continue to be needed into ecological and silvicultural aspects for an indefinite period, though with the current low level of use being made of the State's rainforests for wood production it is difficult to justify any substantial silvicultural research effort.

Nonetheless some work is warranted, largely to help clarify the future options available for management and to identify their environmental effects. The following matters seem to warrant some level of research priority:

1. Over some 40 years a considerable number of growth plots have been established in N.S.W. rainforest, in stands of different types, histories and treatments. A few of these have had analyses made of their growth, and these are discussed in Section 8. However many more have not been critically analysed, and many of those that have, now have data collected over a much longer measurement period. A concerted effort to review this data and to determine more clearly the patterns of growth and mortality in the State's rainforests is long overdue.

2. Similarly a review of past enrichment plantings (section 7.4), both experimental and routine, is warranted. This is a technique that appears to have much to contribute to rainforest silviculture, but its success or otherwise, over a longer period than that for which data has previously been reviewed, needs to be assessed. Previous trial plantings of various species in the open also need to be reexamined.

3. Logging damage (Section 9.3) can affect a large number of remaining stems, even with fairly light selective harvesting. Rather arbitrary divisions have been made between what is regarded as significant and insignificant damage, and at this stage a further evaluation, involving examination of trees previously assessed in different damage classes, the extent of timber defect, and the effects on tree growth, are needed.

4. Whilst the Commission has not been involved to any extent directly in the replanting of mixed rainforest on to cleared land, or in the rehabilitation of heavily cut-over areas and viney scrub patches, there is a need for the collection and collation of data on the success of such projects and on their development. This would involve the establishment of plots in conjunction with various private landowners, and also in those few cases where the Commission has been directly involved (e.g. Big Scrub F.R., Cumberland S.F.), and the periodic remeasurement of these plots and analysis of the data.

5. Though not peculiar to rainforest, the forecasts of the developing greenhouse effect suggest that increasingly plant species and communities are going to become out of kilter with their environment - the situation that in periods of past climatic change has led to broad migrations of vegetation. The fragmentation of natural vegetation patterns by human intervention will make such movements very much more difficult or even impossible, and the numerous, generally small, rainforest communities would appear particularly vulnerable. If such communities are to survive, human intervention will almost certainly again be necessary, and there is a need for research into the nature and manner of this intervention. The results will affect rainforest in all tenures and under varying management practices.

6. Studies are also desirable on the effects of various treatments and disturbance patterns on specific plants and animals - including invertebrates and various rare plants.

Obviously this only touches on research that could usefully be undertaken, but it hopefully identifies the more immediate needs. In particular it is stressed that much unanalysed data is already held, and that critical review of this should receive high priority.

14. ACKNOWLEDGEMENTS

As with other Notes in this series, the material used in these Notes is derived from the work of a large number of foresters, carried out over many years. In the field of research particular credit must be given to A.G. Floyd, who has contributed so greatly to the identification of rainforest trees in N.S.W. and more recently to the recognition of patterns of distribution and occurrence, and to R. Horne and his colleagues, who have made such notable contributions from their analyses of long established plots. In the field, foresters from Tenterfield, Urbenville and Murwillumbah in the north to Bombala and Eden in the south have contributed their ideas and views, often based on long experience with rainforest, to the compilers of these Notes, and the thoughtful opinions of John Bruce are in particular most gratefully acknowledged.

Special thanks are also owed to the following officers who critically read and constructively commented on an earlier draft of these Notes:

D. Binns	R. Horne	C.I.Nicholson
R.G. Bridges	R. Kavanagh	G.D.Pople
J.Bruce	M. Lambert	J.Turner
C. Gray	C.Mackowski	
D.I. Hamilton	J. Mills	

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Appendix 1

LIST OF SPECIES REFERRED TO IN TEXT

Notes: **a**: timber properties described by K.R. Bootle in "The Commercial Timbers of N.S.W. and their Use" (1971), but not in Bootle (1983);
b: timber properties described in Bootle (1983);
c: supplementary species mentioned for use in a (pp. 253-4);
d: woodcraft species mentioned in b (p. 229);
w: propagation described by Wrigley (1979).

Common Name	Botanical Name	Family	
Apple, Black	Planchonella australis	Sapotaceae	b,w
Red	Acmena brachyandra	Myrtaceae	
Rose	Syzygium moorei	Myrtaceae	w
Ash, Bennetts	Flindersia bennettiana	Rutaceae	
Crows	F. australis	Rutaceae	b,w
Grey	Emmenosperma alphitonioides	Rhamnaceae	b
Pigeonberry	Cryptocarya erthroxylon	Lauraceae	b
Prickly	Orites excelsa	Proteaceae	b,w
Red	Alphitonia excelsa	Rhamnaceae	b,w
Silky	Ehretia acuminata	Boraginaceae	
Silver	Flindersia schottiana	Rutaceae	b,w
Yellow	Emmenosperma alphitonioides	Rhamnaceae	b
Banksia	Banksia spp.	Proteaceae	b
White	B. integrifolia	Proteaceae	w
Basswood, Silver	Polyscias elegans	Araliaceae	b,w
White	P. murrayi	Araliaceae	b
Bean, Black	Castanospermum australe	Fabaceae	b,w
Red	Dysoxylum muelleri	Meliaceae	b
Beech, Myrtle (Tas, Vic)	Nothofagus cunninghamii	Fagaceae	b,w
Negrohead	N. moorei	Fagaceae	b,w
Red (NZ)	N. fusca	Fagaceae	
Silky	Citronella moorei	Icacinaceae	b
White	Gmelina leichhardtii	Verbenaceae	b,w
Beefwood	Stenocarpus salignus	Proteaceae	b,w
Bitterbark	Petalostigma pubescens	Euphorbiaceae	w
Blackbutt	Eucalyptus pilularis	Myrtaceae	b,w
Blackwood	Acacia melanoxylon	Mimosaceae	b,w
Blanket - leaf	Bedfordia arborescens	Asteraceae	
Bleeding Heart	Omalanthus populifolius	Euphorbiaceae	w
Bloodwood, Scrub	Baloghia lucida	Euphorbiaceae	w
Bollywood,	Litsea reticulata	Lauraceae	b
Hard	Beilschmiedia obtusifolia	Lauraceae	b
Bolwarra	Eupomatia laurina	Eupomatiaceae	w
Bonewood	Acradenia euodiiformis	Rutaceae	w
Booyong, Black	Argyrodendron actinophyllum	Sterculiaceae	b,w
White	A. trifoliolatum	Sterculiaceae	b,w
Boppel Nut, Red	Hicksbeachia pinnatifolia	Proteaceae	w
Box, Brush	Lophostemon confertus	Myrtaceae	b,w
Boxwood, Yellow	Planchonella pohlmaniana	Sapotaceae	b
Callicoma	Callicoma serratifolia	Cunoniaceae	b,w
Camphorwood	see Sassafras, Olivers	Cunoniaceae	

Cane, Lawyer	Calarnus muelleri	Arecaceae	w
Capparis	Capparis arborea	Capparidaceae	w
Carabeen, Red	Geissois benthamii	Cunoniaceae	b
Yellow	Sloanea woollsii	Elaeocarpaceae	b
Cedar, Onion	Owenia cepiodora	Meliaceae	
Red	Toona australis	Meliaceae	b,w
White	Melia azederach var. australasica	Meliaceae	b,w
Cherry, Blue	Syzygium coolminianum	Myrtacae	w
Brush	S. australe	Myrtacae	w
Sour	S. corynanthum	Myrtacae	
Coachwood	Ceratopetalum apetalurn	Cunoniaceae	b,w
Coral Tree, Batswing	Erythrina vespertilio	Fabaceae	w
Corduroy	Sarcopteryx stipitata	Sapindaceae	d,w
Cordyline	Cordyline spp.	Liliaceae	w
Corkwood	Caldcluvia paniculosa	Cunoniaceae	b,w
Crabapple	Schizomeria ovata	Cunoniaceae	b
Cunjevoi	Alocasia macrorrhizos	Araceae	w
Cypress Pine, Brush	Callitris macleayana	Cupressaceae	b,w
Doughwood	Melicope octandra	Rutaceae	b
Duboisia	Duboisia myoporoides	Solanaceae	b,w
Fern, Birds-nest	Aspleniurn australasicum	Aspleniaceae	w
Elkhorn	Platycerium bifurcaturn	Polypodiaceae	w
Staghorn	P. superbum	Polypodiaceae	w
Tree	see Treefern	Polypodiaceae	
Fig	Ficus spp.	Moraceae	
Deciduous	F. superba var. henneana	Moraceae	
Port Jackson	F. rubiginosa	Moraceae	w
Sandpaper	F. coronata	Moraceae	
Strangling	Various Ficus spp., especially F. watkinsiana	Moraceae	w
Flametree	Brachychiton acerifolius	Sterculiaceae	b,w
Frangipanni, Native	Hymenosporum flavum	Pittosporaceae	w
Ginger, Native	Alpinia caerulea	Zingiberaceae	w
Gooseberry, Native	Physalis peruvian	Solanaceae	
Grape, Native	Cissus spp.	Vitaceae	
Gum, Flooded	Eucalyptus grandis	Myrtaceae	b,w
Gum, Giant Water	Syzygium francisii	Myrtaceae	b
Small-leaved Water	S. luehmannii	Myrtaceae	b,w
Sydney Blue	Eucalyptus saligna	Myrtaceae	b,w
Water	Tristaniopsis spp	Myrtaceae	b,w
Water (opposite-leaved)	Tristania neriifolia	Myrtaceae	w
Heart, Bleeding	Omalanthus populifolius	Euphorbiaceae	w
Hicksbeachia	Hicksbeachia pinnatifolia	Proteaceae	w
Inkweed	Phytolacca octandra	Phytolaccaceae	
Ironbark, Scrub	Bridelia exaltata	Euphorbiaceae	d,w
Ironwood	Choricarpia leptopetala	Myrtaceae	
Ivorywood	Siphonodon australe	Siphonodontaceae	b
Jew, Wandering	Comrnelina cyanea	Commelinaceae	w
Kauri (Qld)	Agathis robusta	Araucariaceae	b,w
Lacebark	Brachycbiton discolor	Sterculiaceae	w
Lantana	Lantana camara	Verbenaceae	
Laurel, Macleay	Anopterus macleayanus	Escalloniaceae	w
Thickleaved	Cryptocarya meisnerana	Lauraceae	
Three-veined	C. triplinervis	Lauraceae	
Leatherwood (Tas.)	Eucryphia lucida	Eucryphiaceae	b,w
Leopard Tree, Broadleaved	Flindersia collina	Rutaceae	w

Lilly Pilly	Acmena smithii	Myrtaceae	b,w
Broadleaved	A. hemilampra	Myrtaceae	w
Lily, Rock	Dendrobium speciosum	Orchidaceae	w
Macadamia	Macadamia spp. (NSW: M. tetraphylla)	Proteaceae	w
Mallet wood	Rhodamnia argentea	Myrtaceae	
Manuka (NZ)	Leptospermum scoparium	Myrtaceae	w
Maple, Queensland (Qld)	Flindersia brayleyana	Rutaceae	b,w
Rose	Cryptocarya rigida	Lauraceae	b,w
Mint -bush	Prostanthera ovalifolia	Lamiaceae	w
Mistletoe	Various Loranthaceae, esp. Amyema spp.	Loranthaceae	
Mock-olive, Gorge	Notelaea microcarpa var. velutina	Oleaceae	w
Veined	N. venosa	Oleaceae	
Murrogun	Cryptocarya microneura	Lauraceae	
Musk, Native	Olearia argophylla	Asteraceae	w
Muskheart, Deep	Alangium villosum ssp. polyasmoides	Alangiaceae	d
Myrtle	Various Myrtaceae, esp. fleshy-fruited spp.	Myrtaceae	
Grey	Backhousia myrtifolia	Myrtaceae	b,w
Weeping	Waterhousea floribunda	Myrtaceae	w
Nettle, Smooth	Elatostemma reticulatum	Urticaceae	w
Oak, Satin	Oreocallis pinnata	Proteaceae	w
Silky	Grevillea robusta	Proteaceae	b,w
Olive, Native	Olea paniculata	Oleaceae	d,w
Olive-berry, Red	Elaeodendron australe	Celastraceae	w
Palm, Bangalow	Archontophoenix cunninghamiana	Arecaceae	w
Cabbage-tree	Livistona australis	Arecaceae	w
Walking-stick	Linospadix rnonostachyus	Arecaceae	w
Pandanus	Pandanus pedunculatus	Pandanaceae	w
Peach, Poison	Trema aspera	Ulmaceae	
Pepper, Native	Piper novae-hollandiae	Piperaceae	w
Pepperberry	Cryptocarya obovata	Lauraceae	
Pepper-bush	Tasmannia spp.	Winteraceae	w
Persimmon, Yellow	Diospyros australis	Ebenaceae	w
Pine, Brown	Podocarpus elatus	Podocarpaceae	b,w
Bunya (Qld.)	Araucaria bidwillii	Araucariaceae	b,w
Cypress	see Cypress Pine		
Hoop	Araucaria cunninghamii	Araucariaceae	b,w
Huon (Tas.)	Lagarostrobos franklinii	Podocarpaceae	b,w
Pinkwood	Eucryphia moorei	Eucryphiaceae	b,w
Plum, Red	Endiandra introrsa	Lauraceae	b
Rusty	Amorphospermum whitei	Sapotaceae	w
Plumwood	Endiandra spp.	Lauraceae	a
Possumwood	Quintinia sieberi	Escalloniaceae	b,w
Pothos	Pothos longipes	Araceae	
Quandong, Hard	Elaeocarpus obovatus	Elaeocarpaceae	w
Mountain	E. holopetalus	Elaeocarpaceae	w
Silver	E. grandis	Elaeocarpaceae	b,w
Quinine	Alstonia constricta	Apocynaceae	w
Ringwood	Backhousia anisata	Myrtaceae	w
Rosewood,	Dysoxylum fraseranum	Meliaceae	b,w
Hairy	D. rufum	Meliaceae	
Scentless	Synoum glandulosum	Meliaceae	b,w
Saffronheart	Halfordia kendack	Rutaceae	b

Sassafras,	Doryphora sassafras	Atherospermataceae	b,w
Olivers	Cinnamomum oliveri	Lauraceae	b,w
Red-barked	C. virens	Lauraceae	b
Southern	Atherosperma moschatum	Atherospermataceae	b,w
Shatterwood	Backhousia sciadophora	Myrtaceae	
Socket wood	Daphnandra micrantha	Atherospermataceae	b,w
Stinger, Giant	Dendrocnide excelsa	Urticaceae	c,w
Small-leaved	D. photinophylla	Urticaceae	w
Sycamore, Silver	Cryptocarya glaucescens	Lauraceae	b,w
Tamarind, Native	Diploglottis cunninghamii	Sapindaceae	w
Tawa (NZ)	Beilschmiedia tawa	Lauraceae	
Teak, Native	see Ash, Crows		
Tea-tree, Yellow	Leptospermum flavescens	Myrtaceae	w
Tickbush	Helichrysum diosmifolium	Asteraceae	w
Tobacco Bush	Solanum rnauritianum	Solanaceae	
Tree fern	Cyathea, Dicksonia spp.	Cyatheaceae, Dicksoniacae	w w
Tuckeroo	Cupaniopsis anacardioides	Sapindaceae	w
Tulipwood	Harpullia pendula	Sapindaceae	d,w
Yellow	Drypetes australasica	Euphorbiaceae	d
Turnipwood	Akania lucens	Akaniacae	
Turpentine, Brush	Rhodamnia rubescens	Myrtaceae	w
Vine, Water	see Water Vine		
Walnut, Mountain	Cryptocarya foveolata	Lauraceae	a
Water Vine	Cissus antarctica	Vitaceae	w
Wattle,	Acacia spp.	Mimosaceae	
Brown Sal	A. aulacocarpa	Mimosaceae	b,w
Silver	A. dealbata	Mimosaceae	b,w
Whalebone Tree	Streblus brunonianus	Moraceae	w
Wheel-of-Fire Tree	Stenocarpus sinuatus	Proteaceae	w
Yellowbark	Maytenus disperma	Celastraceae	
Yellowwood,	Flindersia xanthoxyla	Rutaceae	b,w
Deep	Rhodosphaera rhodanthema	Anacardiaceae	d,w
Thorny	Zanthoxylum brachyacanthum	Rutaceae	d,w

Appendix 2

RAINFOREST LIFE FORMS

A summary of information about the life forms of rainforest plants, particularly as they occur in NSW. Information largely from Richards (1952) and Baur (1968)

Trees: Dominant life form.

* Seldom attain height of eucalypts in adjacent areas (or that they replace where rainforest invasion has occurred, e.g. Norman W. Jolly F.R.), but in most favoured sites may approach 69m.

* Some with massive stem diameters (e.g. Red Cedar, Rosewood, Crow's Ash, Yellow Carabeen, Negrohead Beech, strangling Figs), but overall impression is of slender stems, tall and relatively untapered for their diameters.

* Normally a distinct reverse J-distribution of DBH classes.

* Varied stem forms: most cylindrical; some characteristically fluted or channelled (e.g. Silky Beech, Black Apple).

* Buttressing at base of stem of many larger growing species in certain types of rainforest (e.g. Booyongs, Yellow Carabeen, Red Carabeen, Red Cedar, Figs); shape and form of buttress can be useful feature for identification.

* Stilt-rooting, common in small trees in some tropical rainforests, absent in NSW (but shown by Pandanus of some North Coast headlands).

* Some species regularly produce suckers from base of stem, sometimes from swollen tissue at ground level (e.g. Ringwood). When original tree dies, one or more of suckers may develop as new stems - sometimes producing ring of new trees. Examples include Negrohead Beech, Pinkwood, and Sassafras; see also Johnston and Lacey (1983).

* Bark types very varied, bark often patterned by lichens. (Smooth barks and lichens tend to indicate slow-growing trees; Whitmore, 1975.) Bark (including the "revealed by cutting into inner bark") useful feature for identification (see Floyd, 1976-83).

* A few species (e.g. Thorny Yellowwood, Capparis, Batswing Coral Tree), mostly small trees, have stem prickles; these usually disappear from stems of older specimens.

* Roots markedly concentrated in surface layer of soil, though root activity may be found at depth in deep soils.

* Crown diameters of overstorey trees often small for DBH (low K/D ratio), though some species develop large crowns, which can cause much damage when tree falls (e.g. strangling Figs, Yellow Carabeen). True understorey trees, though smaller, tend to have higher K/D ratio.

* In comparison with tropics, very few species exhibit cauliflory (flowers produced from trunk or old wood of branches). Those that do usually only show it to a limited extent, e.g. *Hedraianthera porphyropetala*, Black Bean, Rose Apple, Sandpaper Fig, Hicksbeachia.

* Crown shape and form may be characteristic - most notably with Hoop Pine, but also many others, e.g. tight, pointed crowns of Grey Persimmon.

* Particularly in the cooler and more exposed sites, dead branches may be common in the upper canopy even in sites undisturbed by human activity.

* Leaf sizes mostly in the notophyll (2 925-4 509mm^2) and microphyll (225-2 025mm^2) classes of Webb (1959), with the smaller sizes predominant in cooler and higher altitude sites. Larger leaf sizes unusual, though distinctive when present (e.g. Giant Stinger, Native Tamarind, Flametree).

* In warmer and fertile sites leaves (or leaflets in the case of compound leaves) tend to be remarkably similar - entire margins, rather soft texture, sometimes flaccid and brightly coloured when first produced, often tip slightly extended into small drip tip (more marked in tropics). In cooler sites leaves tend to be more coriaceous and to have serrated margins, and compound leaves are uncommon. Despite similarities, leaves are extremely useful in identifying rainforest trees (Floyd, 1975, 1976-83; Williams et al., 1984)

* Most species are evergreen, and in some cases the leaves are retained for many years and may become coated with epiphyllous lichens and mosses (Rogers and Barnes, 1986, report a mean half-life of 6.8 years for leaves of the small tree, *Wilkiea macrophylla* i.e. half the leaves are retained for nearly 7 years at least)

* A few species are fully deciduous (e.g. Red and White Cedar); more are partially or semi-deciduous (e.g. Flametree, Crow's Ash, Lacebark, Deciduous Fig, Silky Ash, Silky Oak)

* The stinging hairs on the leaves of the Stingers can have management significance - especially for recreation.

Shrubs: Most obvious life forms to anyone entering rainforest.

* Shrub layer (or layers) consist of both genuine shrubs and small individuals of the trees.

* Some large herbs may also contribute to the shrub layers, e.g. Cunjevoi, Native Ginger.

* Spiny stems or leaves often common among the shrubs.

* Small trees commonly have a single unbranched stem surmounted by a tuft of leaves, developing their more typical, adult, branched form later in life. This monopodial habit (reminiscent of palms) is also found among many of the true shrubs (e.g. Cordyline, Walking-Stick Palm, Macleay Laurel, Tree Ferns)

* Other rainforest shrubs have more typical, multi-branched, spreading habit.

Herbs:

* Usually scattered except where light conditions locally better, when they may cover the ground.

* Ferns usually the most common herbs; also Wandering Jew and relatives, sedges, occasional grasses; in places mosses may cover ground.

* Germinating tree seedlings may sometimes, and seasonally, contribute markedly to the herb layer.

* As noted, some herbs reach sufficient size to contribute to the shrub layer.

Palms: Although often reaching tree size, palms are not strictly trees.

* Besides the small Walking-stick Palm and the climbing Lawyer Cane, two species of the Palm family occur in N.S.W. and reach tree size: Cabbage Tree and Bangalow Palms. Both are most common in rather swampy sites, though not confined to those.

* As well as its representation in the shrub layer, the palm habit - essentially of an unbranched stem surmounted by a tuft of leaves - is found among a number of other rainforest plants, though in the woody species some branching may ultimately occur. Such plants include the Basswoods, Turnipwood and Tree Ferns.

Vines: Vines are second only to trees as a dominant rainforest life form.

* Vines show a range of habits from relatively small stem-climbers (e.g. Pothos, certain ferns), through usually low growing, wiry vines (e.g. *Smilax* and *Ripoponum* spp.), to large lianes with stem thickness up to 30cm or more (e.g. Water Vine, Native Pepper).

* Species are numerous: Williams and Harden (1980) cover 140 species (81 genera, 51 families) in their key to the N.S.W. rainforest vines.

* While some of the smaller vines, especially the stem climbers, tolerate low light intensities, the vines typically are light demanders that regenerate in gaps or openings.

* In gaps the vines grow up with the developing trees, and most tend to reach the upper canopy in this way. Sometimes the vigour and amount of vines are such that they suppress the tree regrowth and produce long lasting vine tangles - a feature of some moist gully sites in predominantly eucalypt forest stands, and also of many sites subject to repeated cyclone damage.

* Larger vines may lace the crowns of a number of trees together, creating problem and danger in tree felling. (In tropical areas vine cutting commonly precedes felling as a routine activity.)

* Vines commonly create a curtain effect along rainforest margins, e.g. along roads, and thus help perpetuate the myth of the impenetrable rainforest.

* Small wiry vines may be common in the undergrowth, particularly where there has been past disturbance.

Epiphytes: A very distinctive rainforest life form, though of limited management significance.

* Epiphytes in N.S.W. rainforest range from large ferns (e.g. Staghorn, Bird's Nest Ferns) and clumps of orchids (e.g. Rock Lily), through small ferns, orchids and other plants to mosses, lichens and liverworts.

* Large clumps of epiphytes (sometimes of mixed species and developing in the remains of a large epiphytic fern) may become very heavy and contribute to branch breakage.

* Non-vascular epiphytes on a branch or stem often indicate slow growth of the host plant.

* In general epiphytes do not appreciably affect the growth or health of the host plant.

Stranglers: Certain trees usually start life as stranglers, though probably all are also capable of independent existence.

* The most typical of all stranglers are some of the rainforest Figs. The seeds, distributed by certain birds, bats and possibly possums, germinate in the crown of the host - often in a branch angle where some moisture and leaf detritus accumulates.

* The young seedling grows slowly, while sending an aerial root towards the ground.

* Once the root reaches the ground growth speeds up. More roots develop and grow around the host stem, while the crown of the Fig, starting life sometimes 30m above ground, expands. The roots gradually strangle the host stem, while the Fig crown shades that of the host, which consequently weakens and dies, leaving the Fig as an independent tree -often one of the largest trees in the rainforest.

* Other local stranglers are usually specific to Tree Ferns that, with their moisture-holding, fibrous stems, provide a suitable medium for the growth of many plants. Possumwood and Pinkwood are two trees that commonly start life as seedlings that have germinated on a Tree Fern that, again, is ultimately overwhelmed by its foster-seedlings. Such germination and early growth some distance (usually only a metre or so) above ground may help the seedlings avoid browsing by wallabies.

Other Life Forms:

* Mistletoe is not uncommon as a hemiparasite in the crown of rainforest trees. Within the rainforest it is usually most readily noted from its fallen flowers on the ground.

* Other parasites in N.S.W. rainforests, and also the saprophytes, are fungi, some with very distinctive and attractive fruiting bodies.

Appendix 3

RAINFOREST LEAGUES AND TYPES RECOGNISED IN CLASSIFICATION OF FORESTRY COMMISSION OF NSW (1989)

A(a) SUBTROPICAL RAINFOREST LEAGUE

This league contains tall rainforest communities of mixed composition and very luxuriant appearance. These are closely allied to the tropical rainforests of the equatorial zones, and they are marked by the prevalence of buttressed trees, vascular epiphytes and lianes. The league occurs in coastal and escarpment sites on soils of high fertility (commonly derived from basalt or alluvium) in areas with ample moisture. It is found as far south as the central South Coast, but reaches its best development in the northern parts of the State, where it is often marked by a partial dominance of Booyongs.

Seven types are recognised, one of these (Palm type) being rather atypical in structure, though clearly derived from certain of the other types in the league.

1. Booyong. Very mixed composition; but with Black or White Booyong, or both, being the most common species. (Black Booyong more common at higher altitudes, and to south.) Other common species include Pigeonberry Ash, Silver Quandong (along watercourses), Giant Stinger, White Beech, Red Cedar, Yellow Carabeen, Crows Ash, Silver Ash, Prickly Ash, Rosewood, Red Carabeen, Flametree, Native Tamarind and strangling Figs. Large Hoop Pine occasionally present; large vines and Lawyer Cane frequent. Typically on basaltic red loam soils in northern NSW, with rainfall exceeding 1 500mm a year. Stand height over 35m, sometimes approaching 60m. Common in Richmond and Tweed River districts, extending south to Manning River.

2. Yellow Carabeen. Similar to Booyong, but with large, wide-crowned Yellow Carabeen approaching dominance and Booyong a subordinate species. Found in higher and more exposed sites than Booyong type under otherwise similar conditions; height generally somewhat less (30m or over)

3. Corkwood-Sassafras-Crabapple-Silver Sycamore. A type of mixed and variable composition, but with at least two, and commonly all four, of the named species among the more common trees present. Booyongs may be present towards north of the range, and Coachwood in more southern sites, but only as subordinate species. Tends to replace types 1 & 2 on similar sites south of the occurrence of the Booyongs, and is found chiefly from the Hastings River south to near Milton; also occurs in MacPherson Ranges on somewhat less fertile soils than basalt (commonly on associated acid igneous flows), often with a predominance of Crabapple or Corkwood.

4. Black Bean. Found on alluvial soils fringing watercourses in northeast of State. Black Bean clearly dominant, with Silky Oak and Brown Pine common associates. A depauperate form often extends well beyond the main stands as a low gallery rainforest.

5. Booyong-Coachwood. Combines the composition of the Booyong(1) and Coachwood-Crabapple (11) types, often with strangling Figs conspicuous, and frequently associated with stands of Flooded Gum and Brush Box in coastal gully sites. The gully sites often carry soils rather less fertile than those normally supporting Booyong type, but better than those where Coachwood types are dominant. A common gully community in parts of the North Coast.

6. Fig-Giant Stinger. A somewhat depauperate type of subtropical rainforest, with rather poorly developed structure: this and the presence of Stinger suggest stands subject to frequent disturbance. Besides the named species, Sassafras, Socketwood, Basswood and various species of Lauraceae and Myrtaceae are commonly present. Often found in rather sheltered sites on fertile soils beyond the general limits of subtropical rainforest - most common in lower South Coast, but found elsewhere (including gullies in Liverpool Range, west of Murrurundi; Fisher, 1985).

7. Palm. A clear dominance of Bangalow Palm, Cabbage Tree Palm or both, often with Lawyer Cane also present, and with other rainforest trees which are usually of low stature. Typically on sites with excessive soil moisture. Usually in small stands of limited extent, within the general bounds of wider rainforest occurrence. Not structurally subtropical rainforest, but clearly derived from it.

A(b) WARM TEMPERATE RAINFOREST LEAGUE

This league is distinguished from the Subtropical Rainforest league by its generally simpler structure and composition. There are usually only two tree storeys; buttressing and lianes are less common; and there is a strong tendency for a single species, often Coachwood, to dominate the communities. Unlike the Subtropical Rainforest league, its floristic affinities lie more with the temperate Gondwanan than the subtropical element. The league occurs in coastal and escarpment sites throughout eastern N.S.W., but typically occupies sites that are either cooler or located on less fertile soils than the Subtropical Rainforest league.

Six types have been recognised, four with Coachwood as the most prevalent species. Whilst these four appear to be ecologically distinct, for most practical purposes they can probably best be regarded as forming a single Coachwood type. The other two types normally lack Coachwood.

10. Coachwood. Coachwood dominant, often occurring with Lilly Pilly and commonly with Native Tamarind. Crabapple and Sassafras rare or absent. Stands often under 2Gm, found in parts of Central and South Coasts.

11. Coachwood-Crabapple. A widespread type on the North Coast, with the Coachwood contributing over 50 per cent of stand. Occurs under generally similar climatic conditions to the Booyong type (1), but on soils of lower fertility (sedimentary or acid igneous rocks). Normally up to 40m in height, and in some places (parts of eastern Dorrigo Plateau) with formerly a Hoop Pine overstorey up to 50m. Other associates include Sassafras, Prickly Ash, Red Plum and Silver Sycamore; Bonewood often common in understorey.

12. Coachwood-Sassafras. Similar to preceding type, but with Sassafras the most common associate, and the Coachwood sometimes less predominant. Replaces the Coachwood-Crabapple type under cooler conditions, and may occur on basalt soils (e.g. at Mt. Wilson, in Blue Mountains). Higher altitudes on North Coast (edge of New England Tableland), and extending to South Coast.

13. Water Gum-Coachwood. A type of limited extent on elevated and exposed sites in northern N.S.W., with dense stockings of rather small trees; associates may include Crabapple, Banksia and Lauraceae. A variant also occurs as a narrow band in sandstone gullies near Sydney.

14. Lilly Pilly. Most common on South Coast, but occurring further north; height rarely over 20m. Associates with Lilly Pilly may include Grey Myrtle, Pinkwood, Water Gum and Scentless Rosewood. A better structured form of the Myrtle type (23).

15. Sassafras. Whilst commonly an associated species in N.S.W. rainforests, Sassafras occasionally is the clear dominant in stands up to 25-30m high, occurring both in gully sites and in more exposed stands, usually at relatively high altitude. Associates may include Crabapple in north and Pinkwood in south of State.

A(c) COOL TEMPERATE RAINFOREST LEAGUE

This league is closely allied to the Warm Temperate Rainforest league, but differs in the following ways:-

1. A significant proportion of the stand is made up of trees, mostly of a single species, of large individual diameter. In the previous league this size class segregation is unusual. .

2. Leaf-sizes tend to be smaller.

3. Non-vascular epiphytes (e.g. mosses and lichens) are very common.

4. Lianes and buttressing are usually rare.

16. Negrohead Beech. A clear dominance of Negrohead Beech, usually as large trees, with associated smaller stems of Sassafras, Southern Sassafras, Prickly Ash, Mountain Quandong and other species. In favoured sites (e.g. Cobark Forest Park on Barrington Tops S.F.) stands may exceed 40m in height, but in exposed sites they may appear as a low dense thicket under 10m high. Occurs both in small stands and over extensive areas in mesic sites over about 750 to 800m, and extending up to 1 500m. Occurs in escarpment regions of the North Coast, from the Barrington Tops northwards.

17. Negrohead Beech-Coachwood. Similar to the previous type, except that Coachwood is the most common associate, usually a smaller tree whose numerous stems may contribute a BA similar to that of the fewer, but larger, Beech trees. Extends to lower altitudes (450m on eastern Dorrigo Plateau), though mostly over 750m altitude.

18. Pinkwood. Stands with a dominance of Pinkwood, often as a large tree surrounded by clumps of basal suckers. Associates may include Sassafras, Southern Sassafras, Lilly Pilly and Mountain Quandong. Found in favoured sites on usually elevated sites on the South Coast.

19. Mountain Quandong. Occasionally is the clear dominant in stands on elevated sites in the far South Coast. Associates include Southern Sassafras and Lilly Pilly.

20. Mountain Walnut. An occasional type at high altitudes in northern N.S.W. Sassafras, Prickly Ash and Possumwood are usually associated. Often rather dense stands under 30m in height.

A(d) DRY AND DEPAUPERATE RAINFOREST LEAGUE

This league contains a number of types, some of which are only remotely allied to each other. However all are dominated by species with clear affinities to the rainforest flora, and they are usually marked by a relatively low (frequently under 12m) closed canopy, above which taller emergent trees may protrude. The stems making up this low canopy are of individually small stature, but tend to be numerous and to produce at times almost impenetrable thickets.

Only the Hoop Pine type is of significant commercial importance, but several of the other types serve important protection functions, notably the Tuckeroo and Headland Brush Box types. Other types can provide a serious regeneration problem in some sites.

Environmentally the league is found under a wide range of conditions. The Hoop Pine and Yellow Tulipwood types tend to replace the Subtropical Rainforest league on fertile soils under a lower and generally more seasonal rainfall regime, and under still drier conditions link the rainforest communities with some of the scrub communities of western New South Wales. Similarly certain phases of the Myrtle type in northern areas replace the Black Bean type as conditions become more adverse. Viney Scrub occurs under varying conditions, often as useless regrowth in sites where the original rainforest had been destroyed to make way for agriculture, while the Tuckeroo and Headland Brush Box types occur in rather exposed maritime situations.

21. Huon Pine. The dense understorey is typically rich in species of Sapindaceae and Euphorbiaceae, with Yellow Tulipwood as one of the most consistent species, and with occasional specialty timber species such as Ivorywood and Yellow Boxwood. The scattered emergent overstorey is dominated by Hoop Pine (sometimes removed by early logging, and still in process of being replaced), with Native Teak, Yellowwood, Silver Ash, Lacebark and other species, often xeromorphic or semi-deciduous. Found on moderately fertile soils with rainfall under 1300m. (Also occurs as a seral stage in the invasion of eucalypt forest by Booyong type; c.f. Cromer and Pryor, 1942.) Hoop Pine may reach 45m, other overstorey trees 35m, with understorey from 8 to 30m. Found in Clarence River district and further north.

22. Yellow Tulipwood. Similar to the Hoop Pine type, but the overstorey is lacking or confined to scattered individuals of Lacebark. Found in rather less favoured sites than the Hoop Pine type as far south as the Hunter River.

22. Myrtle. A general name for stands dominated by various species of Myrtaceae, and usually occurring as relatively narrow bands in coastal gullies. Usually of low height and simple structure. Dominants include, among many others, Grey Myrtle, Ironwood, Weeping Myrtle, Shatterwood (often of taller development) and the opposite-leaved Water Gum. Widespread in areas marginal for development of better structured rainforest.

24. Tuckeroo. Littoral rainforest dominated by Tuckeroo with Three-veined Laurel, Red Olive-berry, various Myrtaceae and other species. Often merely a thicket on exposed dunes, but up to 20m high, and with mixed composition, in more sheltered sites. Found originally along much of the North Coast littoral, and extending to the Central Coast.

25. Headland Brush Box. Dominated by Brush Box, but composition otherwise similar to preceding type, with which it is closely associated. Occurs on exposed coastal headlands; usually very wind shorn and varies from under 2m to over 12m in height.

26. Viney Scrub. Low, dense scrub of mixed composition, interlaced by vines and forming often almost impenetrable thickets. Often an early stage in the succession back to rainforest after its prior destruction. Widely distributed, particularly in some North Coast districts on freehold land.

Appendix 4

DETAILED RAINFOREST CLASSIFICATION FOR N.S.W.

(Floyd, 1984)

Alliance	Suballiance	Forestry Comm Type, Notes
SUBTROPICAL RAINFOREST		
I. White Booyong	1. White Booyong	1
	2. Red Cedar-Flindersia	1 (variant)
	3. Pepperberry-Fig-Giant Stinger- Hoop Pine	1 (variant) 6
	4. Silver Quandong	1 (variant)
	5. Black Bean-Silky Oak	4
	6. Bangalow Palm-Cabbage-Tree Palm	7
II. Black Booyong	7. Black Booyong	1
	8. Black Booyong-Hoop Pine	1
	9. Black Booyong-Red Bean-Giant Water Gum	1
	10. Black Booyong-Giant Stinger-Fig	1 or 6
III. Corkwood	11.Corkwood-Pigeonberry Ash-Prickly Ash -Doughwood-Red Apple	3(variant)
	12. Yellow Carabeen-Rosewood -Black Booyong-Corkwood	2
	13.Crabapple-Sassafras-Corkwood -Silver Sycamore	3
IV. Giant Stinger-Fig	14.Sassafras-Socketwood -Giant Stinger-Fig	6
	15. Giant Stinger-Fig	6
DRY RAINFOREST		
V. Yellow Tulipwood-Hoop Pine	16. Hoop Pine	21
	17. Flindersia -Hoop Pine	21
	18.Yellow Tulipwood-Lacebark- Native Olive	22
	19. Port Jackson Fig-Whalebone-tree-Stinger	6
VI. Black Bean-Weeping Myrtle	20. Black Bean-Silky Oak	4
	21. Weeping Byrtle-Water Gum	24
VII. Ironwood-Backhousia	22. Ironwood	23
	23. Shatterwood-Stinger-Yellow Tulipwood	23
	24. Grey Myrtle-Brush Cherry-Brush Box	23
	25. Grey Myrtle-Lilly Pilly	23
VII. Tuckeroo - Acmena	26. Small-leaved Water Gum -Broadleaved Lilly Pilly	23
	27. Tuckeroo	24
	28. Brush Box	25
	29. Yellow Tulipwood-Bauerella -Red Olive-berry-Brown Pine	22
	30. Lilly Pilly-Fig-Cabbage-tree Palm -Brown Pine	14
	31. Alectryon forsythii-Gorge Mock-olive	26 (thicket)

Alliance		Suballiance	Forestry Comm Type, Notes
WARM TEMPERATE RAINFOREST			
IX.	Coachwood	32.Coachwood-Black Booyong -Yellow Carabeen	5
		33. Coachwood-Native Tamarind- Lilly Pilly	10
		34. Coachwood-Crabapple-Corkwood	11
		35. Coachwood-Sassafras	12
		36. Coachwood-Lilly Pilly-Sassafras	12
		37. Coachwood-Pinkwood-Sassafras- Lilly Pilly	12/18
X.	Sassafras	38.Crabapple-Sassafras-Corkwood -Silver Sycamore-Prickly Ash	3
		39. Sassafras-Possumwood	15
		40. Sassafras-Crabapple	15
XI.	Lilly Pilly	41. Lilly Pilly-Sassafras	14
		42. Lilly Pilly-Grey Myrtle	14
		43. Lilly Pilly-Sassafras/Socketwood -Giant Stinger-Fig	14/6
		44. Lilly Pilly-Cabbage-tree Palm	14/7
		45. Lilly Pilly	14
		46. Lilly Pilly-Pinkwood-Sassafras	14/18
XII.	Water Gum	47. Water Gum-Coachwood-Crabapple	13
XIII.	Yellow Tea-tree	48.Yellow Tea-tree-Veined Mock-olive -Mint-bush	26 (closed scrub)
COOL TEMPERATE RAINFOREST			
XIV.	Negrohead Beech	49. Negrohead Beech-Possumwood-Sassafras	16
		50. Negrohead Beech-Coachwood	17
		51. Negrohead Beech-Callicoma-Water Gum	16
		52. Negrohead Beech-Sassafras -Prickly Ash-Corkwood	16
		53. Negrohead Beech-Mountain Quandong	16
XV.	Pinkwood	54. Pinkwood	18
		55. Pinkwood-Mountain Quandong	18
		56. Pinkwood-Sassafras	18
		57. Pinkwood-Lilly Pilly	18
XVI.	Mountain Quandong	58. Mountain Quandong-Southern Sassafras	19
		59. Mountain Quandong	19
		60. Native Musk-Blanket-leaf	26/224

Appendix 5

CLIMATIC SUMMARIES FOR STATIONS IN OR NEAR RAINFOREST AREAS

CONDONG : **Latitude** 28° 19'S **Longitude** 153° 26' E **Altitude** 5m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
220	**250**	**264**	**149**	**138**	**124**	**93**	**73**	**66**	**88**	**106**	**151**	**1722**

Temperature

Hottest Month: Mean Min : 18.6°C Mean Max: 28.6°C
Coldest Month: Mean Min: 5.8°C Mean Max: 21.2°C

WHIAN WHIAN : **Latitude** 28° 36' S **Longitude** 153° 23'E **Altitude** 380m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
352	382	318	189	155	194	146	103	74	149	135	191	2388

Temperature

Hottest Month: Mean Min : 16.7°C Mean Max: 25.7°C
Coldest Month: Mean Min: 5.8°C Mean Max: 15.5°C

CASINO : **Latitude** 28° 52' S **Longitude** 153° 3'E **Altitude** 25m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
143	157	148	95	73	69	62	45	46	71	86	112	1107

Lowest Annual: 490mm Highest Annual: 1955mm

Temperature

Hottest Month: Mean Min : 18.7°C Mean Max: 31.4C
Coldest Month: Mean Min: 6.3°C Mean Max: 21.3°C
Highest recorded: NA Lowest recorded: -5°C
No. over 32^{0}C: 69 days Over 38^{0}C: 5 days
Av. No. Frosts/ year: 1 Ave frost free period: 317 days

CLOUDS CREEK : **Latitude** 30° 6'S **Longitude** 152° 36'E **Altitude** 590m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
228	188	172	83	62	89	62	68	49	109	122	165	1397

Lowest Annual: 680mm Highest Annual: 2450mm

Temperature

Hottest Month: Mean Min : 14.8°C Mean Max: 26.9°C
Coldest Month: Mean Min: -0.3°C Mean Max: 16.4°C
Highest recorded: 41°C Lowest recorded: -9.4°C
No. over 32^{0}C: 10 days Over 38^{0}C: 1 days
Av. No. Frosts/ year: 62 Ave frost free period: 216 days

BROOKLANA : **Latitude** 30° 18'S **Longitude** 152° 48'E **Altitude** 567m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
209	243	250	161	119	151	113	72	75	91	117	158	1759

Lowest Annual: 931mm Highest Annual: 3294mm

Temperature

Hottest Month: Mean Min : 15.6°C Mean Max: 26.6°C
Coldest Month: Mean Min: -0.6°C Mean Max: 16.9°C
Highest recorded: 38.9°C Lowest recorded: -8.1°C
No. over 32^{0}C: 9 days Over 38^{0}C: less than 1
Av. No. Frosts/ year: 62 Ave frost free period: 238 days

COFFS HARBOUR: **Latitude** 30° 19'S **Longitude** 152° 11'E **Altitude** 3m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
215	251	250	191	134	126	65	105	68	105	100	149	1759

Lowest Annual: 684mm Highest Annual: 3376mm

Temperature

Hottest Month: Mean Min : 19.0°C Mean Max: 26.5°C
Coldest Month: Mean Min: 6.6° C Mean Max: 18.5°C
Highest recorded: 43.3°C Lowest recorded: -3°C
No. over 32^{0}C: 14 days Over 38^{0}C: less than 1
Av. No. Frosts/ year: 0 Ave frost free period: all year

STYX RIVER : **Latitude** 30° 37'S **Longitude** 152° 11'E **Altitude** 1 036m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
204	208	207	106	81	120	81	81	62	105	112	149	1516

Lowest Annual: 1215mm Highest Annual: 2818mm

Temperature

Hottest Month: Mean Min : 14.6°C Mean Max: 25.4°C
Coldest Month: Mean Min: 2.8° C Mean Max: 11.9°C
Highest recorded: 38°C Lowest recorded: -3°C
No. over 32^{0}C: 3 days Over 38^{0}C: 0 days
Av. No. Frosts/ year: 61 Ave frost free period: 192 days

CAMERONS CAMP: **Latitude** 31° 12'S **Longitude** 152° 24'E **Altitude** 840m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
331	299	318	165	130	142	74	73	70	164	191	189	2146

Temperature

Hottest Month: Mean Min : 14.2°C Mean Max: 23.4°C
Coldest Month: Mean Min: 5.0° C Mean Max: 12.4°C

KATOOMBA : **Latitude** 33° 43'S **Longitude** 150° 18'E **Altitude** 1 011m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
161	173	159	122	100	124	93	79	73	89	101	132	1405

Lowest Annual: 618mm Highest Annual: 2782mm

Temperature

Hottest Month: Mean Min : 12.9°C Mean Max: 23.4°C
Coldest Month: Mean Min: 2.7° C Mean Max: 9.3°C
Highest recorded: 38.9°C Lowest recorded: -3.1°C
No. over 32^{0}C: 4 days Over 38^{0}C: less than 1
Av. No. Frosts/ year: 11 Ave frost free period: 200 days

ULLADULLA : **Latitude** 35° 22'S **Longitude** 150° 29'E **Altitude** 9m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
98	116	116	120	129	143	68	90	79	109	96	102	1266

Temperature

Hottest Month: Mean Min : 16.7°C Mean Max: 24.3°C
Coldest Month: Mean Min: 7.2° C Mean Max: 17.1°C

NALBAUGH S.F. : **Latitude** 37° 4'S **Longitude** 149° 21'E **Altitude** 731m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
88	107	78	84	101	127	91	99	75	88	122	105	1165

Temperature

Hottest Month: Mean Min : 10.8°C Mean Max: 23.7°C
Coldest Month: Mean Min: -0.1°C Mean Max: 10.7°C

Appendix 6

RAINFOREST STUMPAGE GROUPS (DECEMBER 1981)

(Price margins relative to Group B. medium sized logs)

Red Cedar Group (Price margin $79 per cubic metre net volume)

Red Cedar	Tulipwood
White Beech	Deep Yellowwood
Ivorywood	Saffronheart
Black Apple	Deep Muskheart
Yellow Boxwood	

Hoop Pine (Margin $46.30 per cubic metre)

Hoop Pine

Group A (Margin $6.75 per cubic metre)

Crows Ash	Crabapple
Silver Ash	Yellowwood
Coachwood	

Group B (No margin)

Pigeonberry Ash	Brown Pine
Prickly Ash	Pinkwood
Bollywood	Possumwood
Yellow Carabeen	Silver Quandong
Corkwood	Rosewood
Brush Cypress Pine	Silky Oak
Flametree	Silver Sycamore
Pepperberry	

Group C (Margin - $3.35 per cubic metre)

Red Ash	Camphorwood
Black Bean	Red Carabeen
Red Bean	Doughwood
Beef wood	Sassafras
Black Booyong	Satin Oak
White Booyong	

Group D (Margin - $10.10 per cubic metre)

Grey Ash	Plumwood
Negrohead Beech	Silky Beech
Hard Bollywood	Other rainforest species

FLOWERING AND FRUITING IN NSW RAINFOREST TREES
(data from Floyd, 1976-83)

Family	No. Species	Seed Type (1)			No Species Flowering (Fruiting) each Month (2)											
		Fl	**W**	**0**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lauraceae	33	33			7(7)	7(12)	7(16)	6(19)	6(15)	3(10)	3(7)	2(4)	3(5)	16(6)	17()	10()
Myrtaceae	33	27	6		11(8)	4(7)	4(8)	5(6)	5(11)	4(10)	4(13)	2(11)	4(6)	7(4)	19(6)	19(3)
Rutaceae	31	9	6	16	13(8)	12(12)	6(12)	4(13)	5(13)	3(12)	2(9)	5(9)	6(8)	10(4)	12(5)	7(2)
Sapindaceae	30	26	3	1	7(6)	5(3)	7(5)	7(7)	4(7)	2(5)	1(8)	2(6)	8(5)	10(6)	12(15)	9(12)
Euphorbiaceae	23	7	2	14	8(9)	2(11)	3(8)	3(10)	2(9)	3(6)	4(5)	4(5)	8(6)	15(4)	18(5)	12(7)
Proteaceae	13	3	7	3	4(4)	3(4)	2(3)	1(5)	1(7)	3(8)	3(4)	4(3)	5(3)	6(1)	6(1)	4(1)
Rubiaceae	12	12			5(2)	5(2)	3(2)	1(6)	2(7)	3(8)	1(9)	2(5)	3(8)	3(1)	7(3)	5(3)
Leguminosae (3 Fam)	11			11	3(2)	1(3)	1(4)	4	(3)	(5)	(3)	2(2)	5(2)	6(3)	7(3)	5(2)
Meliaceae	9	8	1		3(4)	3(5)	3(4)	4(2)	4(3)	3(2)	2(1)	1(3)	(4)	3(2)	3(3)	1(3)
Moraceae	9	9			(5)	(6)	(5)	(6)	(5)	(6)	(5)	(3)	(3)	(3)	(3)	(3)
Monimiaceae	8	4	4		1(4)	1(1)	1(1)	1(2)	3(3)	3(3)	2(4)	2(3)	5(2)	4(1)	3(2)	1(4)
Sapotaceae	8	7		1	1(2)	2(1)	3(1)	2(2)	4(3)	4(3)	4(2)	4(3)	4(5)	5(6)	3(5)	2(2)
Sterculiaceae	8	1	2	5	4(3)	1(1)	1(2)	1(1)	(4)	(4)	1(4)	1(1)	2(1)	2(2)	4(2)	5(3)
Celastraceae	7	7			2(1)	(3)	1(4)	1(6)	(5)	(4)	(3)	1(2)	2(1)	4	4	2
Cunoniaceae	7	1	6		1(1)	(3)	(4)	(3)	(4)	(4)	(3)	1(2)	1	3	4	3
Elaeocarpaceae	7	7			2(2)	1(2)	2(4)	1(3)	1(5)	1(5)	(3)	(3)	2(2)	4(2)	5(1)	3(1)
Urticaceae	4	4			4(1)	3(1)	3	1(1)	(1)	(2)	1(3)	(2)	(1)		2	2
Fagaceae	1			1	(1)	(1)						1	1	1		(1)
Others (39 Fam.)	83	63	13	7	32(34)	20(36)	13(32)	9(34)	9(33)	11(28)	14(21)	13(17)	23(14)	39(14)	49(23)	33(37)
Totals	**337**	**228**	**50**	**59**	**108(104)**	**70(114)**	**60(115)**	**47(130)**	**46(137)**	**43(125)**	**42(107)**	**47(84)**	**82(76)**	**138(59)**	**175(82)**	**123(88)**

Notes: (1) **Fl**: fleshy; (2) 1st no. is species flowering; 2nd (in brackets) is species
W: winged;
O: other

Appendix 8

REGENERATION IN LOGGED RAINFOREST STANDS

A. Subtropical Rainforest

1. South Queensland (Dale, 1933)

Total stocking/ha about 12 years after logging:	
Stems 3-6m high	3 026
Stocking of main commercial species	1 079

2. Former Wiangaree S.F. (Burgess et al., 1975).

Various logging treatments, complete 12 months previously

	Stems under 1.5m high	**Stems >1.5m - 10cm DBH**
Quadrat size m²	4	25
Quadrats stocked %	19	86
Stocking/ha	3 100	1 640

(All regeneration of commercial spp. Most abundant regenerating spp. were Red Carabeen, Corkwood, Pigeonberry Ash, Doughwood and Booyongs.)

B. Warm Temperate Rainforest

3. Moonpar S.F. (Horne and Mackowski, 1987)

Various intensities of logging, 28 years previously. **Stocking /ha.**

	All species	**Commercial species**
Under 30cm high	22 170	9 990
30 - 130cm high	11 090	7 120
130cm high - 2.5cm DBH	7 300	5 290
2.6 - 9.9cm DBH	2 500	1 880

4. Doyles River S.F. (King and Chapman, 1983)

Heavy logging, 25 years previously

	Stocking/ha	
	1m high- 5cm DBH	**5-9.9cm**
Coachwood	7294	108
Bonewood	2696	245
Sassafras	784	157
Prickly Ash	510	69
Corkwood	451	39
All spp.	13 970	755

5. Wild Cattle Creek S.F. (Morora Creek) (Forrest, 1961)

Moderate logging about 15 years previously; seedfall following year. (plots only 0.84 m²)

	Stocking (/ha)	**Tallest height (m)**
Coachwood - Plot 1	c.420 000	2.9
Coachwood - Plot 2	650 000	2.8

6. Wild Cattle Creek S.F. - near site 5 (Forrest, 1961)

Moderate logging 17 years previously. 25 m^2 quadrats. Stems 3.6m high to 10cm DBH

	Coachwood	All species
Quadrats stocked %	62	87
Stocking /ha	1 120	2 330

7. Wild Cattle Creek S.F. (Bo Bo) (Forrest, 1961)

	% Stocked
Moderate logging 16 years previously. 4m² quadrats.	
Stems >6m in quadrat	41
< 6m - Hoop Pine (selected stem)	4
- Coachwood	37
- Other spp.	16
Unstocked	2

Average height of selected Coachwood regeneration about 2m.

8. Orara West S.F. (Forrest, 1961)

Almost complete logging 30 yrs + previously. 4 m² quadrats

	Plots stocked (%)
Coachwood	54
Other useful spp.	34

Average height of Coachwood about 3m.

9. Moonpar S.F. (Forrest, 1961)

Very heavy logging 5-10 yrs previously; heavy dieback.
4 m² quadrats

	Plots stocked (%)
Coachwood	73
Any useful species	76

10. Wild Cattle Creek S.F. (Cascade) (Forrest, 1961)

Almost complete logging 30 yrs + previously.

Total Stocking	Coachwood	All species
30cm-3.6m high	6 672	8 525
3.6m high-5cm DBH	2 669	4 645
5cm DBH +	346	1 359

C. Cool Temperate Rainforest

11. Mt. Boss S.F. (Porada, 1980)

Various logging histories, 2-18 years previously.

	Seedlings (- 60 cm high) **(% 4 m² quadrats stocked)**	**Advanced Growth** (60cm high-10cm DBH) **(% total Adv. Growth stocking)**
Negrohead Beech	32	10
Coachwood	20	17
Sassafras	18	17
Prickly Ash	61	2
Other species	-	55
All species	92	100
Total Stocking/ha	**-**	**1 425**

Appendix 9

RAINFOREST GROWTH RATES - CUMBERLAND S.F. ARBORETUM (WEST PENNANT HILLS)

Note: The following measurements were made at about age 50 years (measured 1988; planted 1938-42) and represent the largest measurements for each species, listed in order of height. Where height and DBH represent measurements from different trees, this is indicated by the symbol*.

Planting and growing conditions vary between both species and individual trees. Growth rates should be regarded as indicative only of likely development under moderately favourable conditions near Sydney.

Species	No. Stems	Best Height (m)	Best DBH (cm)
Hoop Pine	7*	33.6	56
Silky Oak	18	30.1	39
Red Ash	19	26.7	41
Lacebark	2	26.5	42
Crows Ash	8	26.4	30
Bunya Pine	2*	24.4	60
White Beech	3	23.9	26
Black Bean	5	23.4	28
Queensland Maple	2	22.6	30
White Booyong	3	22.3	29
Hairy Rosewood	1	20.9	20
Thickleaved Laurel	1	20.4	35
Broadleaved Leopard Tree	2	20.1	17
Red Cedar	2	20.0	33
Batswing Coral Tree	2	19.6	26
Rusty Plum	7*	19.4	36
Native Tamarind	1	19.0	17
Yellow Ash	2*	18.4	32
Flametree	8	18.0	24
Scrub Ironbark	4	17.5	23
Bitterbark	1	17.4	20
Weeping Myrtle	1	17.0	18
Murrogun	1	16.9	25
Native Frangipanni	5	16.7	16
Ironwood	3*	16.5	16
Scrub Bloodwood	8	16.1	23
Rose Maple	8*	15.9	14
Duboisia	7*	15.1	25
Beefwood	6*	15.1	16
Wheel-of-Fire Tree	3	13.1	11
Water Gum	2	12.8	15
Deep Yellowwood	2*	12.1	30
Silky Ash	1	11.8	14
Brush Turpentine	2	11.8	12
Macadamia	3	11.4	9
Yellow Persimrnon	2	10.6	9
Red Olive Berry	1	10.0	10
Red Boppel Nut	2	8.4	9
Yellow Tulipwood	1	7.4	9
Lilly Pilly	1	4.9	5

Appendix 10

RECORDS OF LARGE RAINFOREST TREES IN N.S.W.

Botanical Name	Common Name	Location	DBH (m)	Height (m) (Note)
Acacia bakeri	Marblewood	Black Scrub F.R.	0.90	40
A. melanoxylon	Blackwood	Mt. Dromedary F.R.	1.00	35
		Maxwells F.R.	0.84	39
Alphitonia excelsa	Red Ash	Koreelah S.F.	1.16	42
Araucaria cunninghamii	Hoop Pine	Toonumbar S.F.	1.42	56
		Beaury S.F.	1.87	50
		Julia Five Day S.F.	1.30	62 (1)
Argyrodendron actinophyllum	Black Booyong	Unumgar S.F.	1.71	50
Backhousia anisata	Ringwood	Irishman S.F.	1.40	43
			1.38	49
B. sciadophora	Shatterwood	Black Creek F.R.	1.01	45
Callitris macleayana	Brush Cypress Pine	N.W. Jolly F.R.	0.19	39
		Kangaroo River F.R.	0.82	33
Ceratopetalum apetalum	Coachwood	Newnes S.F.	1.09	38
Citronella moorei	Silky Beech	Ellis S.F.	2.51	44 (2)
Cryptocarya erythroxylon	Pigeonberry Ash	Toonumbar S.F.	1.22	57
C. foveolata	Mountain Walnut	Little Spirabo S.F.	1.20	45
Daphnandra micrantha	Socketwood	Murray Scrub F.R.	0.56	34
Dendrocnide excelsa	Giant Stinger	Beaury S.F.	4.34	43
Diploglottis cunninghamii	Native Tamarind	Ingalba S.F.	0.57	36
Doryphora sassafras	Sassafras	Cangai S.F.	1.10	44
		Little Spirabo S.F.	0.90	50
Dysoxylum fraseranum	Rosewood	Koreelah S.F.	3.55	57
		Murray Scrub F.R.	1.59	49
D. muelleri	Red Bean	Mebbin Lagoons F.R.	1.61	53
Ehretia acuminata	Silky Ash	Daisy Patch F.R.	0.85	30
Elaeocarpus holopetalus	Mountain Quandong	Brown Mtn. F.R.	2.00	25
Erythrina vespertillio	Batswing Coral Tree	Toonumbar S.F.	0.84	12
Ficus eugenioides	Small-leaved Fig	Chichester S.F.	3.30	50 (2,3)
F. fraseri	Sandpaper Fig	Murray Scrub F.R.	0.61	24
F. watkinsiana	Greenleaved Moreton Bay Fig	Moore Park (nr. Kyogle)	5.60	54 (2,4)
Flindersia australis	Crows Ash	Urbenville District (PP)	2.60	50

Gmelina leichhardtii	White Beech	Wonga Wanga F.R.	1.69	42
		Tooloom Scrub F.R.	2.62	40
		former Roseberry S.F.	2.23	48
		former Goonimbar S.F.	2.61	59
Grevillea robusta	Silky Oak	Unumgar S.F	0.90	42
Nothofagus moorei	Negrohead Beech	Chichester S.F.	2.94	48
Podocarpus elatus	Brown Pine	Toonumbar S.F.	1.29	30
Schizomeria ovata	Crabapple	N.W. Jolly F.R.	1.04	38
Sloanea woollsii	Yellow Carabeen	N.W. Jolly F.R.	1.97	
		Bulga S.F.	2.51	55 (2)
Syzygium francisii	Giant Water Gum	Richmond Range S.F.	1.20	40
Toona australis	Red Cedar	Wild Cattle Creek S.F.	2.26	40 (5)
		Yabbra S.F.	2.90	54
		Julia-Five Day S.F.	1.68	51
		Orara West S.F.	2.49	38 (2)
Tristaniopsis collina	Water Gum	Dingo S.F.	1.45	39

Note: (1). This is the tallest known Hoop Pine in N.S.W., and occurs only 7km from the southernmost specimen. The tallest known Hoop Pine, in Papua New Guinea, has a height of 70.8m, and the largest DBH (also from PNG) is 1.74m.

(2). Diameter measured above buttresses.

(3). Crown spread 40m (largest recorded natural crown spread in N.S.W.)

(4). Crown spread 38m.

(5). The largest recorded Red Cedar (and probably the largest tree to have occurred in N.S.W.) was felled on a private holding near Nulla Creek, in the Macleay River district, in 1883. It reputedly yielded 240 m^3 of timber.

Appendix 11

PRESERVED AREAS WITH RAINFOREST ON STATE FOREST

More complete information about most of these sites is given in the 2nd edition of Forestry Commission of N.S.W. Research Note No. 47, "Forest Preservation in State Forests of N.S.W.", 1989. Types specifically mentioned as occurring in a particular preserved area by Floyd (1984) are listed as "Floyd type"; these types are listed in Appendix 4. Only rainforest types present are referred to, though most areas also carry other vegetation.

Flora Reserves

Tooloom Scrub F.R. No. 1. Beaury S.F. 1665 ha. Booyong, Hoop Pine, Myrtle types. Floyd types 7, 12.

Bruxner Park F.R. No. 3. Orara East S.F. 407 ha. Booyong-Coachwood type. Floyd type 32.

Brown Mountain F.R. No. 4. Glenbog S.F. 955 ha. Pinkwood type. Floyd type 58.

Kerripit Beech F.R. No. 6. Barrington Tops S.F. 243 ha. Negrohead Beech type.

Mount Dromedary F.R. No. 7. Bodalla S.F. 1259 ha. Fig-Giant Stinger, Sassafras-Lilly Filly, Pinkwood types. Floyd types 14, 56.

Sugar Creek F.R. No. 8. Wallingat S.F. 85 ha. Palm, Coachwood-Crabapple types. Floyd type 6.

Bundagen F.R. No. 9. Pine Creek S.F. 73 ha. Red Bean, Tuckeroo, Headland Brush Box types. Floyd types 26, 27.

Boogareem Falls F.R. No. 10. Nullum S.F. 8 ha. Booyong type. Rare spp.

Jerewarrah F.R. No. 12. Ewingar S.F. 243 ha. Yellow Carabeen type.

Woolgoolga Ck. F.R. No. 13. Wedding Bells S.F. 8 ha. Silver Quandong (Booyong) type. Floyd types 4, 32.

Rowleys Rock F.R. No. 15. Bulga and Dingo S.F.'s. 146 ha. Booyong, Myrtle types.

Mines Road F.R. No. 18. Bellangry S.F. 20 ha. Booyong-Coachwood type.

Mobong Creek F.R. No. 19. Wild Cattle Creek S.F. 14 ha. Booyong, Coachwood types.

O'Sullivans Gap F.R. No. 20. Bulahdelah and Wang Wauk S.F's. 320 ha. Coachwood type. Floyd type 32.

Mount Nothofagus F.R. No. 24. Donaldson S.F. 650 ha. Yellow Carabeen, Booyong, Negrohead Beech types. Floyd types 10, 12, 13, 16, 38, 47, 48, 51.

Glenugie Peak F.R. No. 25. Glenugie S.F. 105 ha. Yellow Tulipwood type. Floyd type 18.

Minyon Falls F.R. No. 27. Whian Whian S.F. 110 ha Palm, Booyong type. Floyd type 6.

Black Bull F.R. No. 28. Wild Cattle Creek S.F. 47 ha Coachwood type.

Teak Tree F.R. No. 29. Wild Cattle Creek S.F. 20 ha. Hoop Pine type.

Big Scrub F.R. No. 30. Whian Whian S.F. 196 ha. Booyong type.

Chapmans Plain F.R. No. 31. Clouds Creek S.F. 25 ha. Booyong type, natural grassland.

Tulipwood F.R. No. 32. Kangaroo River S.F. 60 ha. Hoop Pine type.

Lorne F.R. No. 36. Lorne S.F. 179 ha. Booyong type.

Norman V. Jolly F.R. No. 37. Moonpar S.F. 52 ha. Coachwood-Crabapple type.

Boomerang Falls F.R. No. 38. Whian Whian S.F. 52 ha. Booyong, Coachwood types.

Madmans Creek F.R. No. 42. Conglomerate S.F. 92 ha. Hoop Pine type.

Wonga Wanga F.R. No. 43. Orara West S.F. 25 ha. Coachwood type.

Blicks River F.R. No. 46. Hyland S.F. 285 ha. Negrohead Beech occurrence.

Red Cedar F.R. No. 47. Wild Cattle Creek S.F. 46 ha. Booyong type with Red Cedar grove. Floyd type 16.

Cambridge Plateau F.R. No. 49. Richmond Range S.F. 870 ha. Booyong, Hoop Pine types. Floyd type 16.

Bungdoozle F.R. No. 50. Richmond Range S.F. 145 ha. Booyong type.

Murray Scrub F.R. No. 51. Toonumbar S.F. 740 ha. Booyong type. Floyd types 1, 9.

Tinebank F.R. No. 52. Kippara S.F. 141 ha. Yellow Carabeen type.

Mallanganee F.R. No. 53. Cherry Tree North S.F. 222 ha. Hoop Pine type. Floyd types 17, 18.

Ringwood F.R. No. 57. Gladstone and Irishman S.Fs. 60 ha. Yellow Carabeen type, with Ringwood locally dominant; Coachwood-Crabapple type.

Chandlers Creek F.R. No. 58. Marara S.F. 989 ha. Hoop Pine type.

Banda Banda F.R. No. 60. Mt. Boss and Yessabah S.Fs. 1610 ha. Yellow Carabeen, Coachwood-Sassafras, Negrohead Beech-Coachwood, Myrtle types. Floyd type 50.

Steel Box F.R. No. 62. Mt. Pikapene S.F. 20 ha. Hoop Pine type.

Black Creek F.R. No. 63. Lorne S.F. 73 ha. Myrtle type (Shatterwood). Floyd type 23.

Middle Creek F.R. No. 65. Marengo S.F. 156 ha. High altitude Booyong-Coachwood type.

Fenwicks Scrub F.R. No. 67. Doyles River S.F. 110 ha. Coachwood-Sassafras type.

White Beech F.R. No. 71. Girard S.F. 100 ha. Crabapple-Sassafras- Corkwood-Silver Sycamore and Coachwood-Sassafras types.

Daisy Patch F.R. No. 76. Enfield S.F. 522 ha. Booyong, CoachwoodSassafras, Booyong-Coachwood types. Floyd type 35.

Sailors Hill F.R. No. 78. Boundary Creek S.F. 195 ha. Hoop Pine type.Floyd type 16.

Bago Bluff F.R. No. 79. Broken Bago S.F. 132 ha. Yellow Tulipwood type.

Warrawolong F.R. No. 80. Watagan and Olney S.Fs 105 ha. Mixed rainforest elements, including Socketwood, Rosewood, Coachwood and Sassafras.

Black Scrub F.R. No. 81. Nullum S.F. 40 ha. Booyong type.

Little Jilliby F.R. No. 82. Wyong S.F. 27 ha. Red Cedar groves with Black Apple, Rosewood and other subtropical species.

Bar F.R. No. 83. Watagan and Olney S.F.s 65 ha. Coachwood types.

Captains Creek F.R. No. 84. Beaury S.F. 380 ha. Hoop Pine type; much *Flindersia collina*. Floyd type 17.

Ralfes Creek F.R. No. 85. Doyles River S.F. 98 ha. Yellow Carabeen, Coachwood-Sassafras types.

Dorrigo White Gum F.R. No. 87. Moonpar S.F. 21 ha. Hoop Pine type.

Jerusalem Creek F.R. No. 88. Chichester S.F. 60 ha. Coachwood type.

Paddys Brush F.R. No. 89. Stewarts Brook S.F. 70 ha. Negrohead Beach type. Floyd type 53.

Mt. Clunie F.R. No. 90. Koreelah S.F. 485 ha. Booyong, Yellow Carabeen, Hoop Pine types; rainforest-derived scrub. Floyd types 8, 16, 38.

Peach Tree Creek F.R. No. 92. Currowan S.F. 30 ha. Grey Myrtle type.

Bunal F.R. No. 93. Bunal S.F. 182 ha. Western scrub with rainforest affinities.

Wilsons Peak F.R. No. 97. Koreelah S.F. 185 ha. Booyong type, warm temperate rainforest with Malletwood and Blue Cherry, scrub communities of rainforest derivation. Floyd type 8.

Acacia Plateau F.R. No. 99. Koreelah S.F. 585 ha. Booyong, Yellow Carabeen, Hoop Pine and Viney Scrub types.

Silvestris F.R. No. 100. Bodalla S.F. 57 ha. Grey Myrtle-Lilly Pilly type.

Tinpot F.R. No. 101. Bodalla S.F. 92 ha. Grey Myrtle-Lilly Pilly type.

Amaroo F.R. No. 103. Wollumbin S.F. 36 ha. Booyong type.

Cochrane F.R. No. 106. Cochrane S.F. 28 ha. Myrtle type.

Cangai Boards F.R. No. 108. Cangai S.F. 12 ha. Myrtle type.

Dome Mountain F.R. No. 109. Richmond Range S.F. 340 ha. Booyong, Hoop Pine, Myrtle types.

Twelve Sixty F.R. No. 111. Bagawa S.F. 300 ha. Booyong, Booyong-Socketwood-Crabapple, Hoop Pine types.

Dingo Creek F.R. No. 112. Little Spirabo S.F. 150 ha. Sassafras type. Floyd type 49.

Coolamangera F.R. No. 113. Forest Land S.F. 190 ha. Coachwood-Sassafras type. Floyd type 35.

Mebbin Lagoons F.R. No. 115. Mebbin S.F. 11 ha. Booyong-Red Bean type. Floyd type 9.

Maxwells F.R. No. 116. Nadgee S.F. 370 ha. Pinkwood type. Floyd type 57.

Werrinook F.R. No. 118. Bemboka S.F. 255 ha. Mountain Quandong type.

Mogood F.R. No. 121. Clyde S.F. 190 ha. Grey Myrtle type.

Cedar Pit F.R. No. 122. Styx River S.F. 100 ha. Yellow Carabeen type.

The Castles F.R. No. 123. Carrai S.F. 2360 ha. Booyong, Yellow Carabeen, Yellow Tulipwood, Myrtle types. Floyd types 10, 23, 24.

Watergums F.R. No. 127. Nadgee S.F. 238 ha. Pinkwood type.

Arandin F.R. No. 128. Glenugie S.F. 20 ha. Creek side Myrtle type.

Burnt Down Creek F.R. No. 132. Washpool S.F. 196 ha. Yellow Tulipwood type, with numerous Crows Ash. Floyd type 17.

Big Nellie F.R. No. 135. Lansdowne S.F. 58 ha. Coachwood type, with Booyong type elements.

Killiekrankie F.R. No. 135. Oakes S.F. 150 ha. Corkwood-Sassafras-Crabapple-Silver Sycamore type, with Booyong. Floyd type 7.

Cunnawarra F.R. No. 140. Styx River S.F. 400 ha. Coachwood-Sassafras, Negrohead Beech types. Floyd types 49. 59.

Cockerawombeeba F.R. No. 145. Mt. Boss S.F. 78 ha. Yellow Carabeen, Coachwood-Sassafras, Negrohead Beech-Coachwood type. Floyd types 12, 32.

Eucryphia F.R. No. 147. Monga S.F. 205 ha. Pinkwood type, associated with Sassafras in one gully, with Southern Sassafras in another. Floyd type 56.

Note: Flora Reserves No's. 149, 145, and 141 are described in Res. Note No. 47 (2nd edition) as Cunnawarra Forest Preserve No. 23, Cockerawombeeba F.P. No. 244 and Eucryphia F.P. No. 146 respectively. The description above of Banda Banda F.R. No. 60 includes an extension that was part of previous Crown Road Forest Preserve No. 192.

Forest Preserves

38. **Forty Spur F.P.** Mebbin S.F. 8 ha. Hoop Pine type with Ironbark also in overstorey.

120. **League Scrub F.P.** Oakes S.F. 36 ha. Booyong type. Floyd type 7.

124. **London Bridge F.P.** London Bridge S.F. 45 ha. Crabapple-Sassafras-Corkwood type.

140. **Mares Hill F.P.** Yadboro S.F. 18 ha. Coachwood-Sassafras type, with numerous Silky Beech. Floyd type 35.

141. **Lyons Creek F.P.** Currowan S.F. 259 ha. Coachwood-Sassafras type. Floyd type 36.

149. **Murrengenburg F.P.** Currowan S.F. 80 ha. Fig-Giant Stinger type.

159. **Wandella F.P.** Murrabrine S.F. 70 ha. Pinkwood type.

191. **Paddys Creek F.P.** Wandella S.F. 130 ha. Sassafras-Lilly Pilly type, occasional Pinkwood. Floyd type 46.

205. **Copeland Tops F.P.** Copeland Tops S.F. 264 ha. Fig-Giant Stinger, Yellow Tulipwood types.

217. **Hanging Mountain F.P.** Dampier S.F. 484 ha. Pinkwood type. Floyd type 54.

229. Wamban Creek F.P. Dampier S.F. 190 ha. Grey Myrtle type.

234. Coco Creek F.P. Nowendoc S.F. 95 ha. Mountain Walnut type.

237. Kioloa F.P. Kioloa S.F. 154 ha. Coachwood type. Floyd type 33.

242. Wilson River F.P. Mt. Boss S.F. 157 ha. Yellow Carabeen type.

246. Marowin Brook F.P. Kippara S.F. 583 ha. Crabapple-Sassafras-Corkwood-Silver Sycamore type.

266. Waalimma Mountain F.P. Yambulla S.F. 615 ha. Lilly Pilly type.

269. Gap Creek F.P. Olney S.F. 102 ha. Sassafras-Silver Sycamore type. Floyd type 33.

270. Snow Lichen F.P. Nullum S.F. 50 ha. Booyong type.

272. Mount Pericoe F.P. Coolangubra S.F. 860 ha. Fig type.

Note: Forest Preserves including and subsequent to No. 266. (Waalimma Mountain) are not detailed in Research Note No. 47 (2nd edition).