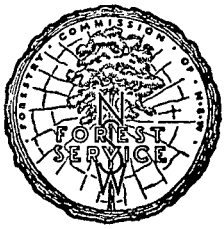

FORESTRY COMMISSION OF N.S.W.

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PREFACE

In 1957 the writer of this Research Note prepared a short paper entitled "Rainforest in Northern New South Wales—Silvicultural Problems" for the 7th British Commonwealth Forestry Conference, which was visiting several of the areas discussed. At that time planned research into the silviculture of the rainforest communities of New South Wales was of very recent origin, and the problems involved were far more obvious than the means of overcoming most of them.

Three and a half years later the stocks of the original paper were practically exhausted and it was suggested that the paper might be revised for republication. In the meantime the research programme had started to yield many results of value, and consequently the opportunity was taken to incorporate these into the revision. As a result this Research Note follows the same general pattern as the earlier one but has been enlarged, new terminology has been adopted in several places, and certain suggested treatments mentioned in the 1957 paper have been slightly modified to agree with the sounder information now available.

TABLE OF CONTENTS

SILVICULTURAL PRACTICES IN RAINFORESTS OF NORTHERN NEW SOUTH WALES

1. SUMMARY

Rainforest has a discontinuous distribution in New South Wales, being confined to the moister parts of the coast and adjacent ranges. Within these limits it occurs in patches of varying extent from the Victorian to the Queensland border and from sea-level to elevations of above 5,000 feet. Four major types of rainforest, subtropical, submontane, temperate and dry, are found, each having its particular requirements of soil and climate. Only about 200,000 acres of commercial rainforest remain within the State.

Past policy has been to convert the rainforests to pure, even-aged stands by artificial means. Various species have been used for conversion, including native and introduced rainforest species, eucalypts and *Pinus* spp. Except with eucalypts the costs of conversion have been very high, but conversion to Flooded Gum (*Eucalyptus grandis*) is employed on a large scale in the coastal gully rainforests (closely related to subtropical rainforest) and is being increasingly used in heavily logged areas of subtropical rainforest, while conversion to *Pinus* seems desirable for reforesting derelict agricultural land formerly supporting rainforest.

Management of the natural stands appears practicable in all types of rainforest. In dry rainforest natural regeneration of useful species (primarily Hoop Pine, *Araucaria cunninghamii*) occurs only sporadically, and emphasis should be directed at liberating those areas where regeneration is densely established and at establishing regeneration artificially by enrichment where it is absent.

The other three types all occur commonly at altitudes above 1,000 feet, where the stands suffer from crown die-back when heavily logged. In these areas light selective logging is necessary. In the submontane and temperate rainforests regeneration of useful species is usually obtained prolifically after logging, enabling silvicultural treatment to improve the composition of the stands. The regeneration should be periodically tended. In subtropical rainforest the proportion of valuable species in the stand is usually low, and desirable regeneration is normally very deficient, necessitating enrichment planting after logging and the progressive culling of the less valuable species from the stand.

2. OCCURRENCE OF RAINFOREST

Rainforest, usually known locally as "brush" or "scrub", has a discontinuous distribution in New South Wales, occurring on the eastern side of the Main Divide from the Queensland to the Victorian border at altitudes of from sea level to over 5,000 feet. The exact area of rainforest in the State is not known: the Forestry Commission of N.S.W. (1957) estimates that some 805,000 acres of mixed eucalypt forest and rainforest remain, but that only a little over 200,000 acres of this carries true rainforest with

merchantable timber. Considerably less than half the area of rainforest present at the time of European settlement still exists, the larger proportion having been cleared for agricultural pursuits over the past 100 years.

Five major centres of rainforest existed prior to European settlement, each coinciding with an area having an annual rainfall in excess of 60 inches (see figure 1). These centres were:

(1) The Richmond and Tweed Valleys and adjoining ranges (approx. latitude 28° 30′ S.), including the "Big Scrub" of the early settlers in the area.

(2) The Dorrigo Plateau west of Coff's Harbour (latitude 30° 20′ S.).

(3) The Hastings River catchment (latitude 31° 30′ S.) and adjoining areas in the Upper Manning and Macleay River catchments.

(4) The Barrington Tops, north-west of Newcastle (latitude 32° S.).

(5) The Illawarra district and Robertson highlands, south of Wollongong (latitude 34° 30′ S.).

Fig. 1.—Subtropical Rainforest, Wiangarie State Forest. Note frequent buttressing and heavy vines.

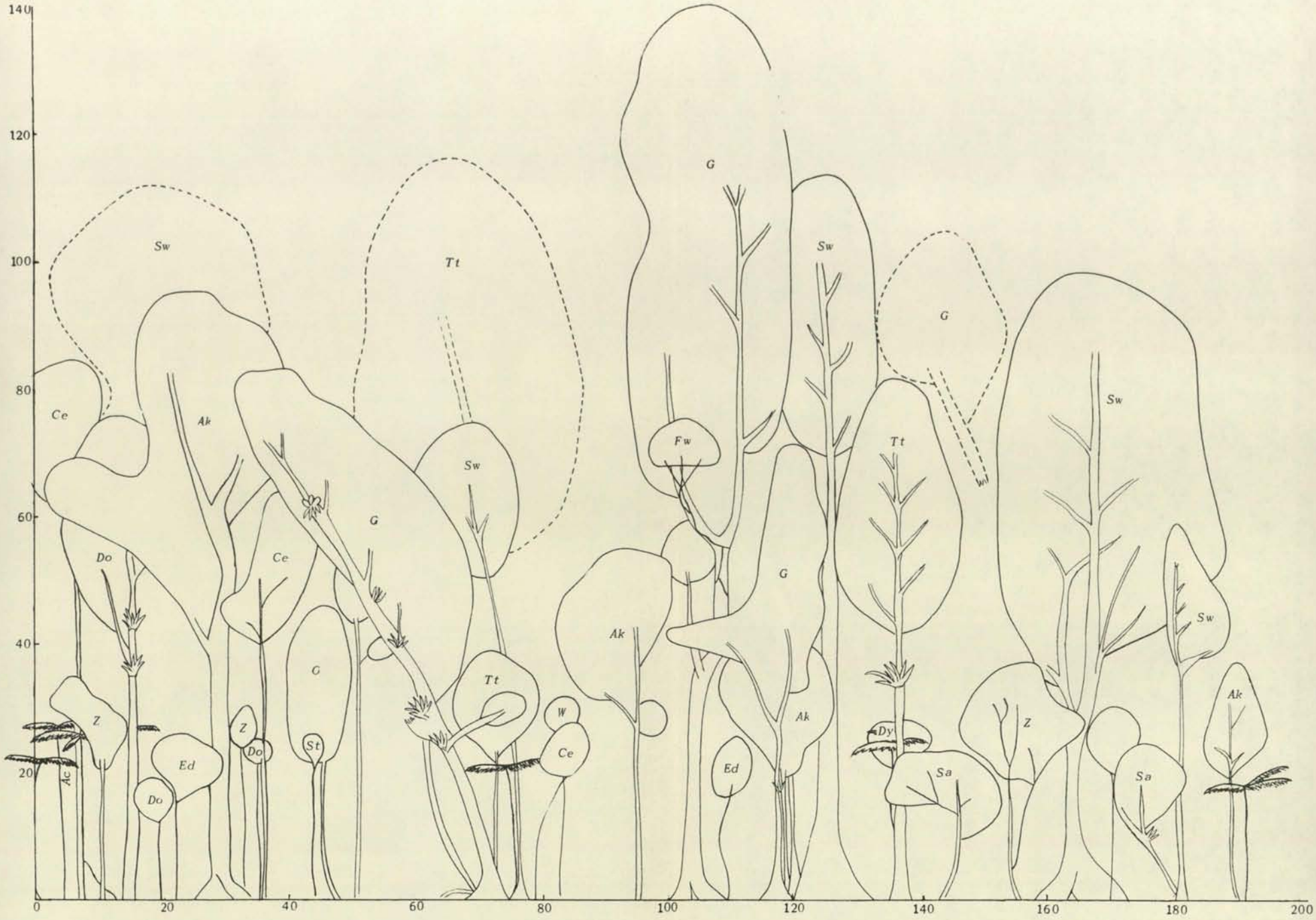

Figure 2.—Profile Diagram of Subtropical Rainforest, Wiangarie State Forest. (Transect 200 ft. long by 25 ft. deep, stems under 20 ft. high omitted. Scale: 1 inch = 20 feet.)

Key to Species Symbols: Ac, Archontophoenix cunninghamiana; Ak, Ackama paniculata; Ce, Cryptocarya erythroxylon; Do, Doryphora sassafras; Dy, Dysoxylum fraseranum; Ed, Endiandra discolor; Fw, Ficus watkinsiana; G. Geissois benthami; O, Orites excelsa; Sa, Sloanea australis; St, Stenocarpus salignus; Sw, Sloanea woollsii; Tt, Tarrietia trifoliolatum; V, Vesselowskya rubifolia; W, Wilkiea austroqueenslandica; Z, Zanthoxylum brachyacanthum;

Cyathea leichhardtii;

Asplenium nidus;

Platycerium bifurcatum.

Dotted lines indicate trees with crowns within the transect but their bases outside.

In addition to these areas, where rainforest formed the dominant vegetation type, there were numerous smaller patches scattered through the coastal plains and ranges in places locally favoured by the topography, soil or climate. In virtually all localities there was a tendency for the rainforest to encroach into the adjacent eucalypt forests, the encroachment being limited by repeated fires which favoured the development of the eucalypts. There seems little doubt that had fires been absent, rainforest would have occupied a far greater land area at the time of European settlement than was actually the case.

The present position is that the Illawarra-Robertson rainforest has been almost entirely destroyed, large parts of the Richmond-Tweed and Dorrigo rainforests have been cleared, as has a small section of the Hastings rainforest on the Comboyne and Bulga Plateaux. Remaining areas are chiefly in hilly or mountainous country unsuited for agriculture or are bordering streams in forests dominated generally by eucalypts.

3. NATURE OF RAINFOREST

Rainforest, as understood in this paper, can be defined as a community dominated by trees, with a continuous canopy and a bole length greater than the canopy depth, mesomorphic leaves, two or more tree layers, and vines and epiphytes present (adapted from Williams, 1955).

Within New South Wales the rainforests vary considerably in their structural and floristic composition. Four main structural types can be recognised:

(1) *Subtropical Rainforest**: This is closely related to the lowland rainforest of the tropics and can be regarded as a latitudinal variant of the true tropical rainforest, with its floristic composition predominantly of Indo-Malayan affinities. Three storeys of trees are present, many species are strongly buttressed, and vines and epiphytes are common (see figure 2). Many species occur, making the selection of a dominant species difficult or impossible. However, Booyong (*Tarrietia* spp.†), and at higher elevations Rosewood (*Dysoxylon fraseranum*) and Yellow Carabeen (*Sloanea woollsii*), are usually the most common tall tree species present. This type is confined to basaltic or rich alluvial soils under high rainfall conditions north of the Hastings River. It is the main type present in the Richmond-Tweed centre and originally occupied much of the western Dorrigo rainforest, whence it has now been almost entirely cleared. Small areas survive down to the southern edge of the Hastings rainforest. It represents some of the finest forest sites in the State, and prior to extensive logging and clearing carried such valuable species as Red Cedar (*Toona australis*) and White Beech (*Gmelina leichhardtii*). North from the Dorrigo centre Hoop Pine (*Araucaria cunninghamii*) occurs in this type, but only regenerates along the rainforest-eucalypt forest margin.

* This name has been altered from that given in the 1957 paper to agree with the more detailed classification of Webb (1959).

† Authorities for botanical names are given in appendix II.

Fig. 3.—Submontane Rainforest, Enfield State Forest. The smooth barked, white stems are Coachwood (*Ceratopetalum apetalum*).

(2) *Submontane Rainforest**: This is the most economically valuable of the State's rainforest types, and is characterised by two distinct tree storeys, the upper one forming a continuous canopy, with buttressing rare (see figure 4). North from the Hastings centre submontane rainforest is confined to relatively poor soils (derived from shales, slates and acid igneous rocks) under high rainfall conditions. In these areas Coachwood (*Ceratopetalum apetalum*) is clearly dominant. Further south there are fewer aggressive species typical of the subtropical rainforest and the submontane type is found on basalt soils, though without the same degree of dominance by Coachwood. Submontane rainforest is the main type occurring in the four southern centres and has a limited occurrence in the Richmond-Tweed centre. Hoop Pine is a common associated species in the Dorrigo centre. Both subtropical submontane rainforests are found under suitable conditions

*This name has been altered from that given in the 1957 paper to agree with the more detailed classification of Webb (1959).

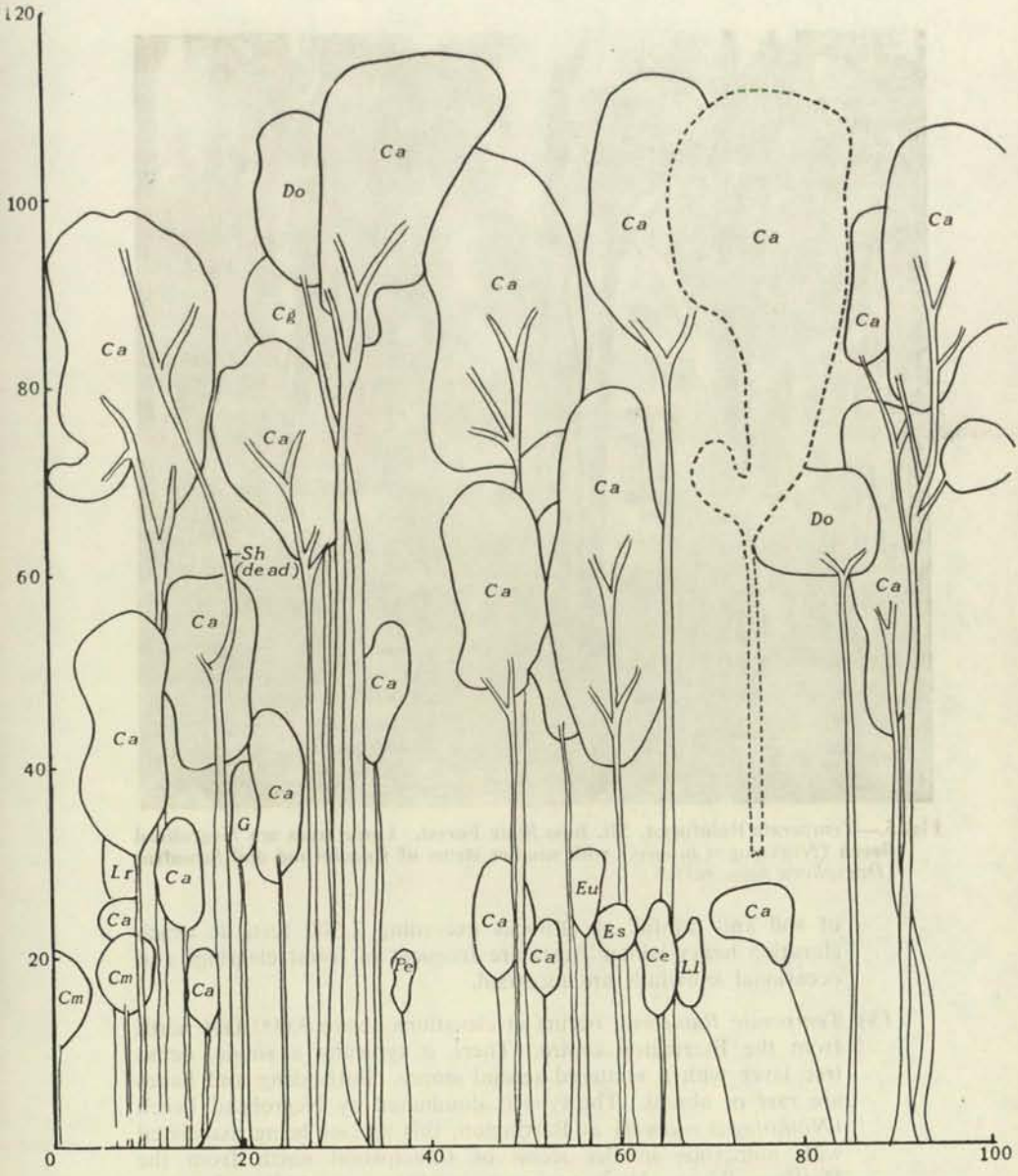

Figure 4.—*Profile Diagram of Submontane Rainforest, Moonpar State Forest.* (Transect 100 ft. long by 25 ft. deep, stems under 20 ft. high omitted. Scale: 1 inch = 20 feet.)

Key to Species Symbols: As for figure 2, plus Ca, Ceratopetalum apetalum; Cg, Cryptocarya glaucescens; Cm, Cryptocarya microneura; Es, Endiandra sieberi; Eu, Eugenia smithii; Ll, Litsea leefiana; Lr, Litsea reticulata; Po, Polyosma cunninghamii; Sh, Schizomeria ovata.

Fig. 5.—Temperate Rainforest, Mt. Boss State Forest. Large trees are Negrohead Beech (*Nothofagus moorei*) with smaller stems of Coachwood and Sassafras (*Doryphora sassafras*).

of soil and rainfall at altitudes exceeding 2,500 feet, at which elevation heavy winter frosts are frequent in forest clearings and occasional snowfalls are recorded.

(3) *Temperate Rainforest* occurs at elevations above 3,000 feet north from the Barrington centre. There is typically a single, dense tree layer with a scattered second storey. Buttressing and lianes are rare or absent. The type is dominated by Negrohead Beech (*Nothofagus moorei*) at Barrington, this species being associated with numerous smaller stems of Coachwood north from the Hastings River. High moisture conditions, including frequent mists, and low temperatures appear to determine the distribution of this type, which is probably of greater importance for watershed protection than for timber production.

(4) *Dry Rainforest* has its main economic occurrence in parts of the Richmond-Tweed centre, where it occurs on basaltic soil under a markedly seasonal rainfall regime of down to 40 inches a year. It is a two-storied community, the upper scattered and containing chiefly deciduous or xerophytic species, notably Hoop Pine. The

Fig. 6.—Dry Rainforest, Unumgar State Forest. Note remnant overstorey stems of Hoop Pine (*Araucaria cunninghamii*) and a low understorey. Large stem in right foreground is a eucalypt occurring near the rainforest margin.

dense second storey rarely exceeds a height of 40 feet and contains many useless species from the families Euphorbiaceae and Sapindaceae. Heavy lianes are common but, unlike the subtropical rainforest, buttressing, vascular epiphytes and strangler figs are rare (see figure 4). Dry rainforest is typically the home of Hoop Pine and also carries other valuable species such as Ivorywood (*Siphonodon australe*), Yellow Boxwood (*Planchonella pohlmaniana*) and several *Flindersia* spp.

Several other forms of rainforest occur in New South Wales (Baur, 1957), but only one is of economic importance. This is the gully rainforest community which is found along creeksides through the better class coastal eucalypt forests in northern New South Wales. Structurally and floristically this is intermediate between the subtropical and submontane rainforest types. It is the climax vegetation for these gullies, but by repeated logging and burning tends to be replaced by the Flooded Gum (*Eucalyptus grandis*) association.

The environmental factors limiting the distribution of these various types are discussed more fully by Baur (in print).

4. PAST RAINFOREST MANAGEMENT IN NEW SOUTH WALES

In 1928, N. W. Jolly, then Commissioner for Forests, expressed the opinion that the rainforests of New South Wales primarily needed artificial regeneration (planting) of either native or exotic species. He believed natural regeneration to be possible with the Negrohead Beech forests and with Hoop Pine in the dry rainforests, but little was done along these lines and the Forestry Commission's policy became one of conversion of the rainforest to plantation. His statement, however, marked the end of the phase in which the rainforests were logged of their most valuable species and were then alienated and cleared for farming.

Planting was delayed for about ten years, and then there was a further interruption due to the Second World War. Hoop Pine was the main species used, supplemented by the Queensland Bunya Pine (*Araucaria bidwillii*) in colder localities. Plantations were commenced in submontane (Coachwood) rainforest at Bo Bo (Dorrigo Area), in dry rainforest at Toonumbar and Mt. Pikapene and in subtropical rainforest at Beaury,

Fig. 8.—Gully Rainforest, Bruxner Park Flora Reserve, Orara East State Forest, showing a veteran emergent stem of Flooded Gum (*Eucalyptus grandis*), 215 ft. high.

Figure 7.—Profile Diagram of Dry Rainforest, Unumgar State Forest. (Transect 100 ft. long by 25 ft. deep, stems under 20 ft. high omitted. Scale: 1 inch = 20 feet.)

Key to Species Symbols: As for figure 2, plus Ar, Araucaria cunninghamii; Cd, Celastrus disperma; Cn, Capparis Nobilis; Di, Diospyros pentamera; Dp, Denhamia pittosporoides; El, Elattostachys nervosa; Eo, Elaeocarpus obovatus; Fl, Flindersia australis; Ha, Hemicyclia australasica; Lp, Laportea photiniphylla; Ma, Mallotus philippinensis; Pe, Polyscias elegans; Ps, Pseudomorus brunoniana; Rh, Rhysotoechia bifoliolata; To, Toechima tenax.

Fig. 9.—Plantation of Hoop Pine (*Araucaria cunninghamii*) aged 16 years. Beaury Creek Plantation, Mandle and Beaury State Forest.

Tooloom and Acacia Plateau, all in the Richmond-Tweed area. A total of 4,000 acres was established in these localities between 1938 and 1954 and, in addition, some areas that failed due to frost damage at higher altitudes at Bo Bo (1,800 feet) and Acacia Plateau (2,500 feet) plantations were replanted with exotic pines.

Another attempt at conversion to plantations was made at Doyle's River (Hastings area) about 1947, when a stand of submontane rainforest, heavily logged during the war, was cleared and planted with Coachwood, the main species originally present. Several hundred acres were established but winter frosts damaged the bulk of the planting.

More successful was the conversion of the coastal gully rainforests to Flooded Gum. This work commenced about 1940 at Pine Creek State Forest, near Coff's Harbour, where a good market for Flooded Gum timber had developed. Originally the eucalypt seedlings were raised in a nursery and then planted in the cleared regeneration area, but present practice is to spot sow the eucalypt seed on areas recently cleared and burnt.

Fig. 10.—Plantation of Flooded Gum, aged 14 years. Pine Creek State Forest.

Various other rainforest species have been planted experimentally. Most of these have proved very frost sensitive when planted in the open, though the introduced Camphor Laurel (*Cinnamomum camphora*) appears more hardy than most, while at low elevations small, successful plantings of White Beech and Southern Silky Oak (*Grevillea robusta*) have been established. White Beech, however, is very difficult to raise in the nursery and makes slow early growth, while the Silky Oak forms a very open canopy which permits heavy weed growth beneath. Red Cedar, which is one of the most valuable of native rainforest species and which has a widespread sentimental appeal*, suffers severely from the attack of Tip Moth (*Hypsipyla robusta* Moore) when planted in the open, and work is now under way to see whether it fares better under shelter of established plantations of other species or can be replaced by foreign relatives such as *Cedrela lilloi*, which is the most promising of its relatives on trial at present. Underplanting is also being tried as a means of establishing some of the other valuable but frost sensitive species, while work on conversion to eucalypts is now being attempted experimentally in types other than the gully rainforests.

* Red Cedar is one of Australia's finest cabinet timbers and has a close association with the history of the North Coast of New South Wales, where the first settlers were axemen seeking this tree (see Hurley, 1948).

Management of the rainforests themselves, as opposed to conversion to plantation, was instituted in late 1956, when provisional working plans were introduced for parts of the Dorrigo area. Spasmodic research had been undertaken since 1935, and more intensive research commenced in 1955. Investigations during the twenty-year period covered the enrichment of dry and submontane rainforests and growth studies in a partly logged Coachwood stand.

The present areas of rainforest in New South Wales vary through all stages from virgin stands to patches logged to a 6 inch d.b.h. by casemillers. Three possibilities for the future economic use of these areas are available:

(1) Log out as thoroughly as possible and then hand over the land for farming.

(2) Convert by artificial means to pure, even-aged stands.

(3) Apply sustained yield management to the natural stands.

In northern New South Wales the first alternative is by virtue of soils and topography limited to a few areas of subtropical rainforest in the Richmond-

Fig. 11.—Trial planting of *Cedrela lilloi*, aged 4 years. Note poor form of stems planted in this way. Tooloom Plantation, Mandle and Beaury State Forest.

Tweed centre, and is a land utilisation problem. The other alternatives require closer consideration, taking into account the financial returns to be expected from the various species that might be grown in these areas.

Fig. 12.—Trial planting of Silky Oak (*Grevillia robusta*), aged 16 years, Mount Pikapene State Forest.

5. STUMPAGE VALUES

Timber sales from State Forests in New South Wales are based on a stumpage appraisal system, with the rates determined by the Forestry Commission. The system aims firstly at placing all sawmills within the State on an equal footing, with high stumpages applying to areas close to markets or able to be easily harvested, and secondly at utilising all species, log sizes and qualities by applying varied stumpage rates to different species groups within a stand (Cooke, n.d.).

Rainforest species are at present classified into four species groups (Appendix I), with further differential stumpage rates applying to the first three groups (A to C) depending upon the centre girth of individual logs. Several of the more valuable special purpose species are excluded from this classification and bring much higher stumpage rates: these include Red Cedar, White Beech, Yellow Boxwood, Black Apple

(*Planchonella australis*), Ivorywood and Hoop Pine. For a typical rainforest stand on the eastern Dorrigo Plateau, the rainforest stumpages are:

Centre Girth	4 ft. 6 in. +	3 ft. 6 in. — 4 ft. 5 in.	Under 3 ft. 5 in.
Group A	26/8	15/8	2/6
B	13/8	8/8	2/-
C	7/8	1/8	1/6
D	....	1/- (all sizes)	....

These stumpages represent the return to the Forestry Commission per 100 superficial feet Hoppus (p.h.s.), after allowing any deductions for defects in the logs. For the same general locality Hoop Pine has a stumpage of 40s. p.h.s., regardless of size, while the other purpose species have a stumpage of 110s. p.h.s.

The groupings are based primarily on the trade's demand for individual species and are kept under constant review, taking cognizance of the findings of the wood technologists.

Fig. 13.—Submontane rainforest shortly after logging by case sawmillers. Orara West State Forest.

Hardwood species (chiefly eucalypts) are similarly grouped by species and size classes, but with much lower margins between the groups. For a similar locality to that taken for the rainforest species, hardwood stumpages are:

Centre Girth	8 ft. +	4 ft. 6 in. –7 ft. 11 in.	Under 4 ft. 5 in.
Group A (e.g. Tallowwood, *Eucalyptus microcorys*).	26/6 p.h.s.	24/6	20/6
B (e.g. Blackbutt, *E. pilularis*, and Sydney Blue Gum, *E. saligna*).	21/6	19/6	15/6
C (e.g. Brush Box, *Tristania conferta*)	18/6	16/6	12/6

These values are based on the gross log volume. After deducting the allowances for defects the net stumpage is appreciably lower (Cooke, n.d.).

Flooded Gum is treated differently to other hardwoods, logs being graded as of either "select" or "case" quality. Select grade logs have the same stumpage as large Group A rainforest species (26s. 8d. p.h.s. in the above locality), while case grade logs are 18s. less, i.e. 8s. 8d. p.h.s. in the area taken as an example.

The thinning of coniferous plantations has only recently commenced in rainforest areas. For a plantation of *Pinus* on the eastern Dorrigo Plateau stumpage for thinnings is 3s. 11d. p.h.s. for logs of under 6.5 inches centre diameter, and 5s. 3d. p.h.s. for logs over 6.6 inches centre diameter. No thinning of Hoop Pine plantations has yet been undertaken, but for the small thinnings stumpage should be similar to *Pinus*. Select quality *Pinus* logs should ultimately bring a stumpage similar to large Group A rainforest species, while select quality plantation grown Hoop Pine should bring a stumpage approaching that for the naturally occurring stems of this species.

It must be assumed that whilst certain rearrangements will occur from time to time within groups, the broad relationship of stumpages between the different groups will remain generally in the same order for a considerable period, and these provide a valuable lead as to the type of treatment that should be given to rainforest stands in various localities.

6. MANAGEMENT BY CONVERSION

(*a*) *General*

In considering the conversion of rainforest to plantation, two major processes can be recognised. The first type, primary conversion, consists of replacing the rainforest directly by an even-aged, pure stand of a desired species. This has been carried out in New South Wales on somewhat more than an experimental scale, using three main groups of species:

(1) Valuable rainforest species, such as Hoop Pine, Bunya Pine and Coachwood.
(2) Eucalypts, especially Flooded Gum.
(3) General purpose softwoods, such as *Pinus taeda*, *P. elliotti* and *P. patula*.

Secondary conversion, which is still only experimental in New South Wales, consists of establishing initially a plantation crop of some fairly hardy, fast growing species and of using this as a nurse crop by underplanting at a later stage with a more desirable species which is, however, unable to make healthy growth in open plantation because of frost damage, insect attack or some other factor. The underplantings of Hoop Pine beneath *Pinus* at altitudes of over 1,500 feet and of Red Cedar beneath various species afford examples of this type of conversion. In this connection it should be stressed that the terms "underplanting" and "enrichment planting" are not regarded as synonymous, the former referring to the establishment of a fully stocked plantation stand under cover of an existing plantation whereas the latter refers to improving the composition of a natural stand by planting seedlings of valuable species at relatively wide spacing within the stand where desirable natural regeneration is deficient. Enrichment planting will be dealt with in the section on the management of natural stands.

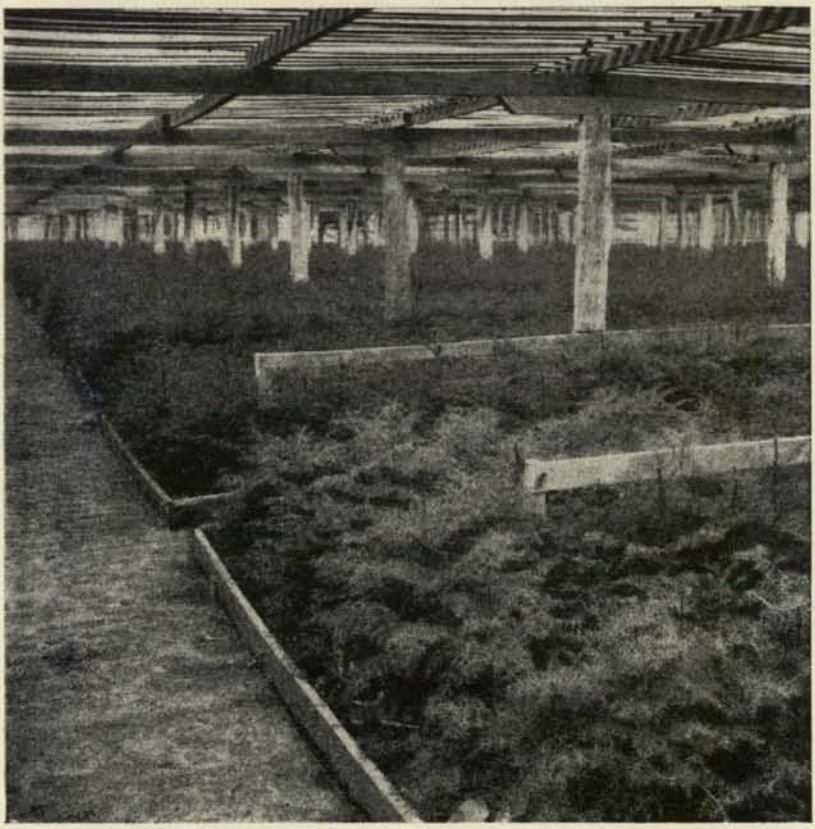

Fig. 14.—Hoop Pine seedlings in high-shade nursery. Seed had been sown twenty months earlier and the plants are now due for tubing, with planting to take place in five months' time.

(b) Conversion to Rainforest Species

At the present time the two Australian araucarias are the only species that could be recommended for extensive planting. South Queensland Kauri (*Agathis robusta*) is moderately good in a number of small trial plantings, but its growth rate is usually behind that of Hoop and Bunya Pines, while several other species, notably *Cedrela lilloi* from Argentina and Camphor Laurel from south-east Asia, are promising but are still only young.

With the araucarias care must be taken to select sites free from heavy and late frosts. This restricts planting to subtropical and dry rainforest areas below about 2,000 feet elevation in the Richmond-Tweed centre. Establishment costs are high: Hoop Pine seed is difficult to collect, is bulky, rarely exceeds 30 per cent. germination capacity and must be stored at temperatures below freezing point; the seedlings are raised in expensive high-shade nurseries under climatic and edaphic conditions highly favourable to weed growth, they remain in the nursery for about two years before planting and they have to be tubed for summer planting; adverse climatic conditions not infrequently lead to the plantation clear-burn being missed for a year; the planting of tubed stock is slow and for up to five years the plants must be protected against aggressive weed competition which, if uncontrolled, may completely suppress or destroy the seedlings. Because of these high costs the planting of araucarias has been curtailed since 1954, though it is now possible to see ways in which the establishment costs could be reduced, notably by greater use of chemical weedicides in the nursery; by delaying planting till the winter, when open-root stock would probably succeed; and by preceding planting with a hormone spraying of the planting area to destroy many of the weeds which become established following the clear-burn.

Early growth of Hoop Pine is satisfactory though not rapid. The figures in table I were obtained from:

A. Assessment of 179 acres at Beaury (subtropical rainforest), one of the State's best Hoop Pine plantation areas.
B. Assessment of 100 acres of established plantation at Bo Bo (submontane rainforest), where frost destroyed much of the original plantings.
C. Growth plot in a particularly good stand at Beaury.
D. Growth plot at Mt. Pikapene (dry rainforest).

TABLE I

Growth of Hoop Pine in Plantation on Rainforest Sites

	Age	Stems/ acre	BA/ acre	Diam. = Mean BA	Mean Dom. Ht*	Site Index †	Merch Vol./ac.	Vol. M.A.I.
	years		sq. ft.	in.	ft.		cu. ft.	cu. ft./ acre
A ..	16	380	118	7·55	56	80	1,881	117
B ..	18¼	360	99	7·10	48	60	1,017	55
C ..	19	445	182	8·65	65	80	3,874	204
D ..	17	480	123	6·86	64	80	2,145	126

* Mean dominant height is the height of the 40 tallest stems per acre.
† Site Index classes are based on the mean dominant height at age 25 years.

Fig. 15.—Bunya Pine (*Araucaria bidwillii*), aged 6 years, destroyed by rats. Tree had a height of 17 feet, D.B.H. of 4½ inches. Acacia Plateau Plantation. Acacia Creek and Koreelah State Forest.

Bunya Pine tends to be slower in height growth, but faster in diameter growth, and is appreciably less frost sensitive than Hoop Pine. Both species yield a first quality ply timber and must be kept well pruned to produce high grade knot-free timber. Both species are also highly susceptible to fire damage, while wallabies and, in one plantation, rats, have damaged young plantations, sometimes severely.

(*c*) *Conversion to Eucalypts*

Conversion to Flooded Gum is now the accepted treatment for the gully rainforests, and is provided for in the Flooded Gum Working Circles of many working plans for North Coast forests. It is not a conversion to an introduced species, but rather to a more rapidly growing, and frequently more valuable, disclimax species of these sites. The establishment technique is to log the site of all merchantable timber, completely clear it during the early spring, burn the debris immediately before the advent of the summer wet season and then spot sow the seed on to the site, preferably within a week of the burn. The usual rate of sowing is 4 oz. seed per acre, but

Fig. 16.—Subtropical rainforest, mechanically cleared and with debris being burnt in heaps prior to being sown with eucalypt seed. Cox's Road Logging Area, Toonumbar State Forest.

may vary from 2 oz. to 1 lb. with local site conditions (Floyd, 1960). The spots are spaced at 8 x 8 feet, with certain latitude allowed so that the seed may be deposited on the most favourable microsite in the vicinity (e.g. well burnt with crumbly soil and some charcoal present). The seed is delivered from a "pepper-shaker" device, calibrated to yield a given quantity of seed per shake (usually the equivalent of 4 oz. per acre at 8 x 8 feet spacing). Germination follows the first good rain, and early growth is rapid allowing the seedlings to keep slightly ahead of the prolific weed growth. When the best seedlings are about 4 feet high, usually about eight months after sowing, the spots are thinned to leave a single stem at each spot. The weeds are not controlled, as these help to force height growth and restrict branching.

On particularly adverse sites, such as grassed paddocks, very steep slopes or broad flat gullies subject to flooding, planting may be required. However, this is considerably more expensive than the spot-sowing technique and is only used under exceptional circumstances (Baur, 1959).

Flooded Gum in these sites shows very fast eary growth, but the rate slows significantly after about fifteen years. Growth figures in table II are from:

A. Newry State Forest, broadcast sown and thinned from 23,000 to 640 stems/acre at age 1 year 6 months (2 measurments).

B. Newry State Forest, broadcast sown and thinned from 9,700 to 490 stems/acre at age 3 years 9 months.

C. Conglomerate S.F., planted.

D. Way Way S.F., planted (2 measurements).

TABLE II

Growth of Flooded Gum in Gully Rainforest Sites

	Age	Stems/acre	BA/acre	Diam = Mean BA	Mean Dom. Ht.
	years		sq. ft.	in.	ft.
A	2 6/12	640	26	2·70	31
	3 7/12	640	45	3.60	41
B ..	5 6/12	485	51	4·40	60
C ..	7 5/12	505	71	5·10	73
D ..	13 6/12	311	117	8·29	118
	16 5/12	311	133	8·87	127

More recently attempts have been made to convert other types of rainforest to eucalypts by similar methods. At Cox's Road (Richmond-Tweed centre) about 9 acres of subtropical rainforest were logged of all merchantable timber and the remaining growth (except for trees too large) was pushed over by bulldozer, aiming at exposing the mineral soil over about two-thirds of the area. Seed from a mixture of species was broadcast over the area at the start of the wet season. Assessment eighteen months later showed an establishment of about 1,200 stems per acre which were, however, clearly clumped, so that effective stocking was reduced to about 340 stems per acre. These had heights up to 14 feet, with the most successful species being Flooded Gum, Blackbutt and Sydney Blue Gum, all of which were above the very dense weed growth. The results were sufficiently satisfactory for the method to be used on a routine scale in selected areas.

At Cascade (Dorrigo centre), poor quality submontane rainforest occurring in some of the gullies has been converted to Flooded Gum by the routine spot-sowing technique. In this area, at the altitudinal limit of Flooded Gum (about 2,500 feet), the eucalypt has shown an unexpected resistance to frost damage, and early results are no less successful than in the coastal gully rainforests.

Conversion to eucalypts is decidedly the cheapest of all types of conversion. About 400 acres of gully rainforest are being converted annually to Flooded Gum in northern New South Wales at present, and this area is likely to be increased as the technique is applied to other rainforest types.

Fig. 17.—Blue Gum (*Eucalyptus saligna*), **3 years old, on former subtropical rainforest site. Cox's Road Logging Area. Toonumbar State Forest.**

(*d*) *Conversion to Pinus*

Most of the early plantings of *Pinus* spp. on rainforest sites were made as a means of restocking failed araucaria plantations. Various species have been used, *P. taeda* being generally the most successful, though *P. elliottii* and *P. patula* are very good, while *P. radiata* (at higher altitudes), *P. caribaea* (in frost-free sites), *P. pseudostrobus* and *P. insularis* are also most promising. The growth figures in table III are from four different areas:

A. Bo Bo Plantation; Dorrigo centre, submontane rainforest.

B. Clouds Creek S.F.; Dorrigo centre, subtropical rainforest.

C. Toonumbar Plantation; Richmond-Tweed centre, dry rainforest.

D. Mebbin S.F.; Richmond-Tweed centre, intermediate between subtropical and dry rainforest.

TABLE III

Growth of Pinus spp. in Rainforest Sites

Site	Age	Stems /acre	BA/acre	Diam.-Mean BA	Mean Dom. Ht.	Merch. Vol./ac.	Vol. M.A.I.
P. taeda	years		sq. ft.	in.	ft.	cu. ft.	cu. ft./ac
A	14	700	256	8·20	50	4,050	289
B	9	646	196	7.46	45	2,680	298
C	6	500	45	4·06	26	190	31
P. elliottii							
A	19	553	276	9·59	58	5,220	275
B	9	510	125	6·69	34	1,270	141
C	6	660	49	3·68	25	..	..
P. patula							
A	12	622	124	6·03	39	1,280	107
B	5	487	32	3·49	24	..	..
D	5	552	39	3·63	28	..	..

Since these three main species are relatively slow in making early height growth, plantings made directly on a clear-burn are likely to suffer severe weed competition. Recent work in allowing a weed crop to become established between the times of burning and of planting, and then spraying with hormone, appears to have given satisfactory weed control. However, until this is proved, it would appear unwise to establish large areas of *Pinus* directly on to rainforest sites unless very high weed control costs can be met. On the other hand, the establishment of these species on former rainforest sites previously cleared for some other purpose, such as derelict farm land, can be readily justified. Young plantings are subject to wallaby and rabbit damage in many areas, necessitating the netting of planting areas, while older stands adjoining rainforest are frequently severely attacked by possums (*Trichosurus caninus* Ogilby) which ringbark the upper stem. A satisfactory control of these arboreal pests is still not known.

(*e*) *Underplanting*

Secondary conversion has been used experimentally with two main aims, firstly to establish plantations of certain valuable species (chiefly Hoop Pine) in frosty localities where open plantings would fail, and secondly to establish crops of the highly valuable Red Cedar by slowing its growth rate and offering it some physical protection from the over-storey in order to reduce the likelihood of Tip Moth attack.

P. taeda and *P. elliottii* have both been used as the overstorey crop for Hoop Pine and various underplanting treatments have been used, such as planting beneath a fully stocked stand which is subsequently thinned, planting along complete rows from which the overstorey has previously been removed, and planting in small gaps formed by the removal of one or more of the over-storey stems. Survival has been good with all treatments

except where a young overstorey was thinned for subsequent row planting and frost was able to penetrate to the ground. However, some subsequent losses have occurred during thinning after underplanting. Growth is generally slow in the understorey and is related to the density of canopy in the overstorey. In this regard the relatively lightly crowned *P. elliottii* makes a better cover crop than the densely canopied *P. taeda*: 6 years old Hoop Pine under a thinned 11 years stand of *P. taeda* at Clouds Creek S.F. has a mean height of 2.2 feet (best stem 3.1 feet), whereas under adjacent 11 years old *P. elliottii* it has a mean height of 4.7 feet (best stem 7.1 feet).

Red Cedar has been planted mainly beneath Hoop Pine, though overstoreys of Silk Oak and Flooded Gum have also been used. With the dense canopy of Hoop Pine it is essential to thin before planting and then to plant in the gaps so formed. If this is not done the understorey will grow towards the nearest gap in the canopy, producing a very bent and probably useless stem. With the much more sparsely crowned Flooded Gum and Silky Oak this problem does not arise. The fastest growth has been obtained under Silky Oak, where the Cedar attained a mean height of 8 feet in three years. However, this is the only such planting where the Cedar

Fig. 18.—Spraying weed growth with hormone, shortly before planting *Pinus taeda*, and six months after burning debris. Submontane rainforest in background. Wild Cattle Creek State Forest.

has been damaged by Tip Moth. Plantings beneath Hoop Pine are much slower: typical figures are a mean height at age five years of 4.0 feet under an overstorey with a basal area of 200 sq. feet. per acre, and of 9.0 feet at the same age where the B.A. of the overstorey is 150 sq. ft. per acre, in both cases planted without thinning the overstorey.

Fig. 19.—Plantation of *Pinus taeda*, aged 9 years. Clouds Creek State Forest.

7. MANAGEMENT OF NATURAL STANDS

(a) Submontane and Temperate Rainforests

Composition.—These two types of rainforest can be considered together, as they have several important characters in common: a general similarity in structure, a clear dominance by one or two species, and a normal occurrence at fairly high altitudes. Virgin submontane rainforest carries a basal area varying from about 220 sq. ft. per acre to over 300 sq. ft. per acre. In the Dorrigo centre (elevation 1,500-2,500 feet) the B.A. is frequently about 240 sq. ft., but this value tends to increase at higher altitudes. Normally somewhat over half of the B.A. is supplied by a single species, Coachwood, though the percentage B.A. from Coachwood ranges on individual experimental plots from 30 per cent. to over 80 per cent. Usually fewer than twenty species attaining a 4-inch or larger d.bd.h. are

found on a single acre, and from all of these only about 10 per cent. of the total B.A. is contributed by useless species or species in stumpage group D (appendix I). However up to 30 per cent. of the B.A. may be occupied by unmerchantable stems.

Fig. 20.—*Pinus elliottii* repeatedly attacked by brush-tailed possum, Bo Bo Plantation, Wild Cattle Creek State Forest.

In the Hastings rainforest centre and further north, but not at the Barrington centre (see Fraser and Vickery, 1938), temperate rainforest typically consists of large veteran Negrohead Beech, contributing about half the B.A., with numerous smaller stems of Coachwood and a few other species. Rarely are more than fifteen species attaining a d.b.h. greater than 4 inches found on a single acre in this type, where the B.A. is normally in the vicinity of 350 sq. ft. per acre. The species composition of virgin plots in both temperate and submontane rainforest is shown in appendix III.

Hoop Pine was formerly plentiful in the submontane rainforest of the Dorrigo Plateau, occurring as scattered emergents. Most of the larger stems have long since been removed from this area, but regeneration in various stages of development is widespread through the area.

Fig. 21.—Red Cedar (*Toona australis*), aged 2 years, planted beneath 18 years old Silky Oak. Mount Pikapene State Forest.

Crown Die-back.—Both submontane and temperature rainforest normally occur at the higher altitudes where winters are severe. After logging operations many of the remaining trees, which in the virgin state appeared healthy and vigorous, develop crown die-back. This is apparently an exposure effect caused by altering the microclimate. Some die-back can be found even in virgin stands, chiefly in the largest stems, but following logging its incidence increases markedly and is related to the intensity of logging, as is shown by four adjacent blocks at Moonpar S.F. (Dorrigo centre, altitude 2,200 ft.):

Percentage B.A. removed in logging ..	0 (virgin)	16	43	62
Percentage stems showing die-back .. (3 years after logging)	8	36	46	67

Virgin B.A. in this area was 238 sq. ft./acre.

With very heavy logging the die-back becomes severe and may cause appreciable tree mortality, but at more moderate intensities of logging the trees will usually firm up their crowns from the centre and ultimately

remake a closed canopy, though probably with an intervening slowing of growth. In the Dorrigo centre die-back tends to be serious where the B.A. falls below 120-130 sq. ft. per acre, i.e., where more than about 40 per cent. of the B.A. is removed at logging. At higher altitudes a greater remaining B.A. is needed to avoid severe die-back, though on account of the greater initial B.A. the percentage that can be removed is probably about the same. Aspect and topography will also cause a variation in the incidence of die-back within a limited area.

Regeneration.—In the Dorrigo and Richmond-Tweed centres, Coachwood regeneration (1-12 ft. high) is usually present in some quantity beneath virgin stands of submontane rainforest and becomes more densely established after logging. The following results were obtained from milliacre sampling in typical stands in these centres, at altitudes of from 1,800 to 2,300 ft.:

State Forest	Stand	No. Plots assessed	No. Plots with Coachwood	% Plots with Coachwood
Moonpar	Virgin	560	116	% 21
Wild Cattle Creek ..	Lightly Logged ..	40	34	85
Orara West	Heavily Logged ..	352	188	54
Whian Whian	Heavily Logged ..	40	24	60

Regeneration of other species characteristic of submontane rainforest was also present in all these sites. Hoop Pine occurred in 9 per cent. of the plots at Moonpar and 6 per cent. at Orara West, and there was much regeneration of other useful, though less valuable species: at Moonpar 75 per cent. of plots carried useful regeneration of some type, and at Orara West 86 per cent.

Appreciable quantities of larger regrowth are also present beneath virgin stands. In the Moonpar stand, assessment with quarter chain square plots (1/160 acre) showed that 85 per cent. of plots contained useful stems between 12 feet high and 4 inches d.b.h., 66 per cent. of them Coachwood. This forms a most valuable reservoir of advance growth to be released by careful logging.

At the Wild Cattle Creek S.F. site (Morora Creek, Dorrigo centre), the establishment and subsequent growth of Coachwood regeneration has been followed from the time of logging. Heavy seed falls occurred in the first two years after logging, resulting in the germination of over 150 seedlings per square yard. After thirteen years the stocking was reduced to 40-90 stems of Coachwood per square yard, with heights up to 10 feet under fairly heavy shade. Under more open conditions faster height growth is obtained.

At higher altitude submontane rainforest, and in the temperate rainforest, regeneration is less plentiful, though observation suggests that adequate amounts are normally obtained following opening of the canopy.

In the Dorrigo centre stands logged very heavily revert in time to dense thickets of weed species and useful regrowth. Two such areas some twenty-five years after logging carried a total of 3,500-4,000 stems per acre over 12 feet high, of which 1,000-1,500 were of Coachwood. Thinning such stands is costly and difficult, but leads to a marked increase in growth rate: in one case Coachwood stems over 1 inch d.b.h. showed a diameter increment of 0.34 inches in a thinned plot, compared with less than 0.10 inches in the control plot, over a period of three years. Restricted treatment in these areas to liberate selected stems without thinning the entire stand would appear to produce the same response at much lower cost, and would seem particularly desirable in the not infrequent areas where Hoop Pine regrowth is plentiful.

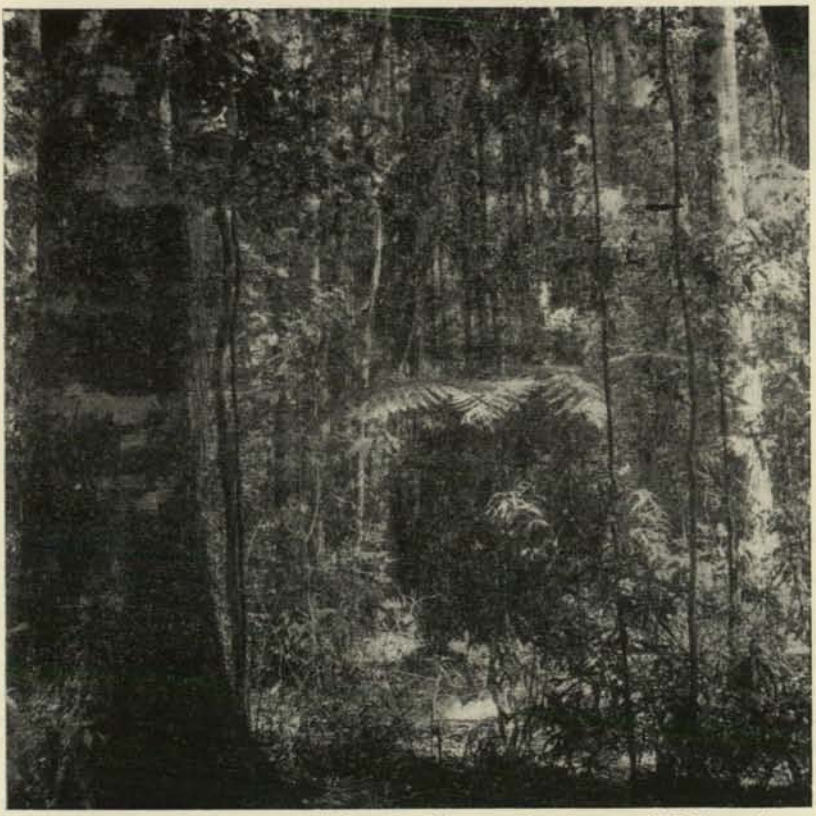

Fig. 22.—Virgin submontane rainforest, with stem basal area of 240 sq. ft. per acre, more than half such basal area being contributed by Coachwood. Moonpar State Forest.

Growth Rate.—Coachwood and its associates have a generally slow growth rate, and the majority of growth plots are of too recent origin to yield reliable growth figures. One Dorrigo plot, however, was established in 1945, following a selective logging of the stand (situated near Bo Bo Plantation) the previous year. The plot has been remeasured biennially since establishment and the results have been analysed in some detail up to

1957. After logging the stand contained only a few stems other than Coachwood, and these were removed when the plot was established. The plot has an area of 0.313 acres, and the distribution of size classes in 1945 and 1957 is shown in table IV.

TABLE IV

Stem Distribution of Coachwood ; Bo Bo Growth Plot

Diameter Class	1945	1957
Under 2 inches	20	14
2 — 4 inches	57	47
4 — 6 inches	27	34
6 — 8 inches	19	22
8 —10 inches	13	11
10—12 inches	17	13
12—14 inches	14	20
14—16 inches	5	10
16—18 inches	2	1
18—20 inches	0	2
20—22 inches	1	1
Total	175	174

One hundred and seventy-five stems per plot is equivalent to 560 per acre, and in addition seven stems died during the twelve years period. Considering stems over 4 inches d.b.h. only, the progress of the plot over the period of measurement has been:

Year	1945	1957
No. Stems/acre	313	364
B.A./acre	159 sq. ft.	199 sq. ft.
Mean Diameter	9·66 in.	10·01 in.
Merch. Volume (stems over 10 in. d. b.h.)	27,300 s. ft. H.	35,700 s. ft. H.

The 313 stems/acre over 4 inches in 1945 had increased their mean diameter to 10.65 inches twelve years later, a P.A.I. of 0.083 inches. Some trees in all size classes showed an increment of 1 inch or more during the twelve years, the percentage of such stems rising from 5 per cent. in the under 2 inch class to 100 per cent. in the 16-18 inches class: all such stems were growing under good light conditions. The fastest individual stem grew from 7.28 inches in 1945 to 10.03 inches in 1957, a P.A.I. of 0.23 inches. Growth analysis suggests a period of about 220 years for the average Coachwood stem to grow from 2 to 20 inches with some stems, on their present rates, attaining this size in half this time. The volume growth (including recruits to 10 inches and over) is equivalent to 75 cubic feet per acre per annum.

These figures apply only to one species on a single plot. More recent plots suggest that most of the associates of Coachwood, except probably Hoop Pine, show no faster a rate of growth, though the actual growth rates can be expected to vary greatly with changes in site and logging intensity.

Fig. 23.—Heavily logged submontane rainforest, showing severe incidence of crown die-back on remaining stems. Moonpar State Forest.

Enrichment Planting.—The widespread occurrence of Coachwood regeneration, and the ease with which it is obtained, makes the enrichment planting of this species unnecessary in the Dorrigo and Richmond-Tweed centres, while except for Hoop Pine the few native rainforest species more valuable than Coachwood do not occur naturally in the submontane and temperate rainforests. However, enrichment with araucarias may be desirable where the natural stocking of Hoop Pine regeneration is low, and has been carried out to some extent on the Dorrigo Plateau. Other species have also been used experimentally, including Coachwood. The results obtained from some of these plantings are given in table V.

Of the plantings listed, those at Never Never were made along snig-tracks following a moderately heavy logging operation, at Orara West along snig-tracks following an extremely heavy logging (residual B.A. of about 80 sq.ft./acre), and at Wild Cattle Creek in a small opening after light logging. The *Cedrela lilloi* was planted in lines brushed through dense regrowth of weeds that followed a small fire, while the four plantings of Coachwood at Moonpar were beneath stands logged respectively to remove 0, 20, 40 and 60 per cent. of the basal area. The relatively low survival

of Coachwood at Orara West was due to a tractor destroying some plants in an experimental area. Wallabies and rats have damaged some plantings, but the incidence of attack varies greatly in different areas and also between species: *P. taeda* seems most susceptible, and Hoop Pine has been severely damaged in some sites. The growth rates are slow at first, but appear to increase with age and are clearly greater where conditions are fairly open. In most areas a liberation treatment will probably be needed between five and ten years after planting to remove competing growth.

TABLE V

Growth and Survival from Enrichment Planting, Submontane Rainforest (Dorrigo Centre)

Species	State Forest	Mean Height, Age 1 year	Age last measured	Mean Height, last meas'd	% Survival	Height P.A.I.	Best Height
		feet	years	feet	%	feet	feet
Hoop Pine	.. Never Never ..	.. 1·14	4	2·44	70	0·43	4·5
	Orara West ..	.. 2·07	4	3·82	86	0·58	5·9
	Wild Cattle Creek	.. ..	18	11·8	100	0·61 (?)	20·0
Bunya Pine	.. Never Never ..	.. 0·77	4	1·02	90	0·08	2·0
Cedrela lilloi	.. Moonpar ..	.. 1·01	4	7·59	89	2·19	12·1
P. taeda ..	.. Orara West ..	.. 0·85	3	2·78	78	0·96	6·0
Coachwood	.. Wild Cattle Creek	.. ..	18	12·1	..	0·66 (?)	15·4
	Orara West ..	.. 0·55	3	1·60	60	0·57	4·1
	Moonpar—A ..	.. 0·48	3	0·55	83	0·04	1·2
	B ..	.. 0·36	3	0·46	83	0·05	0.8
	C ..	.. 0·53	3	0·85	92	0·16	1·3
	D ..	.. 0·53	3	1·03	75	0·25	1·8

Suggested Treatment.—Submontane rainforest dominated by Coachwood has certain characteristics that render it more suitable than most rainforest types for sustained yield management. Its relatively simple floristic composition, the predominance of high value species and the ease of obtaining regeneration (at least in the lower altitude areas) are points in its favour. Except during the 1939-45 war, when many stands were creamed over for particularly high quality logs suitable for aircraft veneer, there has been a general tendency to log these stands very heavily, sometimes with the aim of subsequent conversion to plantation and at other times with no apparent thought for the future. The results of such treatment have usually proved less disastrous than might be imagined, with dense regrowth, much of it Coachwood or other valuable species, becoming established. On the other hand, the practice cannot be recommended: small trees are sold at minimum stumpage rates, whereas if left they could be expected in time to bring up to ten times this value; any remaining potentially valuable stems will usually succumb to die-back; the regrowth requires costly treatment and even with this cannot be expected to produce merchantable timber within a century, and probably for much longer, unless conversion is actually carried out.

From the evidence presented above some type of selection silvicultural system seems necessary. To avoid severe die-back it is necessary that no more than 40 per cent. of the basal area be removed during a felling cycle: on the Dorrigo Plateau this means that B.A. after treatment should not be below 120-140 sq. ft. per acre, while at higher elevations the residual B.A. may rise above 200 sq. ft./acre. Not all the B.A. removed

should be in merchantable stems, since some large, useless stems are usually present and it is obviously desirable to destroy these stems. Their destruction is best accomplished by sap-ringing or poisoning, and their B.A. should be included in the 40 per cent. that may be removed from the stand. No large gaps should be created in logging, as such openings act as focal points for crown die-back: where several large stems that would normally be removed are clumped together, some of these should be left and the B.A. made up by felling some smaller trees. Felling in the submontane rainforest can usually be carried out with little damage to remaining stems, but care must be exercised in snigging to avoid damaging the butts of the standing trees and, equally important, to avoid destroying advance regrowth by the snigged logs sweeping across the ground.

Following logging enrichment planting may be carried out if it is wished to improve the composition of the stand: enrichment is, however, unnecessary where there is already adequate regeneration of Hoop Pine, while except possibly for some high altitude areas, enrichment with Coachwood would never seem warranted.

From the growth rate shown by the Bo Bo plot it appears that a period of twenty-five to thirty years would be required for this stand to increase

Fig. 24.—Dense clump of naturally regenerated Hoop Pine, retained after clearing adjacent submontane rainforest. Wild Cattle Creek State Forest.

its B.A. from 130 to 210 sq. ft. per acre. Growth is likely to be retarded if the B.A. approaches much closer to value of a virgin stand, and for submontane rainforest on the Dorrigo Plateau the above basal areas appear to represent the optimum range for satisfactory growth. Although the felling cycle could be reduced by adopting a smaller range of B.A. (say 150 to 190 sq. ft. per acre), the merchantable yield would also be reduced whilst the extraction costs would be increased. In higher altitude submontane rainforest a higher B.A. range will be necessary, probably rising to 210/270 sq. ft. per acre where the virgin B.A. exceeds 300 sq. ft. per acre.

This type of treatment, which involves tree-marking, destruction of useless stems, careful logging and possibly enrichment planting, is already being applied to virgin stands in both the Dorrigo and Hastings rainforest centres and is equally suited to stands that have been lightly logged in the past. Where past heavy logging has resulted in dense regrowth a liberation thinning to favour the best stems seems urgently needed.

In the temperate rainforests much the same form of treatment should prove suitable. In northern New South Wales these areas offer the appearance of stands where the dominant, overmature Negrohead Beech is being

Fig. 25.—Hoop Pine seedling, 2 years after enrichment planting, severely damaged by wallabies. Moonpar State Forest.

replaced by the more valuable Coachwood. If this is ecologically correct silvicultural treatment should greatly hasten the process, for by concentrating on the removal of Negrohead Beech the stands should be converted to areas with up to 80 per cent. Coachwood by the end of two felling cycles. Enrichment in these areas would appear most desirable: Coachwood planting may be needed if natural regeneration proves difficult to obtain, while Hoop Pine would probably be unsuited to these high altitude stands but Bunya Pine and possibly the Chilean Monkey-Puzzle, *Araucaria araucana,* should be satisfactory to provide high value coniferous veneer timber.

(*b*) *Dry Rainforest*

Composition.—Commercial stands of this type are found chiefly in the lower altitude, low rainfall parts of the Richmond-Tweed centre, with a small occurrence on the northern edge of the Dorrigo centre. Non-commercial stands are found as far south as the Hunter River. Within the Richmond-Tweed centre dry rainforest occupies some fairly extensive

Fig. 26.—Submontane rainforest logged to remove 60 per cent of initial basal area. Note heavy damage to established regeneration during snigging operations. Moonpar State Forest.

areas in locations favoured by fertile soils and somewhat sheltered topography. Communities very similar in both structural and floristic composition to dry rainforest are also found in the ecotonal zone where subtropical rainforest is invading eucalypt forest (see for example Cromer and Pryor, 1942).

Dry rainforest characteristically has a very dense lower storey of small stems of useless species. Usually no individual species is particularly plentiful, but there is a predominance of species from the families Euphorbiaceae and Sapindaceae. Standing above this storey is a scattered overstorey of Hoop Pine, Native Teak, Yellowwood (*Flindersia xanthoxyla*) and occasional other species. Where the type is invading adjoining eucalypt forest eucalypts may be present in the overstorey. Occasional stems of high value species such as Ivorywood and Yellow Boxwood are found in the lower storey.

Basal area is commonly about 150 square feet per acre, up to half of it being contributed by the overstorey. Where this overstorey is particularly dense the B.A. may exceed 200 sq. ft./acre. Up to forty species may occur on an acre, but only about six of these are usually of commercial value. Appendix III gives details of a typical plot.

Regeneration.—The regeneration of useful species tends to be poor within dry rainforest: milliacre sampling four years after logging in an area which had previously carried a heavy Hoop Pine overstorey showed that only 9 per cent. of plots contained regeneration of Hoop Pine and only 11 per cent. contained regeneration of any useful species. Good crops of useful regeneration do occasionally become established, usually on the margins of the dry rainforest. One such establishment occurred on part of Unumgar State Forest about 1920. In 1941 this area carried up to 3,500 stems of Hoop Pine per acre, and removal of the useless overwood and thinning of the regrowth were tried. The response was considerable and five years later the whole area was thinned and released. Consequent growth has been good.

Year	1946		1953	—	1960
Stems/acre ..	212		212		212
B.A./acre ..	16·3 sq. ft.		64·9		112·6
BA PAI ..		6·9 sq. ft.		6·8	
Mean D.B.H. ..	3·73 in.		7·49		9·89
DBH PAI		0·54 in.		0·34	

Attempts to promote similar heavy stockings of regeneration have to date been unsuccessful. Following an excellent Hoop Pine seed crop in December, 1957, a number of trees were selected and the surrounding forest treated in various ways: partly opened, completely opened, and left

untreated. The development of regeneration on a total of 160 yard square plots located around a typical tree was:

Time from Seedfall	2 months	6 months	12 months	26 months
No. plots carrying Hoop Pine seedlings	52	32	10	2
Total no. Hoop Pine seedlings ..	206	74	12	2

The type of treatment made no significant difference to the establishment, and it appears that satisfactory establishment of regeneration will only be obtained in the odd year when a good seedfall is followed by a wet year with an usually high and well distributed rainfall through the normally dry spring.

Growth Rate.—As shown above Hoop Pine regrowth that has been liberated has a basal area increment close to that of plantations of the species in the same B.A. range and planted on similar sites. However, in unliberated stands or growing as small trees still not above the main understorey canopy Hoop Pine is much slower, with diameter increments frequently below 0.1 inch per annum.

Once the stems become emergents the diameter increment increases. Two trees of Hoop Pine overtopping the regeneration at Unumgar show this well:

Tree	DBH, 1948	DBH, 1954	DBH, 1960	PAI, 12 years
	in.			
1	18·45	21·46	23·45	0·42
2	22·00	23·94	25·70	0·31

The same trend is shown by the *Flindersia* spp., but the very high value species of the dry rainforest type, Ivorywood and Yellow Boxwood, neither of which normally rises about the understorey, tend to be very slow. Diameter P.A.Is. in the order of 0.06 inches have been obtained for both species over a period of five years on stems of between 10 and 16 inches D.B.H., with smaller trees even slower.

Enrichment Planting.—Because of the difficulty in obtaining natural regeneration of the most desirable species enrichment planting suggests itself as a means of regenerating the dry rainforests, and some of the earliest silvicultural work in dry rainforest was the enrichment planting of Hoop Pine at Mt. Pikapene State Forest in the 1930's. This was a very intensive treatment, with the seedlings being planted along rows at fairly close spacing and the intervening useless stems being progressively removed: in effect it was plantation establishment with site clearing following, instead of preceding, the planting. Growth plots show an excellent rate of growth

which is, however, greater where the emergent stems of the original community have been removed (A) than where they still remain (B):

	Age	Stems/acre	BA/acre	Mean Diam.	Mean Dom. Ht.
	years		sq. ft.	in.	ft.
A ..	24	354	145	8·66	78
B ..	25	383	65	5·59	65

More recent enrichment has been much less intensive in nature, aiming at establishing about 100 to 150 stems per acre. Originally this was done by planting along brushed lines. Growth has been fairly good where the seedlings have been planted in relatively open conditions, but where the canopy is closed above the seedling or is tending to close in the subsequent growth is very slow. Table VI shows the height of various species planted experimentally along lines at Unumgar under three conditions of overhead canopy.

In order to take advantage of the superior growth in openings, enrichment since 1958 has been confined to snig tracks and other openings in all areas where line brushing is insufficient to create good light conditions. As a result the percentage of stems planted in open conditions has risen from between 20 and 30 per cent. to over 60 per cent.

TABLE VI

Mean Height Following Enrichment Planting, Unumgar S.F.

Species	Age	No.	Mean Height				Best Stem
			Open Canopy	Moderate Canopy	Dense Canopy	All Stems	
	years		feet	feet	feet	feet	feet
Hoop Pine ..	.. 5	70	4·1	2·6	2·6	3·1	8·0
Cedrela odorata	.. 5	3	11·3	5·0	..	7·1	11·3
Silky Oak ..	.. 5	7	6·1	3·2	..	4·0	9·4
Klinki Pine ..	.. 2	18	1·6	1·3	1·3	1·4	2·3
Red Cedar ..	.. 2	29	2·6	2·0	2·0	2·0	3·6
Yellowwood ..	.. 2	31	1·0	0.9	0·8	0·9	1·7
Native Teak ..	.. 2	35	1·3	1·2	1·4	1·3	2·1

Although various species have been used in experimental enrichment planting, Hoop Pine is the only one employed in routine plantings. It has everywhere produced a high survival rate, and the small degree of wallaby attack has been insufficient to cause alarm. The native *Flindersia* spp. have all shown very slow early growth, while with Silky Oak, Red Cedar and the West Indian *Cedrela odorata* very heavy losses have occurred during the normally dry winter and spring seasons.

Suggested Treatment.—The long range aim of silvicultural treatment in dry rainforest would appear to be the conversion of these areas to Hoop Pine, not however by conversion to plantation but by taking full advantage of areas of established regeneration, by carrying out enrichment planting over the large areas where natural regeneration is deficient and by gradually

removing the host of useless species. At the same time regeneration and immature stems of other desirable species should be conserved and encouraged.

Very few remaining areas of dry rainforest carry much in the way of a mature overstorey. The most immediate needs are to liberate established regeneration of all desirable species and to establish regeneration, where this is at present lacking, by enrichment planting. Areas of dense regeneration, such as occurred at Unumgar, should receive priority in treatment with the removal of useless overwood and the thinning of the regrowth. Where regeneration is present but less prolific it should be liberated by removing all competing or overtopping useless stems. Where regeneration is definitely deficient (less than 100 stems per acre) enrichment planting should be carried out, aiming at a somewhat higher stocking than has been the practice in recent years. This planting should be confined as far as possible to openings in the canopy; where logging has recently been carried out sufficient openings will probably exist along the snig tracks, but in other sites suitable openings are likely to be lacking and it is believed that a small bulldozer would be ideal to create the necessary network of tracks at low cost.

Fig. 27.—Hoop Pine regeneration, about 35 years old, thinned 10 years earlier. Unumgar State Forest.

Areas already carrying an overstorey of immature useful stems should be excluded from silvicultural treatment. Elsewhere regeneration sampling (Barnard, 1950) should precede any treatment and should be carried out over treatment blocks of about 100 acres. Within the blocks liberation and enrichment should then be carried out as required. Subsequent treatment to ensure the active growth of the regeneration will be required at irregular intervals until the regeneration is above the lower storey. This follow-up treatment will result in the gradual elimination of the useless species from the stand.

(*c*) *Subtropical Rainforest*

Composition.—This is the most luxuriant of the local rainforest types and occupies some of the State's finest sites. It is found in varying forms, from sea-level up to 3,000 feet. Below 2,500 feet strangling figs (particularly *Ficus kalkinsiana*) are common; above 1,000 feet crown die-back, similar in all respects to that of the submontane and temperate rainforests, follows heavy logging. Weeds, including viney *Rubus* spp., Stinging Tree (*Laportea gigas*) and Native Tobacco (*Solanum auriculatum*), rapidly colonise any openings in the stand: occasional stands dominated by huge veteran Stinging Trees are found, and these are believed to be the result of past destruction of the rainforest by cyclones.

Basal area in virgin stands of tubtropical rainforest is commonly about 250 sq. ft. per acre. An area of 9.6 acres of virgin forest on Wiangarie State Forest (Richmond-Tweed centre, altitude 2,900 feet) carried a mean B.A. of 200 sq. ft. per acre, and smaller plots in other areas have given usually somewhat greater values. Sixty-five species over 4 inches D.B.H. were recorded on the Wiangarie block, plus some occurrence of strangling figs. However, of the sixty-five species, thirty-five were never normally milled, chiefly because of their small size. These thirty-five species contributed only 10 per cent. of the total B.A. Of the sixty-five species on the whole block an average of about thirty-one occurred on any single acre. The distribution of B.A. in this area by species is given in appendix III; by current stumpage groups (appendix I) it is:

Stumpage Group	A and better	B	C	D and useless	Total
No. of species ..	3	4	10	48	65
Percentage of BA	3·0	32·2	33·6	31·2	100·0

The proportion of Group B species here is unusually high; volume assessment (stems over 8 inches D.B.H.) on another section of Wiangarie S.F. showed that only 1.4 per cent. of the volume on 81 acres was contributed by Group B species or better, 35.4 per cent. by Group C species and 63.2 per cent. by Group D, with White Booyong (*Tarrietia trifoliolata*) making up 32.2 per cent .and Black Booyong (*Tactinophylla*) 15.0 per cent. It was estimated that the merchantable volume in stems larger than 16 inches D.B.H. on this latter area amounted to 19,500 super. feet Hoppus per acre.

The degree of logging in subtropical rainforest has varied greatly from area to area, but almost invariably has resulted in the creaming of the more valuable stems, leaving the stands considerably poorer in composition. Table VII shows the distribution of B.A. by stumpage groups in several stands of logged rainforest.

TABLE VII

Basal Area Distribution in Logged Subtropical Rainforest

Location	Rainforest	Remaining BA/ac.	Percentage of Remaining Basal Area			
			Group A or better	Group B	Group C	Group D or useless
		sq. ft.	%	%	%	%
Cox's Road ..	Richmond-Tweed	91	3·3	5·7	14·3	76·7
Whian Whian	Richmond-Tweed	143	..	1·8	17·0	81·2
Clouds Creek	Dorrigo ..	183	3·6	0·2	2·6	93·6
Woolgoolga	Dorrigo ..	151	..	3·9	1·9	94·2
Bruxner Park	Dorrigo ..	176	..	..	8·4	91·6

Crown Die-back.—Die-back occurs in subtropical rainforest at altitudes above 1,000 feet, and may attain serious proportions in heavily logged stands above 2,500 feet. Detailed studies have not yet been carried out on this, but it appears generally to be of less severity in the subtropical rainforests than in the submontane type: this may merely be a reflection of the somewhat more northerly distribution of the subtropical rainforests. There are probably also considerable differences in the susceptibility of the individual species to crown die-back.

Regeneration.—Natural regeneration of desirable species tends to be extremely deficient in virgin and logged stands. Assessment of regeneration between 1 foot in height and 4 inches D.B.H. in a virgin stand at Wiangarie S.F. showed that only 34 per cent. of the 240 milliacre plots assessed carried any regeneration. This was made up as follows:—

Stumpage Group	A or better	B	C	D (millable)	Useless
	%	%	%	%	%
%Plots Stocked	1	4	9	8	12

In logged areas regeneration is usually more prolific, but with the increase coming chiefly from the Group D and useless classes. Small clumps of more valuable species are occasionally encountered in logged stands: Red Cedar (usually severely attacked by Tip Moth), White Beech and Brown Pine (*Podocarpus elata*) sometimes occur in this way and may cover an area of several square chains.

The losses in regeneration following seedfall tend to be very high unless the seed-bed conditions are fairly open. Regeneration on raked lines around a Red Cedar and under moderately dense canopy was followed through for three years in one area: with 48 yard square plots, 47 carried a total of 1,022 seedlings two months after seedfall; after six months there were

255 on 39 plots; at twelve months, 19 on 12 plots; at two years, 9 on 5 plots; and at three years, 5 on 3 plots, none of which could still be regarded as established.

Growth Rate.—Growth studies in subtropical rainforest are of very recent origin and relate to a few previously logged stands where most of the remaining merchantable stems are of the lower species (see table VII). Even for these the information is fragmentary, but certain trends in growth rate are appearing. Most complete data are available for the Booyongs and for two species of *Eugenia, E. corynantha* and *E. crebrinervis,* and all four species show a similar trend for diameter growth: in the smaller stems (4-8 inches) the diameter P.A.I. is below 0.1 inch, but rises to about 0.15 inch on stems between 10 and 16 inches D.B.H., only to fall below 0.1 inch again as the stems exceed 20 inches D.B.H. Black Apple and certain members of the family Lauraceae show a different trend, in which the smaller stems have a diameter P.A.I. of between 0.1 and 0.15 inch which decreases steadily to below 0.05 inch on stems over 20 inches D.B.H., while certain of the more valuable species, including Corkwood (*Ackama paniculata*), Red Bean (*Dysoxylum muelleri*) and Red Carabeen (*Geissois benthami*) show appreciably faster rates of growth (up to 0.3 inch P.A.I.) on the smaller stems, but information on the growth of larger stems of these species is lacking.

Enrichment Planting.—Experimental enrichment has been carried out in a number of sites using a wide variety of species. In most cases the plantings have been made in small openings following logging, so that the overhead canopy is usually fairly open and subsequent weed growth is heavy. In table VIII the results obtained from some of the plantings are summarised: all except the White Beech are located in the Richmond-Tweed centre, and all except the two plantings at Whian Whian are under very open canopy conditions.

TABLE VIII

Growth Following Enrichment Planting, Subtropical Rainforest

Species	Location	Age	Mean Height	Tallest Height	Survival
		years	ft.	ft.	%
Cedrela lilloi ..	Cox's Road	3	10·5	21·6	100
Red Cedar ..	Whian Whian	3	3·6	10·0	28
Native Teak ..	Whian Whian	3	2·4	5·0	68
Coachwood ..	Cox's Road	4	4·6	10·7	20
Camphor Laurel	Cox's Road	3	9·1	17·8	94
Klinki Pine ..	Cox's Road	3	3·2	5·7	100
White Beech ..	Way Way	8	15·8	26·8	71

Pest damage has been severe in some sites. Camphor Laurel at Whian Whian was completely destroyed by wallabies shortly after being planted, though the same species at Cox's Road was undamaged and has made excellent growth. Red Cedar is very prone to Tip Moth attack when planted in all but the most sheltered situations, but the closely related

Cedrela lilloi has received little damage. Other species are being tried, and among the more promising are Hoop Pine and the very valuable Queensland Maple (*Flindersia brayleyana*). Apart from pest damage the greatest difficulty with enrichment in the subtropical rainforest comes from the prolific weed growth which, if untended, will rapidly suppress the slower starting species.

Suggested Treatment.—Subtropical rainforest is the most difficult of all the local rainforest types to attempt to manage without recourse to conversion. Ironically, it is also the type occupying the finest forest soils anywhere within the State. The major problems to its management come from the usually great preponderance of low value species, frequently compounded by past logging having removed the bulk of the original higher value stems; from the paucity of regeneration of desirable species; and from the prolific weed growth that follows logging. On top of these, crown die-back threatens in the higher altitude stands when these are logged too heavily.

The basic problem is essentially economic. Whereas in submontane rainforest more than 50 per cent. of the basal area is commonly contributed by a single Group A stumpage species and useless and Group D species contribute only about 10 per cent. of the B.A., in the subtropical rainforest this position is reversed: Group D species usually contribute over 50 per cent. of the B.A. (and in previously logged stands up to 90 per cent), while Group A species rarely exceed 10 per cent. In the unlikely event of a great demand for the Booyongs developing, so that these two species could be upgraded, the silvictural treatment of the subtropical rainforests of New South Wales would be immeasurably eased. Because of the difficulties, it is in the subtropical rainforest type that conversion practices, to both araucarias and eucalypts, have been most applied.

Much further work is needed before any but the most tentative proposals for silvicultural treatment can be prepared. In particular, information is required about the growth rates of the more desirable species under varying conditions, about the most suitable species to use for enrichment, about the best means of tending both worthwhile regeneration and enrichment planted stock, about methods of destroying useless stems, and about the incidence of crown die-back following various degrees of logging. Research along these lines is now in progress, but some years will elapse before useful results are obtained.

In the meantime two steps are clearly essential in any attempt to manage this type. Firstly, there must be a steady process of "refining" the forest (see Dawkins, 1955) by retaining for the present all but the overmature and useless stems of the more valuable species, and by removing as much as possible of the useless and low value species within the limits set by avoiding severe crown die-back. These limits, which will probably prove to be slightly less stringent than those for die-back in submontane rainforest, will necessitate the refining being progressively carried out over a number of felling cycles. The immediate result of this will be a decrease in the financial returns from logging operations in virgin stands, since fewer high value stems will be removed: this decrease in royalty received should be counted as part of the cost of treatment.

The second essential step is for enrichment planting to be carried out after logging. This will be required in virtually all sites. Initially it appears wise to use a range of the more promising species. but as experience is gained and it can be determined which species, for the potential value of the produce, give the best results enrichment should be concentrated on fewer species. Tending will be required to keep these enriched stems freely growing, but weeds occurring beneath the enriched stems should be left as these encourage natural pruning and help to improve form.

8. CONCLUSIONS

Technically there seems little doubt that the commercial rainforests of northern N.S.W. can be silviculturally treated with the aim of bringing them under sustained yield management, and this indeed is being done in many areas of temperate, submontane and dry rainforest at present. In the subtropical rainforest further research is needed before silvicultural treatment on a large scale could be started.

In all types it is apparent that emphasis should be concentrated on the more valuable species. Economically it appears futile to attempt to maintain Group C or D species in the stands, though it may prove desirable to retain some of these on silvicultural and ecological grounds. To this conclusion should be added a further proviso: many species in the lower stumpage groups are of very scattered natural occurrence, so that although they may possess highly desirable timber qualities there has never been sufficient quantity available to warrant these special qualities being utilised. Silvicultural treatment in some instances could readily increase the stocking of such species, resulting in their being upgraded to a higher stumping group. Conversely, when destroying small stems of low value species to make way for more desirable species there is always the uncertainty that the species destroyed may themselves ultimately prove to be most desirable. This merely emphasises the need for the closest liaison between the silviculturist and the wood technologist and the necessity for both to keep some jumps ahead of the timberman in their thinking.

Conversion of the rainforest to plantation can be most readily justified in the case of the subtropical and gully rainforest types where the proportion of valuable species is usually very low, and conversion to eucalypts such as Flooded Gum is certainly the cheapest of the conversion techniques available. It appears without doubt the most desirable management procedure where the rainforest occurs in small, disjunct belts, as is almost invariably the case with gully rainforest. It also has application in some areas very heavily logged in the past and left in a derelict condition, though enrichment planting as a stage in rehabilitating such stands may well prove more desirable and less costly. On costs alone conversion to araucarias and other rainforest species in pure plantation can scarcely be warranted and, despite the excellent growth rates attained, conversion to *Pinus* is difficult to justify when the high establishment and tending costs are considered and when the large areas of low quality eucalypt forest capable of producing an equally good rate of growth for *Pinus* at far lower cost in other parts of the State are taken into account. *Pinus* has its main use in the rainforest belts as a means of reforesting the appreciable areas of derelict farming land that once were covered by rainforest and which appears likely to revert to forestry land use over the next decades.

However conversion of the main occurrences of rainforest appears financially impracticable. In any case rainforest is already very limited in extent in New South Wales, and it is from these stands that the State's finest cabinet and specialty timbers are obtained. Despite some uncertainty as to the future demand for timbers of this type, the retention and management of these rainforest areas seems most desirable.

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CURRENT STUMPAGE GROUPS FOR NATIVE RAINFOREST SPECIES

Group A

Coachwood (Scented Satinwood)	Ceratopetalum apetalum.
Yellowwood	Flindersia xanthoxlya
Silver Ash (Cudgerie)	Flindersia schottiana.
Brown Pine	Podocarpus elata.
Brush Cypress	Callitiris macleayana.
Saffron-heart	Halfordia kendack

Group B

Red Carabeen (Brush Mahogany)	Geissois benthami.
Brown Alder (Corkwood, Pencil Cedar)	Ackama paniculata.
Silver Quandong (Blue Fig, Blueberry Ash)	Elaeocarpus grandis and kirtonii.
Silver Sycamore (Jackwood)	Cryptocarya glaucescens.
White Birch (Crabapple)	Schizomeria ovata.

Group C

Prickly Ash (Southern Silky Oak)	Grevillea robusta, Orites excelsa.
Rose Maple (Pigeonberry Ash)	Cryptocarya erythroxylon.
Rose Mahogany (Rosewood)	Dysoxylum fraseranum.
Yellow Carabeen	Sloanea woollsii.
Sasssfras	Doryphora sassafras.
Negrohead Beech	Nothofagus moorei.
Red Silky Oak (Beefwood)	Stenocarpus salignus.
Bollywood	Litsea reticulata.
Miva Mahogany (Red Bean)	Dsyoxylum muelleri.
Crow's Ash (Native Teak)	Flindersia australis.
Onionwood	Owenia cepiodora.
Doughwood	Melicope australasica.
Red Almond (Red Ash)	Alphitonia excelsa.
Black Bean	Castanospermum australe.
Silky Beech	Citronella moorei.
Satin Oak	Embothrium pinnatum.

Group D

Brown and Blush Tulip Oak (Booyong, Blackjack).	Tarrietia trifoliolata and actinophylla.
N.S.W. Walnut (Plumwood)	Endiandra virens.
Camphorwood	Cinnamomum oliveri.

and others may be approved from time to time.

Note:—The following special purpose species are excluded from this grouping:—

Red Cedar	Toona australis.
White Beech	Gmelina leichhardtii.
Yellow Boxwood	Planchonella pohlmaniana.
Black Apple	Planchonella australis.
Ivorywood	Siphonodon australe.
Hoop Pine	Araucaria cunninghamii.

LIST OF SPECIES MENTIONED

Botanical Name	*Common Name*	*Family*
A. Native Rainforest Spe ies.		
Ackama paniculata Engl.	Corkwood	Cunoniaceae.
Alphitonia excelsa Reissek	Red Ash	Rhamnaceae.
Araucaria cunninghamii Ait.	Hoop Pine	Araucariaceae.
Archontophoenix cunninghamiana Wendl. and Drude.	Bangalow Palm	Palmaceae.
Asplenium nidus L.	Bird's-nest Fern	Polypodiaceae.
Austromyrtus acmenoides (F. Meull.) Burret.	.....	Myrtaceae.
Baloghia lucida Endl.	Scrub Bloodwood	Euphorbiaceae.
Callitris macleayana F. Muell.	Bush Cypress Pine	Cupressaceae.
Capparis nobilis F. Muell.	.....	Capparidaceae.
Castanospermum australe A. Cunn.	Black Bean	Leguminosae.
Celastrus disperma F. Muell.	Orange-Bark	Celastraceae.
Ceratopetalum apetalum D. Don	Coachwood	Cunoniaceae.
Cinnamomum oliveri F.M.B.	Camphorwood	Lauraceae.
Citronella moorei Howard	Silky Beech	Icacinaceae.
Cryptocarya erythroxylon M. and B.	Pigeonberry Ash	Lauraceae.
Cryptocarya foveolata W. and F.	.....	Lauraceae.
Cryptocarya glaucescens R. Br.	Silver Sycamore	Lauraceae.
Cryptocarya microneura Meissn.	.....	Lauraceae.
Cyathea leichhardtii F. Muell.	Tree Fern	Cyatheaceae.
Denhamia pittosporoides F. Muell.	.....	Celastraceae.
Diospyros pentamera F. Muell.	Black Myrtle	Ebenaceae.
Doryphora sassafras Endl.	Sassafras	Monimiaceae.
Dysoxylum fraseranum Benth.	Rosewood	Meliacease.
Dysoxylum muelleri Benth.	Red Bean	Meliaceae.
Elaeocarpus grandis F. Muell.	Silver Quandong	Elaeocarpaceae.
Elaeocarpus kirtonii F. Muell.	Silver Quandong	Elaeocarpaceae.
Elaeocarpus obovatus G. Don	Hard Quandong	Elaeocarpaceae.
Ellatostachys nervosa Radlk.	.....	Sapindaceae.
Embothrium pinnatum C. T. White	Satin Oak	Proteaceae.
Endiandra discolor Benth.	Domatia Tree	Lauraceae.
Endiandra sieberi Nees	.....	Lauraceae.
Endriandra virens F. Muell.	N.S.W. Walnut	Lauraceae
Eugenia corynantha F. Muell.	Sour Cherry	Myrtaceae
Eugenia crebrinervis C. T. White	.....	Myrtaceae.
Eugenia smithii Poir.	Lilly Pilly	Myrtaceae.
Ficus watkinsiana F.M.B.	Green-leaved Moreton Bay Fig.	Moraceae.
Flindersia australis R. Br.	Native Teak	Rutaceae.
Flindersia schottiana F. Muell.	Cudgerie	Rutaceae.
Flindersia xanthoxyla Domin.	Yellowwood	Rutaceae.
Geissois benthami F. Muell.	Red Carabeen	Cunoniaceae
Gmelina leichhardtii F. Muell.	White Beech	Verbenaceae.
Grevillea robusta A. Cunn.	Silky Oak	Proteaceae.
Halfordia kendack Guillaumin	Saffron-heart	Rutaceae.
Hemicyclia australasica F. Muell.	.....	Euphorbiaceae.
Laportea gigas Wedd.	Giant Stinging Tree.	Urticaceae.
Laportea photiniphylla Wedd.	Smooth-leaved Stinging Tree.	Urticaceae.
Litsea leefeana Merr.	Brown Bollywood	Lauraceae.
Litsea reticulata F. Muell.	Bollywood	Lauraceae.
Longetia swainii de Beuz. and White	Hairy-bark	Euphorbiaceae.
Mallotus philippinensis F. Muell.	.....	Euphorbiaceae.
Melicope australasica F. Muell.	Doughwood	Rutaceae.
Orites excelsa R. Br.	Prickly Ash	Proteaceae.

Botanical Name	*Common Name*	*Family*
Owenia cepiodora F. Muell.	Onionwood	Meliaceae.
Planchonella australis Pierre	Black Apple	Sapotaceae.
Planchonella pohlmaniana Pierre	Yellow Boxwood	Sapotaceae.
Platycerium bifurcatum (Cav.) C. Chr.	Stag-Horn Fern	Polypodiaceae.
Podocarpus elata R. Br.	Brown Pine	Podocarpaceae.
Polyosma cunninghamii J. J. Benn.	.....	Escalloniaceae.
Polyscias elegans Harms.	Celery-wood	Araliaceae.
Pseudocarapa nitidula Merr. and Perry	.....	Meliaceae.
Pseudomorus brunoniana Bur.	Grey Handlewood	Moraceae.
Quintinia sieberi A. DC.	Possumwood	Escalloniaceae.
Rhysotoechia bifoliolata Radlk.	.....	Sapindaceae.
Schizomeria ovata D. Don	Crabapple	Cunoniaceae.
Siphonodon australe Benth.	Ivorywood	Celastraceae.
Sloanea australis F. Muell.	Maiden's Blush	Elaeocarpaceae.
Sloanea woollsii F. Muell.	Yellow Carabeen	Elaeocarpaceae.
Solanum auriculatum Ait.	Native Tobacco (intod.)	Solanaceae.
Tarrietia actinophylla F.M.B.	Black Booyong	Sterculiaceae.
Tarrietia trifoliolata F. Muell.	White Booyong	Sterculiaceae.
Toechima tenax Radlk.	.....	Sapindaceae.
Toona australis Harms	Red Cedar	Meliaceae.
Vesselowskya rubifolia Engler	.....	Cunoniaceae.
Wilkiea austroqueenslandica L.S. Smith	.....	Monimiaceae.
Zanthoxylum brachyacanthum F. Muell.	Thorny Yellow-wood.	Rutaceae.

B. Eucalypts and Related Myrtaceae.

Eucalyptus grandis (Hill.) Maiden	Flooded Gum.
Eucalyptus microcorys F. Muell.	Tallowwood
Eucalyptus pilularis Sm.	Blackbutt
Eucalyptus saligna Sm.	Sydney Blue Gum
Tristania conferta R. Br.	Brush Box

C. Introduced Species.

Botanical Name	*Common Name*	*Family*	*Origin*
Agathis robusta Mast.	SouthQueensland Kauri.	Araucariaceae.	S. Queensland.
Araucaria araucana K. Koch	Monkey Puzzle	Araucariaceae	Chile.
Araucaria bidwillii Hook.	Bunya Pine	Araucariaceae	S. Queensland.
Araucaria klinkii Diels	Klinki Pine	Araucariaceae	N. Guinea.
Cedrella lilloi C. DC.	.....	Meliaceae.	Argentine.
Cedrela odorata L.	Cigar-Box Cedar	Meliaceae.	W. Indies.
Cinnamomum camphora (L.) Nees and Eberm.	Camphor Laurel	Lauraceae.	S. E. Asia.
Flindersia brayleyana F. Muell.	Queensland Maple.	Rutaceae	N. Queensland.
Pinus caribaea Morelet	Caribbean Pine	Abietaceae	Cent. America.
Pinus elliottii Engel	Slash Pine	Abietaceae	S.E. U.S.A.
Pinus insularis Endl.	.....	Abietaceae	Philippines.
Pinus patula Schl. and Cham.	Silky Pine	Abietaceae	Mexico.
Pinus pseudostrobus Lindl.	.....	Abietaceae	Mexico.
Pinus radiata D. Don	Monterey Pine	Abietaceae	California.
Pinus taeda L.	Loblolly Pine	Abietaceae	S. U.S.A.

RAINFOREST COMPOSITION—PLOT SUMMARIES

(Stems over 4 inches D.BH.)

A. Temperate Rainforest.

1. *Mt. Boss State Forest* (Hastings Centre). Altitude 4,000 feet.
Plot Area = 0·2 acres.

Species	No. Stems	Per cent. Basal Area
Ceratopetalum apetalum ..	43	35·3
Nothofagus moorei	6	48·2
Orites excelsa	5	2·3
Doryphora sassafras	3	1·7
Ackama paniculata	2	1·3
Sloanea woollsii	1	3·9
Others (5 spp.)	11	7·3
Total (11 spp.)	71 (355 / ac.)	100·0 (333 sq. ft./ ac.)

Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A ..	1	36
B ..	1	1
C ..	4	56
D ..	5	7
Total	11	100

B. Submontane Rainforest.

1. *Styx River State Forest* (Dorrigo Centre.) Altitude 3,000 feet.
Plot Area = 0·13 acres.

Species	No. Stems	Per cent. Basal Area
Doryphora sassafras	18	24·0
Ceratopetalum apetalum ..	9	30·5
Cryptocarya foveolata ..	6	3·0
Ackama paniculata	5	9·2
Polyosma cunninghamii ..	5	1·2
Quintinia sieberi	4	2·9
Tarrietia actinophylla ..	3	3·5
Citronella moorei	1	18·9
Others (4 spp.)	5	6·8
Total (12 spp.)	56 (430/ac.)	100·0 (285 sq. ft./ ac.)

Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A ..	1	31
B ..	1	9
C ..	4	48
D ..	6	12
Total	12	100

2. *Moonpar State Forest* (Dorrigo Centre). Altitude 2,400 feet.

Plot Area = 0·4 acres.

Species	No. Stems	Per cent. Basal Area
Ceratopetalum apetalum ..	40	52·1
Schizomeria ovata	8	22·8
Doryphora sassafras	7	4·8
Longetia swainii	5	9·1
Geissois benthami	4	2·4
Litsea reticulata	3	2·6
Others (6 spp.)	7	6·2
Total (12 spp.)	74 (185 /ac.)	100·0 (296 sq. ft./ac.)

Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A ..	1	52
B ..	3	25
C ..	4	11
D ..	4	12
Total	12	100

C. Dry Rainforest.

1. *Unumgar State Forest* (Richmond-Tweed Centre). Altitude 800 feet.

Plot Area = 0·21 acres.

Species	No. Stems	Per cent. Basal Area
Elattostachys nervosa ..	9	3·6
Hemicyclia australasica ..	7	9·8
Austromyrtus acmenoides ..	7	1·7
Laportea photiniphylla ..	6	6·3
Toechima tenax	6	2·5
Celastrum disperma	4	6·8
Siphonodon australe	4	7·3
Flindersia australis	4	35·5
Araucaria cunninghamii ..	2	12·0
Others (15 spp.)	29	14·5
Total (24 spp.)	78 (381/ac.)	100·0 (197 sq. ft./ac.)

Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A ..	2	19
C ..	1	36
D ..	21	45
Total	24	100

D. Subtropical Rainforest.

1. *Cox's Road Logging Area* (Richmond-Tweed Centre). Altitude 2,000 feet.

Plot Area = 0·15 acres.

Species	No. Stems	Per cent. Basal Area
Tarrietia trifoliolata	18	65·0
Baloghia lucida	7	7·5
Orites excelsa	5	8·4
Pseudocarapa nitidula ..	5	2·2
Diospyros pentamera ..	4	2·2
Planchonella australis ..	1	0·5
Geissois benthami	1	0·2
Others (6 spp.)	7	15·1
Total (13 spp.)	48 (312/ac.)	100·0 (234 sq. ft./ac.)

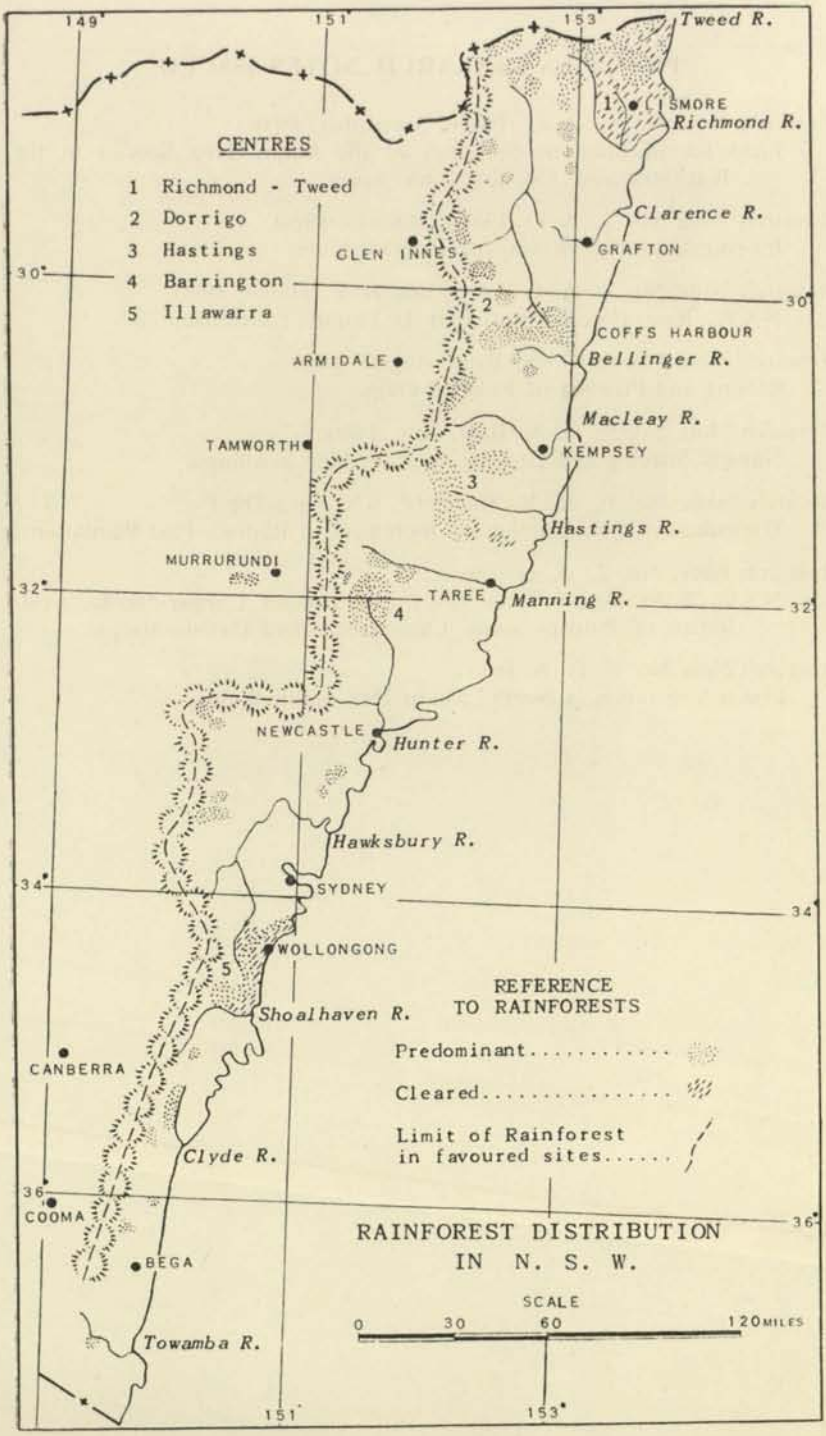
Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A & B ..	2	1
C ..	1	8
D ..	10	91
Total	13	100

2. *Wiangarie State Forest* (Richmond-Tweed Centre). Altitude 2,900 feet.

Plot Area = 9·6 acres.

Species	No. Stems	Per cent. Basal Area
Ackama paniculata	334	22·7
Doryphora sassafras	137	3·8
Sloanea woollsii	123	14·6
Tarrietia trifoliolata	122	13·4
Geissois benthami	110	9·2
Baloghia lucida	97	1·7
Cryptocarya erythroxylon ..	81	4·7
Orites excelsa	74	3·2
Sloanea australis	71	1·6
Planchonella australis	59	2·1
Cinnamomum oliveri ..	45	1·9
Dysoxylum fraseranum ..	33	5·5
Others (53 spp.)	495	15·6
Total (65 spp.)	1,781 (186 /ac.)	100·0 (200 sq. ft./ac.)

Per cent. B.A. by Stumpage Groups		
Group	No. Spp.	Per cent. B.A.
A ..	3	3
B ..	4	32
C ..	10	34
D ..	48	31
Total	65	100


149
151
153
Tweed R.
LISMORE
Richmond R.
CENTRES
1 Richmond - Tweed
2 Dorrigo
3 Hastings
4 Barrington
5 Illawarra
Clarence R.
GLEN INNES
GRAFTON
30
30
COFFS HARBOUR
Bellinger R.
ARMIDALE
Macleay R.
TAMWORTH
KEMPSEY
Hastings R.
MURRURUNDI
32
TAREE
Manning R.
32
NEWCASTLE
Hunter R.
Hawksbury R.
34
SYDNEY
34
WOLLONGONG
Shoalhaven R.
REFERENCE
TO RAINFORESTS
Predominant.....
Cleared.....
Limit of Rainforest
in favoured sites.....
CANBERRA
Clyde R.
36
COOMA
36
BEGA
RAINFOREST DISTRIBUTION
IN N. S. W.
SCALE
0 30 60 120 MILES
Towamba R.
151
153

PREVIOUS RESEARCH NOTES ISSUED

Research Note No. 1. A. G. Floyd, September, 1958.
Field Identification of Seedlings of the Major Tree Species in the Blackbutt and Flooded Gum Areas.

Research Note No. 2. A. G. Floyd, January, 1960.
Investigations into Sowing of Flooded Gum.

Research Note No. 3. A. G. Floyd and H. C. Hayes, 1960.
N.S.W. Rain Forest Trees. Part I: Family Lauraceae.

Research Note No. 4. G. N. Baur, August, 1959.
Raising and Planting of Flooded Gum.

Research Note No. 5. G. N. Baur, July, 1960.
Nursery Spacing and Grading of Slash Pine Seedlings.

Reearch Note. No. 6. K. R. Shepherd, B.Sc.For., Dip.For.
The effects of Low Pruning on Increment in Radiata Pine Plantations.

Research Note. No. 7. A. G. Floyd.
N.S.W. Rain Forest Trees. Part 2—Familiies Capparidaceae, Ecalloniaceae, Pittosporaceae, Cunoniaceae and Davidsoniaceae.

Research Note No. 8. G. N. Baur.
Forest Vegetation in North-Eastern New South Wales.

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