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NATURE and DISTRIBUTION of RAINFORESTS in NEW SOUTH WALES

by

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(Terminology updated by A.G. Floyd)

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NATURE AND DISTRIBUTION OF RAIN-FORESTS IN NEW SOUTH WALES.

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SUMMARY.

Rain-forest has a discontinuous distribution along the coast and adjoining ranges of New South Wales, extending to altitudes of over 1220 m . Four major subformations can be recognized, along with two other structural forms which may deserve subformation status. The subformations have been defined as subtropical, warm temperate, cool temperate and dry rain-forest. Six floristic alliances and their associations are briefly described.

For the widespread development of rain-forest an annual rainfall exceeding 1500mm is required, though rain-forest is found under much lower rainfalls in places favoured by the soil or topography. The Drypetes alliance (dry rain-forest) is found in areas showing a distinctly seasonal rainfall distribution, while the Nothofagus alliance (cool temperate rain-forest) requires cold and very moist conditions. The Castanospermum alliance occurs along creek banks, usually away from the main rain-forest patches, and the Cupaniopsis alliance is found close to the coast, apparently requiring wind-borne supplies of moisture and mineral nutrients for its development. The Heritiera (subtropical) and Ceratopetalum (warm temperate) alliances occur under similar climatic conditions in the north, but with the Ceratopetalum alliance restricted by competition to the less fertile soils. In the south of the State, where climatic sifting has removed many tropical rain-forest species, the Ceratopetalum alliance occurs on the richer soils.

The discontinuity of the rain-forest distribution has been brought about by past climatic changes. Human influences have always restricted rain-forest spread, and since European settlement the area of rain-forest in New South Wales has been reduced by about half.

1. INTRODUCTION

The aim of the present paper is, firstly, to describe the structure and composition of the rain-forest communities in New South Wales and secondly, to discover those factors which are of the greatest importance in determining the nature and distribution of rain-forest.

Particular emphasis has been placed on the rain-forests north of the Bellinger River, since these not only include all the main forms of rain-forest encountered in New South Wales, but also represent the bulk of the State's commercial rain-forest areas from a forestry viewpoint.

The present paper is based largely on data collected during two field trips to the Casino and Coffs Harbour forestry districts, followed by the analysis of collected plant and soil materials at the laboratories of the Department of Botany, University of Sydney.

The communities studied were all characterized by a more or less closed canopy of one or usually more layers of mesomorphic trees and shrubs, generally from a number of different genera and families. Lianes and epiphytes were commonly abundant, but Eucalyptus spp., except as a fairly obvious remnant from an earlier community, were absent. A more detailed definition of rain-forest and its various subformations will be considered later in this review.

11. DISTRIBUTION OF RAIN-FOREST IN NEW SOUTH WALES.

General discussions on the extent of rain-forest in New South Wales have been given by the Forestry Commission of New South Wales (1947), Wood (1950), and Francis (1951), and maps have been included by the last two authors. All three references contain inaccuracies and omissions. The Forestry Commission publication fails to mention or to show on its map the rather extensive stands of rain-forest in the Barrington Tops area, but otherwise gives the most complete account of rain-forest distribution and the most accurate map. Francis makes no mention of the important rain-forests of the Hastings River watershed, whilst Wood, in a very small scale map, gives these communities undue prominence but barely acknowledges the presence of the equally important Dorrigo Plateau rain-forests.

The area of rain-forest in New South Wales has been estimated as about 283,000 ha of which some 182,000 ha have been dedicated as state forest. (Forestry Commission of N.S.W. 1947). In addition large areas formerly occupied by rain-forests have been cleared to make way for farming land.

Data on the distribution of rain-forest are still far from complete, though the major areas are now fairly well known. The map (Fig. I) shows the presence of five main areas in New South Wales. Besides these there are numerous smaller and relatively isolated patches, and extensive areas in which rain-forest occurs along the banks of creeks and in sheltered gullies. The five major areas are:-

The McPherson Range and Richmond-Tweed Valleys.

The Dorrigo Plateau and Bellinger River headwaters.

The Hastings River headwaters, with extensions north to the Carrai Plateau, and south to the Bulga and Comboyne Plateaux.

The Barrington Tops district.

The Illawarra district and Robertson highlands.

The Illawarra rain-forest has been almost entirely destroyed by clearing, as have considerable portions of the Richmond-Tweed rain-forest (the "Big Scrub" of the early settlers) and the Dorrigo and Bulga-Comboyne rain-forests. Similarly the alluvial flats of all the major coastal streams north of the Shoalhaven River originally supported dense rain-forests which have been destroyed, first for their timber wealth (particularly red cedar, *Toona australis*), and later to make way for agriculture.

The rain-forest areas shown enclosed by the broken line in Figure I are of particular importance and have been reserved for more detailed discussion in Section III. Short descriptions of all the areas are given in Sections II (a) to II (d) below.

(a) Rain-forest North of the Clarence River.

The far northern areas will be dealt with more fully in the next section. The few remaining pockets of rain-forest along the Richmond-Tweed lowlands are characterized by their general luxuriance. Francis (1951) has compared these stands, remnants of the Big Scrub, with the truly tropical rain-forests of North Queensland. The species present here are very mixed and dominants are hard to recognize. *Ficus* spp. and *Heritiera* spp. are relatively common, and apparently *Toona australis* and *Flindersia* spp. were originally frequent. A number of important Queensland species reach their southern limit here. This type of rain-forest is confined to areas

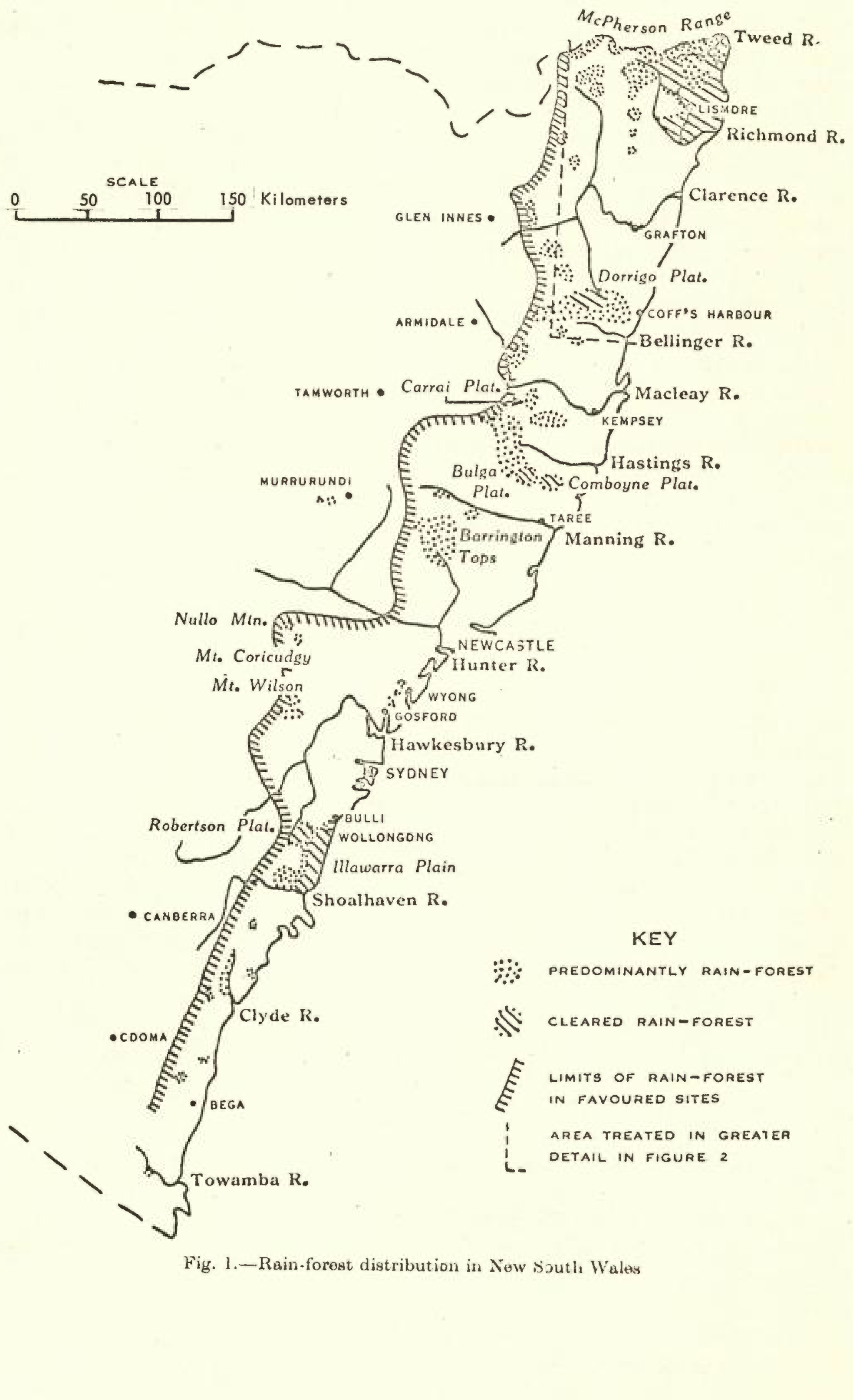


Fig. 1.—Rain-forest distribution in New South Wales

of basalt or alluvium under high rainfall conditions.

Similar soils further from the coast support an almost equally luxuriant community, in which the Heritiera spp. are rather clearly dominant, while at higher altitudes Dysoxylum fraseranum competes with the Heritieras as the dominant species. Still higher, on the frequently clouded points of the McPherson Ranges small stands of Nothofagus moorei occur. High rainfall areas with less fertile soils support a rain-forest dominated by Ceratopetalum apetalum (coachwood) or, in more adverse sites, wet sclerophyll forest.

Where rainfall decreases, particularly in the river valleys, rain-forest is usually absent except as a fringing community along the watercourses. The vegetation in these areas (e.g. the Richmond valley north and west of Kyogle) is typically a tall woodland Eucalyptus association, with a narrow fringing rain-forest containing a high proportion of Castanospermum australe, Grevillea robusta, and Podocarpus elatus. Away from the creeks, but in locally favoured situations, patches of a low growth of rain-forest species forming a closed canopy are commonly encountered. These contain numerous species of the Sapindaceae and Euphorbiaceae, and are frequently overtopped by an open stand of hoop pine, Araucaria cunninghamii. Such areas are locally known as "dry scrub", "viney scrub", or "bastard scrub", "scrub" being a general North Coast term for rain-forest.

Most of the Clarence valley is an area of poor soils and low rainfall. Rain-forest, now completely cleared, once extended along the Clarence River banks to slightly west of Grafton, while small dry scrub pockets and fringing rain-forest occur in parts of the western valley. To the south drainage is off the Dorrigo Plateau, the second major stand of rain-forest in this State.

(b) Rain-forest on the Dorrigo Plateau.

The Dorrigo Plateau has an elevation of about 450m in the east where it rises sharply from the coast behind Coffs Harbour, and then rises gently to more than 1500m in the west (Point Lookout, 1600m). It decreases gradually in elevation to the north, but drops steeply down to the Bellinger River in the south. Extensions of the Plateau occur in rugged highland to the south of the Bellinger valley. The eastern part of the plateau is of shale, but in the west this has been covered by basalt flows of Tertiary age. The town of Dorrigo lies on the junction of the shale and basalt. The shale region is still largely forested and contains mainly Ceratopetalum-type rain-forest. Nothofagus occurs but only as an associate species to Ceratopetalum along watercourses. Wet sclerophyll forest, containing Eucalyptus microcorys, E. saligna, E. andrewsii, and E. pilularis,* is found along the ridges.

The basalt region has been almost entirely cleared for dairying pursuits. Only isolated outliers of basalt are still forested, supporting a Heritiera rain-forest. Associated with these basalt pockets are a number of small natural grasslands on the basalt, surrounded by rain-forest. The main basalt region near Dorrigo originally contained a rain-forest with much Dysoxylum fraseranum, Toona, Geissois benthami, Gmelina leichhardtii, and other commercially valuable species. Nothofagus occured on rocky knolls near the southern scarp of the Plateau, where the land is frequently covered in mist. At higher elevations further west, rain-forest

* The terminology of Eucalyptus species throughout the present paper is that of Pryor & Johnson, A Classification of the Eucalypts (1971).

is absent from the basalt plateau and its place is taken by a community of snow-grass (Poa spp.), and scattered snow gums (E. pauciflora). Valleys cutting through this plateau are fringed by a Nothofagus rain-forest, containing also some Ceratopetalum and Orites excelsa.

Rain-forest continues round the Bellinger and Nambucca River watersheds, but is absent from most of the northern Macleay valley. Areas of Ceratopetalum and Nothofagus rain-forests occur further west in the Styx River region. The coastal lowlands support mainly wet sclerophyll forest, but with rain-forest communities of varying complexity occupying most gullies. These gully rain-forests are a characteristic feature of the coastal vegetation from north of Coffs Harbour to south of Sydney.

(c) Rain-forest between the Macleay and Hunter Rivers.

West of Kempsey is the Carrai Plateau, containing both Ceratopetalum rain-forests and more complex communities with much Toona. These are linked to the large Hastings watershed rain-forest by patches of gully rain-forest. The Hastings rain-forest is predominantly of Ceratopetalum, particularly in the west where some ecological studies have been made by Burges and Johnston (1953). More complex communities dominated by Dysoxylum or Heritiera are present on areas of better soil, whilst at high elevations in the north of the region (Mt. Banda Banda, 1260m) are extensive areas of Nothofagus rain-forest. In the south the rain-forest extends on to the Bulga and Comboyne Plateaux, large areas of which have been cleared for agriculture. The Manning River originally supported rain-forest along its lower banks and small pockets occur in the western valley. Some of these follow creeks up into the Barrington Tops rain-forest area. This region has been extensively studied by Fraser and Vickery (1937, 1938, 1939). The parent rock is basalt and the area has a high rainfall. Higher elevations support a Nothofagus rain-forest, though the plateau top itself carries mainly a snow-grass community with some snow gum. At lower elevations is a fairly luxuriant mixed rain-forest community, in which Schizomeria ovata, Ackama paniculata, Doryphora sassafras, and Cryptocarya glaucescens are common. No Ceratopetalum or Heritiera spp. are found in this area.

Small patches of rain-forest occur between Barrington and the coast, though the dominant vegetation is sclerophyll forest. Isolated pockets near the coast have been described by Osborn and Robertson (1939), while the species from the Krambach district have been recorded by Maiden (1895). West of the Barrington Tops, rain-forest occurs on a number of the higher outlying mountains, and is found also in sheltered sites at lower elevations. Several such areas occur in the Liverpool Range foothills west of Murrurundi.

(d) Rain-forest in Southern New South Wales.

South of the Hunter River, which originally carried rain-forest along its lower reaches, some fairly rich communities are found in gullies in the Gosford-Wyong districts. The extensive Hawkesbury Sandstone area, however, contains only occasional patches of depauperate rain-forest in some of its gullies. Basalt-capped peaks in the Blue Mountains and also further north (Nullo Mountain, and Mt. Coricudgy near Rylstone) support a Ceratopetalum rain-forest, as do the deeper, sheltered gullies of this region. Such sites at Mt. Wilson have been studied by Brough, McLuckie, and Petrie (1924) and by McLuckie and Petrie (1926).

South of Sydney rain-forest occurs with some luxuriance in gullies overlying Narrabeen chocolate shales, and originally covered most of the Illawarra Plain from Bulli to the Shoalhaven River. This area has now been almost completely cleared, though remnants along the western scarp still exist. Some of these were studied by Davis (1936, 1941) and were shown to contain a mixture of species from the Ceratopetalum type and from the more complex northern communities. Rain-forest extends up to the eastern edge of the Robertson Plateau on the basalt and, under high rainfall conditions, also occurs on the adjacent Wianamatta Shale where the dominant species are Doryphora sassafras and Acacia melanoxylon (Phillips 1947).

South of the Shoalhaven River no extensive areas of rain-forest occur. Only a few of the typically northern species survive far south of the Shoalhaven, and there is an increasing proportion of Victorian temperate species entering into the sheltered gorges. The transition to the Myrtle Beech (Nothofagus cunninghamii) rain-forests of southern Victoria and Tasmania takes place gradually along this length of coast and in eastern Victoria. Myrtle beech itself does not occur in New South Wales but is found in the ranges of eastern Gippsland (Forest Commission of Victoria 1948).

III. RAIN-FOREST LOCALITIES IN NORTHERN NEW SOUTH WALES.

(a) Geology.

The country between the Bellinger River and the Queensland border (Fig. 2) is characterized by two elevated areas, the Dorrigo Plateau at the south and the McPherson Ranges in the north. Between these lies the extensive Jurassic sedimentary basis (Clarence series) of shales, sandstones, conglomerates and coal measures. The Dorrigo Plateau is an elevated area of shales, probably Carboniferous, which have been covered from the west by a Tertiary basalt flow.

Stretching north from the Dorrigo Plateau is a long spur known as the Coast Range. This extends from Coffs Harbour to the mouth of the Clarence River, running parallel to the coast and roughly 8km inland. Its average height is about 300m , but it rises in places to 760m . In the south it is composed of the Silurian shales and in the north of rocks from the Clarence series.

The McPherson Ranges and their spurs are mainly formed from a succession of Tertiary larva flows which cover the Clarence series. These flows also cover much of the lower Richmond Valley, reaching the coast between Ballina and Point Danger. The flows contain basic and acid rocks, and in places the complete series can be seen, with the upper and lower basalt flows sandwiching a series of acid rocks including rhyolite, obsidian, and trachyte. Small areas of basalt are found to the south and west of the main flows, mainly along the low ridge that forms much of the Richmond Range.

(b) Climate.

Typical rainfall figures are shown in Table I. The general picture is one of high rainfall along the ranges and closely adjacent lowlands, with an extensive low rainfall area occupying most of the Clarence Basin.

Table I.

Mean Annual Rainfall - North Coast Localities

Station	Years of Record	Rainfall (mm)	Station	Years of Record	Rainfall (mm)
Brooklana	32	1650	Grafton	72	900
Byron Bay	52	1900	Kyogle	31	1150
Casino	71	1100	Mt.Pikapene S.F.	17	1050
Clouds Creek	15	1300	Newfoundland S.F.	7	1150
Coffs Harbour	36	1600	Roseberry Nursery	14	1150
Dorrigo	28	1900	Whian Whian S.F.	10	2300

In the upper valley of the Richmond River rainfall is also low, though there is evidence that the forested ranges receive higher falls than the nearby velley bottoms, where most weather stations are situated. Thus Munns (1953) states that Roseberry, 20 km upstream from Kyogle and with an elevation of about 120 m, has a corrected rainfall of 950mm , while Toonumbar State Forest 5 km away but with an altitude of 350 m receives 1400mm.

Throughout the region there is a tendency for wet summers, preceded by dry winters and springs. This is clearly shown by the monthly averages for Mt. Pikapene State Forest (Table 2).

Temperatures along the coastal section of the region are warm in summer and mild in winter with occasional frosts. Away from the coast frosts are frequent in the winter and on rare occasions snow has been recorded at stations higher than about 750 m. Table 3 gives mean monthly temperatures for two localities, one coastal and the other on the Dorrigo Plateau.

(c) Vegetation North of the Clarence River.

The luxuriant *Heritiera*-dominated rain-forests are common in McPherson Ranges. Good examples can be seen on the Queensland side of the border near Binna Burra Lodge, Lamington National Park; at Wiangarie State Forest, 22 km north of Kyogle; at Whian Whian State Forest, 26 km north of Lismore; and on Mt. Lindsay, on the Queensland border at the head of the Richmond River. At Tooloom Plateau and Acacia Plateau, both about 19 km westwards from Woodenbong; similar communities occur, but with a tendency for dominance by *Dysoxylum fraseranum*.

Table 2.

Monthly Rainfall Averages - Mt. Pikapene State Forest.

17 years to 1953.

Month	Rainfall (mm)	Month	Rainfall (mm)	Month	Rainfall (mm)
Jan.	160.5	May	49.8	Sept.	35.1
Feb.	153.6	June	103.9	Oct.	74.9
Mar.	160.5	July	42.9	Nov.	94.0
Apr.	49.0	Aug.	33.3	Dec.	108.4

At Lamington National Park, acid volcanic rocks close by the _Heritiera_ rain-forests support typical _Ceratopetalum_ communities, with _Eucalyptus andrewsii_ wet sclerophyll forest in the more exposed parts. More elevated points carry stands of _Nothofagus_. One small area, which according to Herbert (1951) occurs on volcanic glass, carries a stand of mallee (_Eucalyptus approximans_); the pocket is fringed by a poor _Ceratopetalum_ rain-forest.

Table 3.

Month	Clouds Creek 600m.		Newfoundland S.F. 80m	
	Mean Max. °C.	Mean Min. °C	Mean Max. °C	Mean Min. °C
Jan.	26.6	14.4	29.0	19.1
Feb.	25.5	13.9	27.8	19.1
Mar.	24.1	11.5	26.8	17.7
Apr.	21.4	6.3	24.4	13.4
May	19.2	3.1	22.7	10.7
June	16.1	0.8	20.2	8.7
July	15.9	0.3	18.6	7.3
Aug.	17.8	0.4	20.1	8.1
Sept.	20.6	3.1	23.1	10.3
Oct.	22.4	6.7	24.4	13.0
Nov.	25.4	10.6	26.8	16.4
Dec.	26.1	12.7	27.7	18.0

At Whian Whian the complete range of volcanic rocks is present, and upper and lower _Heritiera_ communities are separated by a belt of _Ceratopetalum_ rain-forest and _Eucalyptus pilularis-E. saligna_ wet sclerophyll forest on the acid rocks. The lower altitude _Heritiera_ rain-forest appears to be the largest Big Scrub remnant still existing; unfortunately it has been rather heavily logged.

Gullies through these _Heritiera_ stands are bordered by a somewhat different community, in which _Elaeocarpus grandis_ is dominant.

The vegetation of Mt. Lindsay shows a transition from the relatively dry valley of the Richmond River (altitude about 152m) to the frequently cloud-bound heights of the peak (altitude about 1150m, but with sheer cliffs above 800m). The valley bottom runs through Jurassic shales but soils from the base of the cliffs down to the river all show signs of basalt influence. In the valley vegetation is a tall woodland of _Eucalyptus maluccana_ and _E. tereticornis_ associated with _E. melliodora_ and _E. siderophloia_, giving way higher up the slope to a wet sclerophyll forest of _E. saligna_, _E. microcorys_, and _E. eugenioides_. At about 550m the forest is reduced to an open stand of veteran _E. saligna_ and _Casuarina torulosa_, and slightly higher is the edge of the rain-forest, with a fringing tangle of vines, including much _Lantana_. Lower levels of the rain-forest are dominated by _Heritiera_, and elements from this community persist to near the base of the cliffs. Forming a thin belt around the cliff-base is a low (9-12m) stand of _Schizomeria ovata_ and _Banksia integrifolia_, with a shrubby understorey. On steep slopes at slightly lower levels are denser, more mixed stands of similar low height, with their branches festooned by a pendent moss. An overstorey of _Araucaria cunninghamii_, also moss covered, is present, and epiphytic ferns are very common, even coating rock slopes.

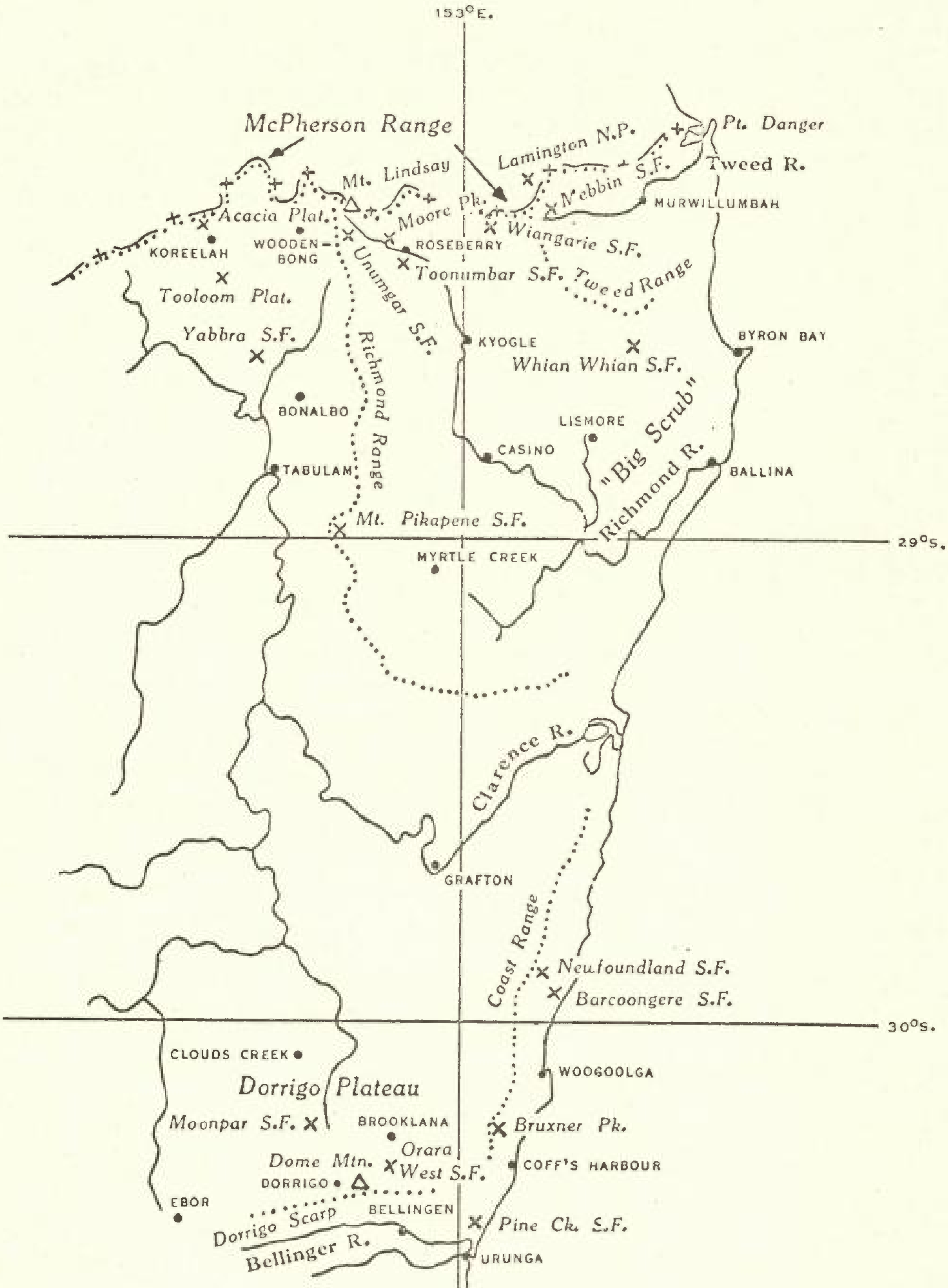


Fig. 2.—North-eastern New South Wales. *S.F.*, State Forest; *N.P.*, National Park

The river-bank rain-forests which fringe the watercourses in the drier areas were examined at Moore Park, a small flora reserve 5km upstream from Roseberry Nursery; at Mt. Pikapene State Forest, about 40km south-west of Casino; and along Myrtle Creek between Casino and Grafton. In the first two localities the communities are fairly rich in species, and are dominated by Castanospermum australe, Grevillea robusta, and Podocarpus elatus. At Myrtle Creek the stand is very impoverished, and has Syzygium floribundum as its dominant species.

Dry scrubs are also common in these areas. The main area is at Mt. Pikapene State Forest where an extensive stand occurs on basalt along the eastern fall of the Richmond Range. Over 405 ha have been converted to Araucaria plantation since 1939. Surrounding the dry scrub is a tall woodland of Eucalyptus maculata, and E. rummeryi. Similar communities are found at Unumgar State Forest, on the southern side of Richmond River opposite Mt. Lindsay; in the upper Clarence valley near Koreelah; and in the Upper Tweed valley at Mebbin State Forest. The Koreelah stand is very small, occupying a single steep slope adjacent to the Lindsay Highway. The overstorey of Araucaria is missing here, and the ground surface is extremely stony.

(d) Vegetation South of the Clarence River.

Most of the Clarence basin carries tall woodland, predominantly of Ecualyptus maculata, while the northern section of the Coast Range, with very poor soils derived from the Jurassic sandstones and conglomerates, supports a dry sclerophyll forest of E. planchoniana and E. signata. The junction with the Silurian shales occurs in the Barcoongere and Newfoundland State Forests, about 16km north of Woolgoolga. Better soils in this region carry E. pilularis, but rain-forest is absent. The land here is being used for the planting of the American slash pine (Pinus elliottii, syn. P. caribaea), and it appears that while the E. pilularis sites will produce good stands of Pinus, the E. planchoniana sites are worse than marginal.

The southern end of the Coast Range carries chiefly a wet sclerophyll forest dominated by E. pilularis, with a rain-forest intermediate in character between the Heritiera and Ceratopetalum types in the gullies. These rain-forests are frequently overtopped by veteran stems of Eucalyptus grandis. Similar vegetation is found along the coast south of Coffs Harbour and up into the eastern foothills of the Dorrigo Plateau. Good examples of the gully rain-forests occur at Bruxner Park, a flora reserve on the Coast Range near Coffs Harbour, and at Pine Creek State Forest, on the Pacific Highway between Coffs Harbour and Urunga. Present forest policy in such gullies aims at converting the rain-forest, which is largely unmerchantable, to stands of E. grandis.

A type of rain-forest community, frequently dominated by wind-swept trees of Tristania conferta and Cupaniopsis anacardioides, occurs commonly as a very narrow band just back from the sea along many of the headlands near Coffs Harbour. An excellent example is seen about 3 km north of the town. The destruction of this community frequently leads to deaths of more economically valuable trees immediately inland, possibly due to the unimpeded entrance of salt-laden wind and spray from the sea. Another unusual rain-forest community, rather sparsely canopied but containing typical rain-forest species, borders a creek flowing through Recent beach sand deposits at Pine Creek State Forest. This stand contains much

Cupaniopsis anacardioides, with Archontophoenix cunninghamii along the creek bank.

The eastern part of the Dorrigo Plateau, with underlying shale, carries mainly a Ceratopetalum-dominated rain-forest, with wet sclerophyll forest along the ridges. Excellent examples occur at Orara West State Forest and Brooklana, both about 16 km east of Dorrigo township; at Dome Mountain, about 8 km south-east of the town; and at Moonpar State Forest, about 16 km north-west. Much of this rain-forest country originally carried also an overstorey of Araucaria, which has since been removed. At Brooklana attempts were made during 1938-42 to clear the rain-forest and establish Araucaria plantations. However, spring frosts caused the death of the young trees on all but the highest topographic positions, and the area has since been replanted with Pinus taeda and P. elliottii which are growing well. Creek sides at Brooklana and Dome Mountain support a fringe of Nothofagus, though the Nothofagus-dominated communities themselves are only found on the higher elevations west of Dorrigo. Altitude at both Dome Mountain and Brooklana is between 500m and 600m.

Throughout this area, as well as in the more northern rain-forest zone, there are clear signs of the sclerophyll forest being invaded by the rain-forest. Fine examples can be seen at Moonpar, where the original community was of Eucalyptus microcorys and E. saligna, and at Orara West, with the overstorey of Tristania conferta and Callitris macleayana. At the latter site the Tristania has produced an A_o litter layer up to 15 cms deep.

Clouds Creek is situated beyond the main rain-forest area, about 26 km north of Dorrigo, on the road to Grafton. Most of the forest is of E. microcorys and E. saligna, while sheltered gullies support a Ceratopetalum rain-forest. In several places the shale has been covered by basalt, outliers of the main western Dorrigo flow, and these support a Heritiera rain-forest. Within this basalt area are a number of small clearings covered by dense grass growth, with a very narrow fringe of E. saligna and the rain-forest margin immediately behind. Pinus taeda planted on one of these "plains" has shown phenomenal growth. The rain-forest surrounding the plains contains scattered E. saligna, suggesting a gradual encroachment on to the grassland, with an intermediate eucalypt stage.

IV. RAIN-FOREST STRUCTURE.

Structure has been described (Beadle and Costin 1952) as the spatial arrangement of plants within a community. Richards (1952) has discussed this very fully, in relation to the tropical rain-forest, and his remarks apply generally to the rain-forest communities of New South Wales.

Under local conditions, rain-forests can be recognized in the field more readily than the features which distinguish them from other formations can be defined. Neither Schimper's (1935) "evergreen, hygrophilous forest" nor Beadle's and Costin's "closed community dominated by usually mesomorphic meso- or megaphanerophytes forming a deep, densely interlacing canopy in which lianes and epiphytes are invariably present, with mesomorphic subordinate strata of smaller trees, shrubs and ferns and herbs" are truly satisfactory in that both definitions exclude communities that are characteristically regarded as being rain-forest. Nonetheless these communities do share to a greater or less extent a number of distinctive structural features, which themselves are capable of considerable variations in importance from one community to another.

TABLE 4.

SUMMARY OF STRUCTURAL CHARACTERISTICS - NORTH COAST RAIN-FOREST SITES

a, absent; r, rare; p, present; + common; ++ very common.

Locality	Type of Rain-forest	Tree Layers (> 6m) Present	Over-storey*	Buttr-essing	Lianes	Vascular Epiphytes	Remarks
Mt. Lindsay	Heritiera	3		++	p	++	
Wiangarie State Forest	Heritiera	3		++	+	++	
Whian Whian	Heritiera	3		++	+	p	Upper basalt flow
Whian Whian	Heritiera	3		++	+	+	Lower basalt flow
Clouds Creek	Heritiera	2	p	++	+	p	Adjoining grassland
Tooloom Plateau	Dysoxylum	3		++	p	p	
Whian Whian	Ceratopetalum	2	p	p	p	p	
Brooklana	Ceratopetalum	2	p	a	r	a	
Orara West	Ceratopetalum	2	p	r	r	r	Under *Tristania*
Orara West	Ceratopetalum	2		r	p	p	
Clouds Creek	Ceratopetalum	2		r	r	r	
Moonpar State Forest	Ceratopetalum	2	p	r	r	a	Under *E. microcorys*
Moonpar State Forest	Ceratopetalum	2		r	p	r	
Dome Mountain	Ceratopetalum	3		p	p	p	Top storey of *Araucaria*
Unumgar State Forest	Dry Scrub	2		r	++	+	
Koreelah	Dry Scrub	2		r	++	p	
Mt. Pikapene State Forest	Dry Scrub	2		r	++	r	
Mt. Lindsay	Schizomeria-Banksia	1		a	a	r	Community at cliff base.
Coffs Harbour	Headland	1		r	+	a	On windswept headland.
Moore Park	Castanospermum	2		p	p	r	
Wiangarie State Forest	Elaeocarpus grandis	3		+	++	+	Storeys tending to merge.
Bruxner Park	Sloanea woollsii	2	p	+	p	p	

* Overstorey refers to typically sclerophyllous species, remnants of an earlier community.

Following Richards (1952, p.20) these features are:-

(i) The stratification and nature of the trees, shrubs, and herbs.

(ii) The presence and nature of (1) lianes, (2) stranglers, and (3) epiphytes.

Stratification is invariably present in New South Wales rain-forests and the individual storeys are usually well defined, though in certain sites, notably on steep slopes and in immature stands, a degree of merging occurs. Excluding herb layers, up to five different storeys can be recognized, whilst a sclerophyllous overstorey may also sometimes be present. Herbs are usually rare except where the overhead canopy is locally sparse. The trees are typically evergreen, but deciduous or partly deciduous species are present in some stands, usually in the upper storeys; such species include _Brachychiton_ spp., _Erythrina vespertilio_, _Flindersia australis_, _Toona australis_, and _Melia azederach_ var. _australasica_.

Buttressing is particularly common in some communities and imparts a most characteristic appearance to the whole stand. Cauliflory is very rare in New South Wales rain-forests; only _Hedraianthera porphyropetala_ (family Celastraceae) shows it clearly, though _Castanospermum_ and _Dysoxylum fraseranum_ possess it to a lesser extent.

Lianes are present in most communities, and may be very frequent. Two main types occur, one tall-growing and usually possessing thick, rope-like stems, and the other low and rather wiry. Stranglers are present in many communities but are seldom very common. In New South Wales they are all species of _Ficus_, with one insignificant exception (_Quintinia sieberi_) on tree ferns.

Epiphytes are a distinctive feature of most rain-forest communities. Non-vascular epiphytes are invariably present, at least on the lower trunks of the trees, and in some communities, (e.g. parts of Mt. Lindsay) dominate the whole appearance of the stand. Vascular epiphytes, probably always either orchids or pteridophytes, are also frequently present and may be very common.

Table 4 summarizes some of the more important features of rain-forest structure in various localities in northern New South Wales. One important group of rain-forests is not included here althouth it occurs fairly commonly in New South Wales. This is the rain-forest dominated by _Nothofagus moorei_, which has been thoroughly studied by Fraser and Vickery (1938) at Barrington. Its structure is similar to the stands dominated by _Ceratopetalum apetalum_, but with a denser crowned upper storey and with buttressing and lianes rare. Vascular epiphytes in the form of the beech orchid (_Dendrobium falcorostrum_) are sometimes very common. Quite frequently the second tree layer is very scattered, so that only one tree layer can be recognized.

Excluding the _Nothofagus_ stands, Table 4 shows the presence of three well-defined subformations in the area, plus several others which are more local in extent and as yet very incompletely known. The three main subformations are:-

(i) Those dominated by _Heritiera_ spp., _Dysoxylum fraseranum_, and _Elaeocarpus grandis_.

(ii) Those dominated by _Ceratopetalum apetalum_.

(iii) The "dry scrub" communities.

Ideally all formations and their subdivisions should be defined only on their physiognomic characters, but in the case of rain-forests historical influences have given them names implying certain environmental features and it would be unprofitable at this stage to alter these well-established, though in some ways undesirable, names. Thus Beadle and Costin (1952) define the tropical, sub-tropical, temperate, and monsoon subformations in Australia, while Richards (1952) writing about the tropical rain-forest in its truly climatic sense, mentions also the seasonal evergreen, montane, and submontane rain-forests.

Three of the above terms are applicable to the local communities mentioned above, but a new combination seems necessary for the dry scrubs, and the name "dry rain-forest" is suggested. The four main subformations occurring in New South Wales thus are:-

(i) Sub-tropical Rain-forest - Communities characterized by three tree layers, very common buttressing, with lianes and vascular epiphytes fairly common. The Heritiera, Elaeocarpus grandis, and Dysoxylum communities fall into this category. These locally represent a very marginal form of sub-tropical rain-forest, as is indicated by the absence of cauliflory, the limited number of species, the relatively small leaves, and the tendency to dominance by a few species.

(ii) Warm Temperate Rain-forest - Communities showing two tree layers, the upper one forming a fairly continuous canopy; rare buttressing, and lianes and vascular epiphytes present but seldom common. The northern Ceratopetalum communities and also the communities from Barrington and the Illawarra scarp conform to this description.

(iii) Cool Temperate Rain-forest - Communities with a dense, deeply canopied upper storey and a scattered second storey, buttressing practically absent and lianes rare. Nothofagus communities are the oft-quoted examples of this subformation, which barely fits Beadle's and Costin's definition of rain-forest since lianes and sometimes vascular epiphytes are rare or absent; indeed Warming (1909) likens its structure to that of the northern spruce forests.

(iv) Dry Rain-forest - Communities with two tree layers, the upper one scattered and containing mainly deciduous or xerophytic species; buttressing rare, heavy lianes common, and vascular epiphytes usually not common. These communities have been studied in Queensland by Blake (1941), who regards them as monsoon forest (Blake 1940), or in the terminology of Beadle and Costin, monsoon rain-forest. However, they differ quite markedly from Schimper's (1935) illustrations of the Burmese monsoon rain-forests, where large, deciduous trees clearly dominate the entire stand, while the second storey of trees is far more open than in Australia. Hence the new term seems warranted.

Of the other stands summarized in Table 4, the Bruxner Park community, a typical "gully rain-forest", is structurally intermediate between the warm temperate and subtropical subformations. The Moore Park community is intermediate between the sub-tropical and dry rain-forests; it is characteristic of the gallery forests once common along watercourses in the drier parts of the Richmond River valley, and further study will probably show it to deserve subformation status. Similarly the Coffs Harbour headland stand, typifying a littoral community common on the North Coast, should ultimately be put into a distinct subformation. The curious Mt. Lindsay Schizomeria-Banksia community is the only such community so far recorded in New South Wales; it clearly represents a local adaptation to extraordinary environmental conditions, and appears to be structurally related to the montane rain-forests.

The classification given here allows the appearance of the main rain-forest stands to be readily understood, and at the same time broadly groups communities whose silvicultural characters might be expected to be similar. This in turn offers a handy approach to solving the problems associated with applying forest management to these stands.

V. RAIN-FOREST FLORISTICS.

The floristic classification of New South Wales rain-forests is still very incomplete, owing to the scanty information on the species composition of the various communities, and the almost complete absence of any frequency studies on the subject. However, a rudimentary classification can be made, and is shown in a summarized state in Table 5. This is likely to be considerably altered and enlarged as more information becomes available, but in the meantime it should act as a useful basis for later work.

Six alliances, as defined by Beadle and Costin (1952), and a number of associations appear clearly marked.

(a) Nothofagus moorei Alliance.

The cool temperate rain-forest found in cool moist sites from Barrington in the south to the McPherson Ranges. North of the Hastings River Ceratopetalum is almost invariably present as an important associate, but at Barrington Nothofagus is apparently the sole tall tree species (Fraser and Vickery (1938). Thus two associations can be recognized, depending on the presence or absence of Ceratopetalum in the upper storey. A species list for the alliance from Barrington is given by Fraser and Vickery.

(b) Ceratopetalum apetalum Alliance.

A warm temperate rain-forest, and economically the most valuable of the rain-forest alliances. In the north it is confined to areas of high rainfall and relatively poor soils, but in the south it encroaches on to the richer soils. A number of distinct associations can be recognized. In some of these Ceratopetalum itself is absent but its common associates dominate the stand. This suggests that these associations should be included in the alliance. The associations so far recognized are:

(i) Ceratopetalum-Schizomeria Association - The typical North Coast form, in which Schizomeria ovata is usually the second most common tree. Species lists for Moonpar State Forest and the Hastings River Catchment are given respectively in Appendix I and by Burges and Johnston (1953).

TABLE 5.

RAIN-FOREST FLORISTIC GROUPS IN NEW SOUTH WALES.

Subformation	Alliance	Association	Typical Locality	Remarks
Cool Temperate	Nothofagus moorei	(i) Nothofagus moorei (ii) Nothofagus-Ceratopetalum	Barrington Mt. Banda Banda	
Warm Temperate	Ceratopetalum apetalum	(i) Ceratopetalum-Schizomeria (ii) Ceratopetalum-Doryphora (iii) Schizomeria-Doryphora-Ackama-Cryptocarya glaucescens (iv) Ceratopetalum-Diploglottis (v) Doryphora-Acacia melanoxylon (vi) Sloanea woollsii	Moonpar S.F.* Mt. Wilson Barrington Bulli Robertson Bruxner Park	Typical North Coast form Also allied to Heritiera alliance. Degenerate form Linking with Heritiera alliance
Subtropical	Heritiera spp.	(i) Heritiera spp. (ii) Dysoxylum fraseranum (iii) Elaeocarpus grandis (iv) Toona-Flindersia spp (?)	Wiangarie S.F. Tooloom Whian Whian S.F. Whian Whian S.F.	 Higher altitudes Along creeks in associations (i) and (iv). Big Scrub rain-forest
Dry	Hemicyclia australasica	(i) Araucaria cunninghamii (ii) Brachychiton discolor	Mt.Pikapene S.F. Koreelah	 More adverse conditions
"Littoral"	Cupaniopsis anacardioides	(i) Cupaniopsis anacardioides (ii) Tristania conferta	Pine Creek S.F. Coffs Harbour	Behind beach dunes Exposed headlands
"Gallery"	Castanospermum australe	(i) Castanospermum australe (ii) Syzygium floribundum	Moore Park Myrtle Creek	
"Montane"	?	(i) Schizomeria-Banksia integrifolia	Mt. Lindsay	

* S.F. = State Forest.

(ii) Ceratopetalum-Doryphora Association - Discussed by Brough, McLuckie and Petrie (1924) from Mt. Wilson, where there is a strong Antarctic element in the associated species. A very similar community occurs at Styx River State Forest, east of Armidale, where the Nothofagus alliance occurs also. A species list is given by the Mt. Wilson authors.

(iii) Schizomeria-Doryphora-Ackama-Cryptocarya glaucescens Association - The Barrington community from which Ceratopetalum itself is absent. A species list is given by Fraser and Vickery (1938).

(iv) Ceratopetalum-Diploglottis Association - The South Coast form, which has many features of the sub-tropical subformation and many species from the Heritiera alliance. Neither species used to name the association is necessarily a true dominant, but both are usually present, are quite distinctive, and represent typical species from the two alliances whose mixture forms the association. Davis (1941) gives a species list for the association.

(v) Doryphora-Acacia melanoxylon Association - The degenerate community from Robertson, mentioned by Phillips (1947). It possibly represents a Ceratopetalum-Doryphora or Ceratopetalum-Diploglottis association considerably altered by man's activities.

(vi) Sloanea woollsii Association - The fairly common North Coast "gully rain-forest", which is both structurally and floristically intermediate between the Ceratopetalum and Heritiera alliances. Both of the species giving their names to these alliances are frequently present, but Sloanea woollsii is generally the dominant species in the stand. A list of species from Bruxner Park is given in Appendix I.

(c) Heritiera spp. Alliance.

A subtropical rain-forest found on good soils north of the Comboyne Plateau, with its floristic influence felt south of Sydney. In all areas it is extremely luxuriant, and floristically very rich and varied. The two Heritiera spp. H. trifoliolatum and H. actinophyllum, either together or separately, are frequent and distinct species throughout the alliance. The selection of true dominants is very hard owing to the difficulty in telling which floristic changes are due to chance, and which to environment. However, three or possibly four associations can be distinguished: the Heritiera association, in which one or both of the above species are the commonest dominants; the Dysoxylum fraseranum association, found in the more elevated and cooler areas, with Dysoxylum becoming the commonest dominant; the Elaeocarpus grandis association, found as narrow bands along creeksides within the Heritiera association; and possibly a fourth, in which Toona australis and Flindersia spp. were originally common, occupying the rich Big Scrub area on the lower Richmond and Tweed Valleys. The Elaeocarpus association also occurs within this last association. Species lists for the first two associations from Wiangarie State Forest and Tooloom Plateau are given in Appendix I. The Sloanea woollsii and Ceratopetalum-Diploglottis associations link this alliance to the Ceratopetalum alliance.

(d) Drypetes australasica Alliance.

Structurally a dry rain-forest in which a scattered overstorey of Araucaria cunninghamii, Flindersia spp., Brachychiton discolor, and other species is usually present. The main, low level storey is marked by a family dominance of the Sapindaceae and Euphorbiaceae rather than of any individual species: however, Drypetes was chosen to name the alliance as it is one of the most frequent and constant members of the community. The alliance is found in usually somewhat sheltered sites in the drier areas north of the Clarence River. It appears identical with the Araucaria subclimax of Cromer and Pryor (1942) and the Stanley Basin communities studied by Blake (1941), both from southern Queensland. Two associations can be recognized on the overstorey species: in better areas the overstorey is less scattered and contains much Araucaria, while in more adverse sites the deciduous Brachychiton is the only tall species common. A species list for the Araucaria association at Mt. Pikapene State Forest is given in Appendix I.

(e) Cupaniopsis anacardioides Alliance.

The small patches of rain-forest occurring commonly along the coast north of Sydney. Two associations can be recognized: Cupaniopsis anacardioides association, found along tidal estuaries and behind the coastal sand-dunes; and Tristania conferta association, clearly dominated by windswept specimens of this widespread species, on the more exposed headlands. Osborn's and Robertson's (1939) rain-forest stands on the Myall Lakes belong to this alliance.

(f) Castanospermum australe Alliance.

A riverbank community of the drier areas and apparently confined to land north of the Clarence River. Again two associations occur, the fairly rich Castanospermum australe association, for which the species list for Moore Park is given in Appendix I, and the species-impoverished Syzygium floribundum association of the less favourable localities. The Castanospermum association is recognized by Cromer and Pryor (1942) as the Castanospermum-Grevillea robusta association.

(g) Others.

There is finally the wind-dominated Schizomeria-Banksia integrifolia association from Mt. Lindsay. This is clearly a distinct association which, being derived from the Heritiera alliance, should probably be included in that alliance. It is, however, both structurally and floristically distinct from all other communities.

VI. FACTORS AFFECTING RAIN-FOREST DISTRIBUTION.

Although Clement's monoclimax theory, with its emphasis on climate, dominated Australian ecological thought for a considerable period, it is now recognized that a number of environmental factors are responsible by their interaction for determining the distribution of vegetation. This view is in keeping with that of Jenny (1941) on the formation of soil. Not all authors agree about the actual factors concerned, but probably five are involved - climate, soil, topography, history and the biotic factor. Each of these in turn is made up of a number of components. Theoretically this leads to the recognition of five types of climax community, depending upon which factor limits the further development of the community. In practice considerable difficulties are found in attempting to identify these climaxes, and it may be doubted if there is any purpose in the attempt.

The effects of these factors on rain-forest distribution in New South Wales are considered in detail below.

(a) Climatic Factor.

Four main components of the climatic factor can be recognized; temperature, light, water and wind. Each of these, like other environmental factors, acts on the indifidual species in the community. As the components vary, the community undergoes a sifting and some species are added to the community, others are lost. It is this sifting effect which ultimately determines the distribution of vegetation. Its importance has been stressed by Herbert (1935).

Temperature in itself can have little effect on the broad distribution of rain-forest, since rain-forest covers a very wide range of temperature conditions in New South Wales. Most localities experience occasional summer days when the temperature exceeds 38°C, while all but the most maritime situations receive winter frosts. The higher altitude rain-forests, which include the Nothofagus, Dysoxylum and Ceratopetalum-Schizomeria associations, have very severe and lengthy winters, and periodically receive snowfalls. The rain-forest canopy greatly modifies these extreme conditions within the community, but it is common experience that logging activities, by opening the canopy of the stand, cause the gradual deterioration and in some cases ultimate death of the remaining stems in the elevated rain-forests. It is possibly due to some similar cause that the Robertson rain-forest is stated by Phillips (1947) to be in the process of invasion by eucalypts.

Fraser and Vickery (1938) suggest that warmth limits the lower boundaries of the Nothofagus association, whilst cold probably limits the upper boundaries of the warm temperate rain-forests where these border the Nothofagus association. However, the main effects of temperature appear to be in limiting the range of many species along the New South Wales coast. This effect is clearly shown by the gradual impoverishment in species of the rain-forest communities from north to south; its importance has been stressed by Francis (1951), while de Beuzeville's (1943) study of the climatic tolerance limits of various species shows the mechanics rather well.

Openings in the higher-altitude rain-forests develop into frost hollows which have an economic importance exemplified by the failure of attempts to establish Araucaria plantations on the Dorrigo Plateau. The cold in such openings appears also to be the reason for the perpetuation of the grasslands at Cloud's Creek; only in the rare sequence of relatively warm winters can Eucalyptus saligna regeneration become established around the edges of the clearings, and then subsequently the Heritiera association moves in under shelter of the Eucalypts.

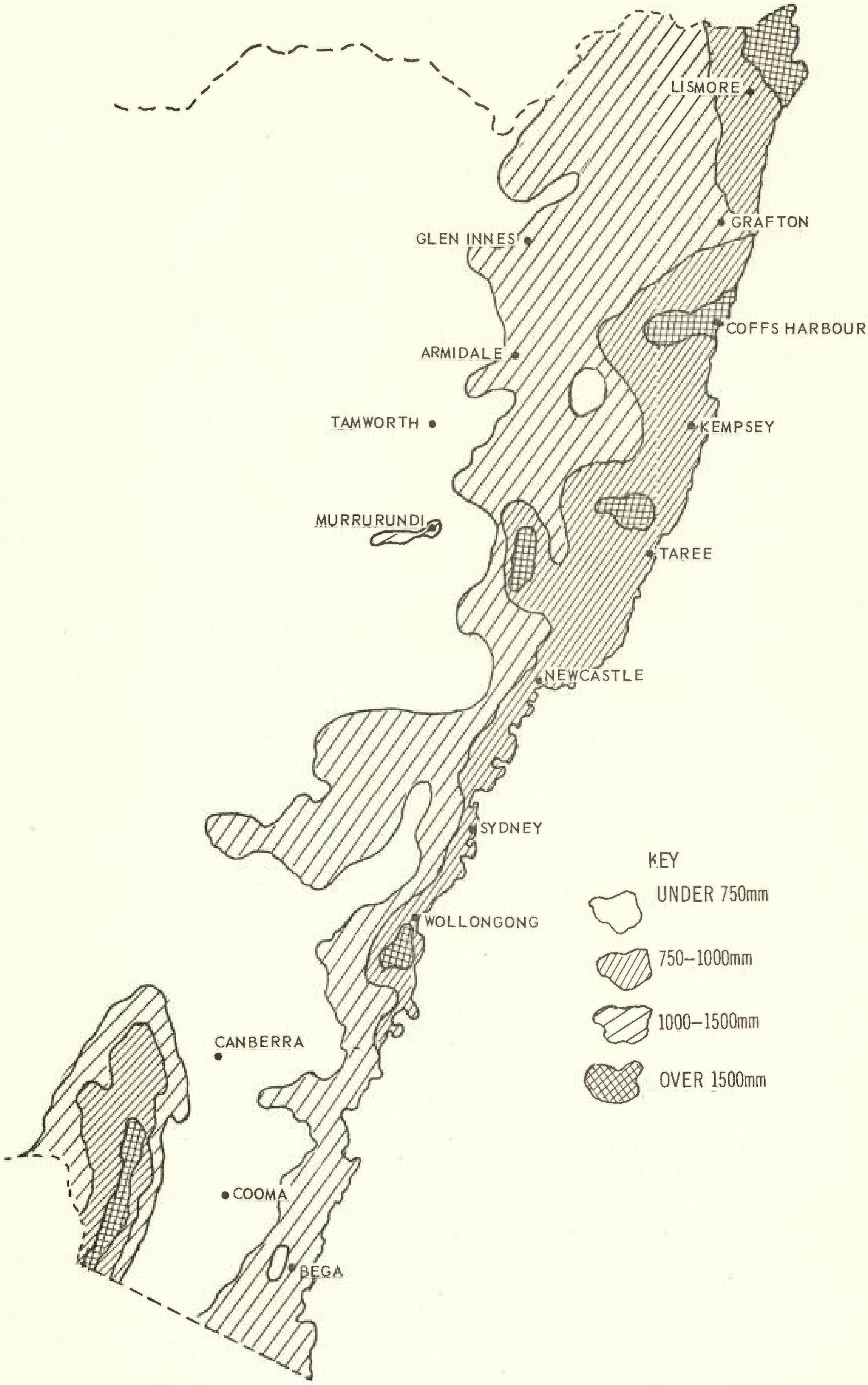
Light, like temperature, has little effect on the overall distribution of rain-forest in New South Wales. It does, however, have one important effect; low light intensities within the rain-forest direct the course of succession to a community of species which can either ecesize in these low light conditions, or else establish themselves during the occasional brief periods when gaps occur in the canopy. It thus tends to prevent the establishment of the light-demanding eucalypts within the rain-forest, and so precludes the invasion by sclerophyll forest of any but the most degenerate rain-forest communities, such as the Robertson community of Phillips (1947). Evidence for the invasion of healthy rain-forest by eucalypts, such as that presented by Brough, McLuckie, and Petrie (1924) for the Mt. Wilson Ceratopetalum-Doryphora association, must be viewed very critically.

Atmospheric water in its various forms affects plant growth in two ways, either by supplying moisture for growth in such forms as rain, smow, dew, and mist, or by influencing the rate of transpiration, a humidity effect. Rain-forest apparently needs constantly high humidities, but provided soil moisture is adequate the communities can maintain their own high humidities within the canopy (Richards 1952). Trees from the upper storeys must be able to tolerate wider humidity variations, and where a protracted dry season is experienced it is noteworthy that many of the taller trees tend to be xeromorphic (e.g. Araucaria) or deciduous (e.g. Brachychiton). These features are well shown by the dry rain-forests, as well as by certain rain-forest-margin communities. Indeed the close floristic and structural similarity between the Drypetes alliance in northern New South Wales and the Araucaria subclimax of Cromer and Pryor (1942) in Queensland has already been noted. Dry rain-forest is apparently maintained as a climax community by reason of a seasonal period of low humidity, which in turn is dependent on a long annual drought (see monthly rainfall averages for Mt. Pikapene State Forest, Table 2).

The high internal humidities of the rain-forest provide almost nightly dewfalls, which supply a regular source of water to the non-vascular epiphytes. Constant mists, a feature of many rain-forest localities, are of more importance in relation to rain-forest distribution. The dense moss growth found towards the upper rain-forest levels on Mt. Lindsay appears to owe its existence to the frequent cloud which enshrouds the mountain, whilst the restriction of cool temperate rain-forest to cool sites commonly fogbound suggests the importance of mist in determining the limits of the Nothofagus alliance, probably by acting on the transpiration rate. Snow is too infrequent to be of any importance as a water supplier to the rain-forest economy.

The early recognition of the importance of rainfall to rain-forest distribution is reflected in the very name of the formation. It is true that, under favourable edaphic and topographic conditions, rain-forest is found in areas where rainfall is less than 1000mm yearly, or where there is a long and severe dry season. However, it only becomes a dominant feature on undulating land where the rainfall exceeds 1500mm per annum, and possibly slightly less towards the south. This is clearly shown by studying the rainfall map of New South Wales (Commonwealth Bureau of Meteorology 1948) on to which the isohyets of Fraser and Vickery (1937) for the Barrington area have been added (Fig. 3). Six regions have rainfalls in excess of 1500mm: The Kosciusko region, with its alpine and subalpine climate, and the five major rain-forest areas previously mentioned.

The influence of rainfall is well shown by the vegetation series on Mt. Lindsay. Here on a single slope and on soils derived from the one parent material, but under conditions of rainfall clearly increasing with elevation, the series runs from tall woodland at the valley bottom through wet sclerophyll forest to tropical rain-forest. The absence of dry sclerophyll forest from this and other areas of similar soil in the district suggests that


LISMORE
GRAFTON
GLEN INNES
COFFS HARBOUR
ARMIDALE
TAMWORTH
KEMPSEY
MURRURUNDI
TAREE
NEWCASTLE
SYDNEY
KEY
UNDER 750mm
750–1000mm
1000–1500mm
OVER 1500mm
WOLLONGONG
CANBERRA
COOMA
BEGA

Locality	Parent Material	Texture	Total	Exch. Bases	Na	K	Ca
Rainforest – Heritiera alliance							
Lamington N.P.	Basalt	Cy L	2940	15.8	0.5	0.8	10.5
Whian Whian S.F.	Basalt	Cy L	6200	25.9	0.5	0.8	21.9
Tooloom Plateau	Basalt	Cy L	7620	62.0	0.6	1.9	47.2
Tooloom Plateau (cleared)	Basalt	–	6720	47.2	0.6	2.8	37.6
Lynches Creek	Basalt alluvium	–	3930	–	–	–	–
Wiangarie S.F.	Basalt	–	3960	–	–	–	–
Clouds Creek S.F.	Basalt	–	5120	–	–	–	–
Rainforest – Ceratopelum alliance – Ceratopetalum – Schizomeria association							
Lamington N.P.	(acid igneous)	Sl Cy	520	5.1	0.6	0.8	3.5
Whian Whian S.F.	(acid igneous)	Sl Cy L	–	4.4	–	–	–
Whian Whian S.F.	(acid igneous)	–	630	2.3	0.1	0.6	1.1
Whian Whian S.F.	(acid igneous)	–	480	–	–	–	–
Brooklana	Shale	Cy L	1090	3.6	0.4	1.0	1.8
Orara West S.F.	Shale	CyL	1070	11.3	–	–	–
Dome Mountain	Shale	Cy L	840	–	–	–	–
Rain forest – Ceratopetalum alliance – Sloanea woolsii association							
Bruxner Park	Shale alluvium	Cy L	1290	–	–	–	–
Rainforest – Ceratopetalum alliance – Ceratopetalum – Dorphora association							
Mt. Wilson	Basalt	Cy L	3180	–	–	–	–
Rainforest – Ceratopetalum alliance – Ceratopetalum – Diploglottis association							
Gosford	Shale alluvium	Sd L	510	5.0	0.2	0.2	3.5
Rainforest – Hemicyclia alliance							
Unumgar S.F.	Basalt	Cy	2940	–	–	–	–
Koreelah	Basalt	Cy	3040	55.8	–	–	–
Mt Pikapene S.F.	Basalt	Cy	2420	68.1	–	–	–
Rainforest – Cupaniopsis alliance							
Pine Creek S.F.	Beach Sand	Sd	650	16.0	–	–	–
Wet Sclerophyll forest							
St Ives	Shale	Cy	960	6.8	0.4	0.9	2.3
Gosford	Shale	Cy L	770	10.2	0.3	0.7	5.9
Lynches Creek	Shale	–	1680	–	–	–	–
Whian Whian S.F.	Volcanic	–	1710	–	–	–	–
Barcoongere S.F.	Shale	–	510	9.0	0.3	0.5	4.9
Bruxner Park	Shale	–	720	–	–	–	–
Dome Mountain	Shale	–	1050	–	–	–	–
Tall Woodland							
Mt. Pikapene S.F.	Basalt	–	1580	–	–	–	–
Dry sclerophyll forest							
Barcoongere S.F.	Shale	–	110	0.9	0.1	0.1	0.4
Wet mallee							
Lamington N.P.	Obsidian	Sl L	226	4.5	–	–	–
Grassland							
Clouds Creek S.F.	Basalt	–	3380	–	–		

* Cy, clay: L, loam: Sd. sand: Sl, silt

this subformation may be edaphically controlled.

The Nothofagus alliance is normally confined to areas where rainfall exceeds about 1750mm per annum and where frequent mists lower the transpiration rate. Outside this rather restricted zone Nothofagus moorei itself occurs as a creek-bank species: this is just one example of a rain-forest community existing under lower rainfall conditions than would usually be expected. It is brought about by local edaphic or topographic conditions compensating for the lower precipitation, and it suggests that rainfall tolerance limits for species such as are given by de Beuzeville (1943), may not have much meaning.

Winds, in their effects on vegetation, can be desiccating, constructive, or destructive. All three effects can be found in New South Wales rain-forests, and, as would be expected, the wind factor is closely allied to the topographic factor. Desiccating winds in this state are those from the north and west and their effect is the restriction of rain-forests, outside the five main areas, to regions sheltered from these directions. Even in the high rainfall areas westerly slopes frequently do not carry rain-forest.

Constructive winds are those bringing regular supplies of moisture, and in some cases plant nutrients, to the rain-forest communities. Excluding the rain-bearing winds, the main influence here is with the Cupaniopsis alliance, which appears to receive a degree of moisture, whose main effect is to lower transpiration, from the winds blowing almost continually off the sea, thus allowing rain-forest growth in areas with a lower rainfall than that normally required by rain-forest. The same winds bring in certain chemical elements, notably sodium and phosphorus, to the plant community. Abnormally high contents of both these elements can be found in plants collected from maritime stations, and the composition of these coastal rain-forests is probably limited by their tolerance to perpetual wind, with its strong shearing effect, and by their ability to withstand very high sodium concentrations.

Shearing is one of the destructive effects of wind. It occurs not only along the coast but also in other exposed regions, and seems mainly responsible for the low height of the Schizomeria-Banksia association on Mt. Lindsay. Cyclones have little effect on the nature or distribution of rain-forests in New South Wales, though "hurricane forests", (communities deficient in large trees) have been reported from overseas (Beard, quoted by Richards 1952). In New South Wales the occasional tropical cyclone will destroy overmature trees and allow regrowth to develop, and may in rare cases fell all trees over relatively extensive areas. During the cyclone of February, 1954 in the northern part of the State, openings totalling about 80 ha were made in a Heritiera alliance in Yabbra State Forest, near Bonalbo, and it is thought that similar cyclone destruction, followed by fire, may have originated the Clouds Creek grasslands.

(b) Edaphic Factor.

It is not intended to review here all the effects that soil can have upon vegetation though many of these doubtlessly influence the New South Wales rain-forests in various ways. Local rain-forests occur on soils which vary in texture from sands behind many beaches to clays derived from shales and basalt (See Table 6). Rain-forest appears only on sands where there is an ample supplementary supply of soil moisture, while the rain-forest clay soils are notable for their very good structure. Heavy texture, which in more southern regions has been regarded as the cause of treeless areas on basalt soils (Cambage 1918; Patton 1930), certainly does not interfere with rain-forest development and is definitely not the cause of the Clouds Creek grasslands, as Cambage infers. Dry rain-forest is confined to heavy textured soils, probably due to their high water-holding capacity.

The same reason appears to account for the situation at Clouds Creek, where Ceratopetalum is restricted to the gullies, with wet sclerophyll forest on higher topographic positions on the same soil parent material (shale), while a nearby elevated basalt pocket supports Heritiera.

Under New South Wales conditions soil nutrients can be shown to exert a profound influence on rain-forest distribution. In Table 6 soil contents of phosphate and certain exchangeable cations are shown. Phosphate was determined by a method similar to that described by Beadle and Tchan (1955), the cations were extracted by the leaching apparatus described by Black (1947), and the content of calcium, potassium and sodium was determined by an EEL Flame Photometer. Appendix II shows the amounts of these same ions in the ash of various plants.

Sodium is not generally regarded as an essential plant nutrient, but is invariably present in plant ash in measurable quantities. Acmena smithii, Eucalyptus spp., and Wilkiea huegeliana contain characteristically high quantities of sodium (in Acmena smithii sodium regularly makes up about 5 per cent of the total weight of ash), while some, though not all, other species show locally high values when exposed to constant salt-bearing winds. The very high value of sodium in Wilkiea from Coffs Harbour is due to crystalline salt on the outside of the leaves. Sodium is mainly deposited in the soil from wind-blown ocean spray, and its chief effect on rain-forest distibution might be expected to be in locally limiting the growth of plants which cannot tolerate high concentrations of the ion, while conversely the composition of the coastal Cupaniopsis communities must be largely determined by a tolerance of the constituent species to high values of sodium.

Table 7.

Soil Nutrient Levels for Various Communities.

Community	Exch.Cations (m-equiv/ 100g)	Exch.Ca. (m-equiv/ 100g)	Exch. K (m-equiv/ 100g)	Total PO_4 p.p.m.
Heritiera alliance	15.8-62.0	10.5-47.2	0.8-2.8	2940-7620
Ceratopetalum-Schizomeria association	2.3-11.3	1.1- 3.5	0.6-1.0	520-1090
Sloanea and Ceratopetalum-Diploglottis associations	5.0	3.5	0.2	510-1290
Ceratopetalum-Doryphora association				3180
Drypetes alliance	55.8-68.1			2420-3040
Wet sclerophyll forest	6.8-10.2	2.3- 5.9	0.5-0.9	480-1710
Dry sclerophyll forest and wet mallee	0.9- 4.5	0.4- 3.2	0.1-0.9	110- 226

The other three nutrients are regarded as essential for plant growth. Apart from certain individual peculiarities, such as the very low calcium contents of Orites, the calcium and potassium contents of plant ash show a fairly general relationship to the total ash content, species with much ash having high levels of calcium and potassium. This relationship does not hold for phosphorus, some species with much ash having relatively low phosphorus contents (e.g. some samples of Claoxylon), while some species with very little ash can have high phosphorus levels (e.g. Pinus, Eucalyptus gummifera).

Extending this comparison, the various nutrients in the leaf can be compared with the same nutrients as they occur in the soil at the site whence the leaf was collected. No relationship can be observed in such a comparison between exchangeable cations and plant ash, exchangeable potassium and plant potassium, or exchangeable calcium and plant calcium. With phosphorus, however, a distinct relationship between leaf phosphorus and total soil phosphorus can be recognized. This is best shown by individual species (e.g. Ceratopetalum, Claoxylon, E. gummifera), but all species lumped together clearly show the same trend. At two sites, Pine Creek and Gosford, leaf phosphorus is higher than would be expected from the soil values. The Pine Creek leaf values are due to sea spray constantly supplying phosphate from the sea, and bear no relationship to the soil levels, while at Gosford the soil analysed was sandy, and probably represents a recent deposition of coarse alluvium in which phosphorus and other nutrients have yet to be accumulated by the vegetation.

Finally the range of values of the soil nutrients was tabulated according to the type of community they support (Table 7).

This table is based on relatively few determinations, but enables some general conclusions to be made. Firstly, low soil levels of phosphorus are usually associated with low levels of other nutrients, thus obscuring the identity of the limiting nutrient. Certain communities are confined to soils with definite nutrient characteristics; Heritiera and Drypetes alliance soils are plentifully supplied with bases and phosphorus, as are the Ceratopetalum alliance soils derived from basalt (Ceratopetalum-Doryphora and some Ceratopetalum-Diploglottis association soils). The Ceratopetalum-Schizomeria association in northern New South Wales and the wet sclerophyll forests which were studied are on soils with much lower levels of the nutrients, both communities occurring over the same range of values. The dry sclerophyll forest and wet mallee soils are even lower in nutrients.

The major difference between phosphorus and the two cations is their behaviour in the plant. Calcium and potassium occur over a limited range of values in any particular species, and their contents in the plant do not tend to increase with rises in the soil level. The reverse is true of phosphorus; its range of value in any species is high and is related to the amount of phosphorus in the soil (or for maritime sites, the spray). This suggests that phosphorus is a true limiting factor, and all that is in the soil is utilized by the plant. Partial support for this theory is provided by those species, notably Pinus elliottii and Eucalyptus gummifera, which have been sampled from soils covering a wide range of nutrient levels. As before, calcium and potassium in the leaf are at relatively constant levels, whilst leaf phosphorus increases greatly with increasing soil phosphate. In the case of Pinus, it can be shown that leaf phosphorus also bears a close relationship to site quality, a measure of the inherent fertility of the soil.

The theory of the limiting nature of phosphorus is particularly helpful in explaining certain features of the distribution of rain-forest and associated vegetation types in New South Wales.

In northern New South Wales, soils containing between about 500 and 1200 p.p.m. PO_4 will, under favourable climatic and topographic conditions, support a warm temperate Ceratopetalum-Schizomeria association; where conditions are locally more arid the vegetation becomes wet sclerophyll forest. As the PO_4 content increases above 1200 p.p.m. the structure of the rain-forest becomes increasingly tropical and Ceratopetalum loses its dominance, and finally disappears from the community, which becomes dominated by Heritiera or Dysoxylum. Even under the highest soil phosphate regimes the more arid sites will carry wet sclerophyll forest (e.g. below the rain-forest margin on Mt. Lindsay and at Wiangarie State Forest). Under still more xeric conditions at high soil phosphate levels the vegetation is of tall woodland (e.g. Mt. Lindsay, Mt. Pikapene). Wet sclerophyll forest possibly exists at somewhat lower phosphate levels than the Ceratopetalum-Schizomeria association, but below 300 p.p.m. (and probably even higher) it is replaced by dry sclerophyll forest or wet mallee. As seen at Lamington National Park the Ceratopetalum rain-forest can border directly on to the mallee formation, without any intervening wet sclerophyll forest band.

Towards southern New South Wales, the Ceratopetalum alliance occurs on soils with much higher phosphate levels. This can be explained on grounds of competition. Under the more favourable climatic conditions of the north competition for space is very active and Ceratopetalum and its associates are restricted to the less fertile soils. Where soil phosphate is higher, other species, which owing to their phosphate tolerance limits are unable to grow successfully at lower levels, enter the community and squeeze Ceratopetalum out. When competition is relaxed Ceratopetalum is very successful on these soils, as can be seen from isolated trees and plots planted on such sites. However, climatic sifting tends to remove many of the most successful competitors from these more fertile soils towards the south. With this release of competitive pressure Ceratopetalum is able to encroach on to these soils,and may even dominate the stand (e.g. Mt. Wilson). On other sites where the climate is less severe the remaining species typical of the sub-tropical rain-forest still hold Ceratopetalum in check so that though present it does not truly dominate the stand (Ceratopetalum-Diploglottis association). A similar occurrence of Ceratopetalum on the more fertile soils is found at the altitudinal limits of rain-forest, where Ceratopetalum is associated with Nothofagus on soils derived from basalt (e.g. Mt. Banda Banda and the gullies of the high western Dorrigo Plateau).

Like Ceratopetalum, Nothofagus and its temperate rain-forest associates appear to be fairly tolerant of low phosphate contents. The Drypetes alliance is confined to soils derived from basalt and rich in nutrients. However, whilst the soil nutrients doubtlessly determine to some extent what species will be present, the occurrence of the community appears to be more strongly related to topographic and soil physical conditions.

Whilst it is not claimed that phosphate in the soil is the only nutrient influencing the nature and distribution of rain-forest in New South Wales, it does seem clear that phosphate does exert a very great influence on the local coastal vegetation, and particularly on rain-forest.

The various soil characteristics, both chemical and physical, are closely related to the soil parent material. Of the various materials, basalt appears the most favourable for the development of rain-forest, since it gives well-structured soils of heavy texture and high phosphate content. On such soils the most luxuriant types of rain-forest develop, and rain-forest grows well, beyond what would otherwise be its climatic limits. Other rock types also commonly carry rain-forest, though low phosphate values make for a less complex type of community. Excessively drained soils and soils derived from rocks low in nutrients, such as sandstone, will not normally support rain-forest except where there are supplementary supplies of water (e.g. in low topographic positions) or nutrients, the latter provided either by accumulation (e.g. gullies in the Hawkesbury sandstone) or by spray.

(c) Topographic Factor.

Exposure to atmospheric conditions and the effects of slope are the main influences that topography has on vegetation. Under conditions favourable to rain-forest development, exposure is chiefly related to the presence of desiccating winds, which may determine the local patterns of vegetation. Thus in typical rain-forest areas rain-forest can only maintain itself in sites specifically sheltered from the north and west. This can be seen in the *Drypetes* dry rain-forest in northern New South Wales, in the *Ceratopetalum-Doryphora* association on Mt. Wilson, and on the high basalt plateaux of Dorrigo and Barrington, where the windswept plateau surfaces carry grassland and stunted snow gums, with *Nothofagus* rain-forest confined to the protected gully floors. Occasionally communities of rain-forest resistant to exposure can be found; the curious *Schizomeria-Banksia* association of Mt. Lindsay is an example.

The influence of slope on rain-forest distribution is exerted through the distribution of water nutrients in the soil. High topographic positions tend to be quickly drained of water and to lose their nutrients rapidly. On lower positions the soils are deeper, they accumulate the nutrients leached from above, and moisture conditions are more favourable. This topographic sequence gives a soil catena whose effect on vegetation is frequently profound, leading to the development of what might be termed a vegetation catena. An example familiar to all foresters in northern New South Wales is the sequence *Eucalyptus paniculata-E. acmenioides-E. propinqua* on the ridge tops, *E. pilularis-E.saligna* on the slopes, and *E. grandis* or *Sloanea woollsii* association in the gullies. In this case the restriction of rain-forest to the gullies is probably an effect of moisture rather than of nutrients; in the Hawkesbury sandstone gullies, however, nutrients appear more important (Beadle 1954).

The fringing *Castanospermum* alliance is essentially limited in its distribution by topography, occurring in the lower topographic positions where moisture is plentiful.

It will be noted that the effect of the topographic factor always seems to be one of modifying either the climatic or edaphic conditions. For this reason it should perhaps be regarded as a subsidiary factor of distribution, rather than of equal status to soil and climate.

(d) Historic Factor.

Present-day vegetation patterns have largely developed as the result of past migrations of the flora. This certainly applies to the pattern of rain-forest distribution in New South Wales. The very marked discontinuity of this distribution results from the severe climatic changes of the Pleistocene and Early Recent eras, when the previously existing widespread rain-forest flora was driven northwards by the Ice Age cold and then destroyed over large areas by the Aridity, thus restricting it by and large to its present stongholds. However, in this connection it is worth noting that even under the most favourable climatic conditions it is unlikely that the barren Clarence and Hawkesbury sandstone plateaux ever supported rain-forest save in scattered gullies.

More recently, with climatic amelioration, rain-forest has again started to extend its boundaries. Examples of rain-forest invading eucalypt forest are common in northern New South Wales, and Cromer and Pryor (1942) discuss examples from southern Queensland. Only where man's activities have disturbed the rain-forest microclimate are there signs of eucalypts invading the rain-forest.

Another historic effect appears to be found in the absence of certain species from localities that seem suitable for their development. This has been suggested as the reason for the absence of Ceratopetalum from Barrington, while Castanospermum australe, which is well capable of ecesizing under rain-forest localities when introduced to southern localities, appears to be confined to northern New South Wales through some historical accident.

(e) Biotic Factor.

The three components of the biotic factor are flora, fauna, and man. The first and last are of some importance in their effects on the local rain-forests.

One major effect of flora is due to the tolerance limits of individual species to the various environmental factors, as has been discussed. Allied to this effect is the tolerance of various species to competition which may prevent their growth on sites environmentally suited to them. This appears to explain the distribution of Ceratopetalum apetalum which is limited to poor soils in northern New South Wales, where competition is fiercest, but which, owing to the elimination of competitive species by climatic sifting, is able to establish itself on, and even to dominate, the rich basalt soils further south.

Dispersal capacity is another effect of flora on distribution, and seems to be the reason for the continued restriction of Castanospermum to northern New South Wales. Planted trees have naturalized themselves in a rain-forest pocket south of Newcastle, but the species is not found naturally south of the Bellinger River, its spread being hampered by its large seeds and pods which are normally water-dispersed.

Man has had a profound effect on rain-forest distribution. Aboriginal influence was exerted, chiefly unintentionally, through the use of fire, which tended to restrict the advance of rain-forest and to favour the growth of sclerophyll forest in sites otherwise suitable for rain-forest. The use of fire has been extended since white settlement, and it is a valuable weapon in maintaining the economically valuable fire-climaxes, such as the Eucalyptus grandis association.

Despite their similarity to the Bunya Mountains clearings in Queensland which Herbert (1938) believes are due to aboriginal activity, there is no evidence that the Clouds Creek clearings are caused by human interference.

Civilised man's influence on the rain-forest has been immense and almost entirely destructive. The area of rain-forest in the state has been reduced by about 50 per cent in the last 100 years, and the rain-forest has been replaced by grasslands which are maintained by grazing, fire, and clutivation. Most of the remaining area has been logged and previously left in a fire-susceptible or degenerate state. Scientific management of the natural rain-forest is still being formulated with the emphasis upon retaining the rain-forest environment to facilitate regeneration.

VII. CONCLUSIONS.

This study has dealt with two aspects of the rain-forests of New South Wales. Firstly, an attempt has been made to classify the rain-forest communities in the state, and, secondly, an explanation for the distribution of these communities has been offered in terms of the various factors of distribution.

The classification is tentative, and more detailed study will doubtlessly show the need for some alterations and further subdivision, particularly in the floristic classification. At the same time the six alliances and the various associations described can all be readily recognized in the field and should serve as reference points for subsequent work.

The structural classification shows the presence of four major subformations in New South Wales, along with two other structural types which probably deserve subformation status: these last two are the littoral communities in the *Cupaniopsis* alliance and the gallery communities in the *Castanospermum* alliance. The four major types have characteristic structures and occur over relatively wide areas. Despite their distinctiveness, however, it is a curious fact that there are no records of any deliberate previous attempts to distinguish between three of these.

The terminology of rain-forest subformations in general is very confused, and the names given to the four local groups, subtropical, warm temperate, cool temperate, and dry should be used in conjunction with the definitions of these groups, and should not be regarded as having any environmental significance. This is different from Richards's use of the term "tropical rain-forest", which he applies to all rain-forests growing under tropical conditions and which includes a number of distinct structural forms, as for example in the five communities studied in British Guiana (Richards 1952, pp. 236-43). Indeed, it would appear desirable to replace in time the current terms by a new set using purely structural characters to distinguish them.

The distribution of rain-forest in New South Wales appears to be primarily determined by the availability of moisture. For rain-forest to develop the average annual rainfall should be over 1500mm or else some supplementary moisture supplies should be provided by favourable topographic or soil conditions. Where the rainfall is markedly seasonal, dry rain-forest results, and the same conditions of periodic low humidity that seem important in producing this community also lead to many rain-forest margins in the north of the State having very similar structural and floristic composition to the dry rain-forests.

Low temperatures and very moist conditions produce cool temperate rain-forest. In northern New South Wales the warm temperate and subtropical rain-forests occur under similar climatic conditions but on soils of markedly different fertility, the subtropical stands being restricted to soils with a relatively low phosphate status. This explains the differing successes that have accompanied land utlilzation experiments in parts of the State. Thus the western part of the Dorrigo Plateau, formerly covered by subtropical rain-forest, now carries rich dairy farms; while cleared land on the eastern plateau, which supported warm temperate rain-forest, now carries mainly derelict farms.

Subtropical rain-forest is restricted to areas north of the Hastings catchment apparently by temperature, and south of here warm temperate rain-forest occurs on the more fertile soils. The absence of certain of the warm temperate community species from the richer soils in the north is apparently due to the intense competition of the species characteristic of the subtropical stands.

The general discontinuity of the rain-forest stands throughout the state is the result of past climatic changes, particularly during the Pleistocene and Early Recent periods.

It can be seen that the present distribution of rain-forest is the result of a complex interaction of many environmental factors. Together these produce the State's most complex and most interesting natural plant communities, which furthermore are of considerable economic value. In the past, consideration of these communities has been confused by lumping all the rain-forests not dominated by Nothofagus moorei together as subtropical. This study shows that this should not be done, and that the rain-forests of New South Wales are themselves very varied, each type having its own particular points of interest and its own potentialities for future management. It is hoped that this study may lead to the introduction of forest management to these stands.

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APPENDIX I.

TYPICAL SPECIES LIST FOR NORTHERN LOCALITIES.

Species lists for six localities are given in Table 8 below. These localities belong to the following alliances or associations:

Moore Park	*Castanospermum* alliance
Tooloom Plateau	*Dysoxylum* association
Wiangarie State Forest	*Heritiera* association
Mt. Pikapene State Forest	*Drypetes* alliance
Bruxner Park	*Sloanea woollsii* association
Moonpar State Forest	*Ceratopetalum-Schizomeria* association.

Other lists for New South Wales given in the literature are: Mt. Wilson (*Ceratopetalum-Doryphora* association)(Brough, McLuckie, and Petrie 1924); Hastings Catchment (*Ceratopetalum-Schizomeria* association)(Burges and Johnston 1953); Bulli District (*Ceratopetalum-Diploglottis* association)(Davis 1941); Barrington Tops (*Nothofagus* alliance and *Schizomeria-Ackama-Doryphora-Cryptocarya* association)(Fraser and Vickery 1938); and Myall Lakes (*Cupaniopsis* alliance)(Osborne and Robertson 1939).

The scientific nomenclature of plants other than eucalypts in the present paper is that used by the National Herbarium, Sydney (1973).

TABLE 8.

SPECIES LISTS.

Family and Species	Moore Park	Tooloom Plateau	Wiangarie	Mt. Pikapene	Bruxner Park	Moonpar
Cyatheaceae						
Cyathea leichhardiana			+		+	+
Araucariaceae						
Araucaria cunninghamii				+		+
Cupressaceae						
Callitris macleayanus						+
Podocarpaceae						
Podocarpus elatus	+					
Palmaceae						
Calamus muelleri					+	
Linospadix monostachyus		+	+		+	+
Archontophoenix cunninghamiana			+		+	
Araceae						
Aocasia macrorrhizos	+		+			
Pothos longipes			+		+	

Family and Species	Mr. Pk.	T. Plat.	W'garie	Mt. Pik	Br. Pk.	M'par.
Flagellariaceae						
Flagellaria indica			+		+	
Liliaceae						
Cordyline terminalis		+	+	+		
C. stricta						+
Philesiaceae						
Geitonoplesium cymosum		+		+	+	+
Smilacaceae						
Smilax glacyphylla					+	
S. australis	+		+	+	+	+
Rhipogonum discolor			+	+	+	+
R. sp.					+	
Dioscoreaceae						
Dioscorea transversa				+	+	+
Petermanniaceae						
Petermannia cirrosa						+
Zingiberaceae						
Alpinia coerulea		+			+	
Orchidaceae						
Calanthe triplicata			+			
Piperaceae						
Piper novae-hollandiae			+			
Ulmaceae						
Celtis paniculata				+		
Trema aspera	+	+				+
Aphananthe philippinensis						
Moraceae						
Ficus macrophylla	+			+		
F. watkinsiana		+	+	+	+	
F. coronata	+					
Cudrania cochinchinensis	+	+		+		
Malaisia scandens				+	+	
Streblus brunonianus				+		
Urticaceae						
Dendrocnide excelsa		+	+	+		
D. photiniphylla				+		
Proteaceae						
Helicia youngiana						+
Orites excelsa			+		+	+
Grevillia robusta	+			+		
Oreocallis pinnata						+
Stenocarpus sinuatus					+	
S. salignus						+
Ranunculaceae						
Clematis sp.	+				+	+

Family and Species	Mr. Pk.	T. Plat.	W' garie	Mt. Pik	Br. Pk.	M' par.
Menispermaceae						
Stephania japonica var. discolor	+					
Legnephora moorei	+			+		
Winteraceae						
Drimys insipida		+			+	+
Anonaceae						
Rauwenhoffia leichhardtii		+	+	+		
Eupomatiaceae						
Eupomatia laurina		+	+			+
Monimiaceae						
Doryphora sassafras			+		+	+
Daphnandra micrantha	+	+	+			
Wilkiea huegeliana			+		+	+
W. macrophylla			+			
Hedycarya angustifolia		+				
Palmeria scandens			+			+
Lauraceae						
Cinnamomum virens		+			+	+
C. oliveri			+		+	
Litsea cassia		+	+			
Neolitsea dealbata	+	+	+		+	+
Litsea reticulata		+	+		+	+
Beilschmiedia obtusifolia	+	+	+		+	
B. elliptica	+		+		+	
Cryptocarya rigida					+	+
C. obovata	+		+		+	
C. glaucescens					+	+
C. microneura		+			+	+
C. erythroxylon		+	+			
C. triplinervis	+	+				
C. meissneri						+
Endiandra introrsa						+
E. crassiflora						+
E. muelleri	+				+	+
E. pubens			+			
Capparidaceae						
Capparis arborea	+	+	+	+	+	
Escalloniaceae						
Quintinia verdonii			+			+
Polyosma cunninghamii			+		+	+
Anopterus macleayanus						+
Pittosporaceae						
Pittosporum undulatum		+				
P. revolutum	+					+
Hymenosporum flavum	+		+		+	
Citriobatus multiflorus	+	+	+	+		+
C. pauciflorus		+				
Billardiera scandens						+

Family and Species	Mr. Pk.	T. Plat.	W' garie	Mt. Pik.	Br. Pk.	M' par
Cunoniaceae						
Callicoma serratifolia					+	+
Ceratopetalum apetalum					+	+
Schizomeria ovata					+	+
Ackama paniculata			+		+	+
Geissois benthami			+		+	+
Leguminosae						
Acacia maideni				+		
A. sp.						+
Abarema sapindoides	+			+		
A. grandiflorum			+			+
Cassia floribunda				+	+	
Erythrina vespertilio				+		
Lonchocarpus blackii				+	+	
L. sp.			+			
Derris involuta		+	+			
Castanopsermum australe	+					
Rutaceae						
Bosistoa euodiiformis					+	
Zieria arborescens						+
Euodia micrococca		+		+		+
Zanthoxylum brachyacanthum		+	+	+		
Geijera salicifolia		+				
Melicope octandra			+			
Acronychia oblongifolia	+					
A. baueri		+	+	+		
A. suberosa			+			+
Halfordia kendack			+			
Simaroubaceae						
Guilfoylia monostylis	+		+			
Meliaceae						
Toona australis	+	+	+			
Melia azederach var. australasica	+			+		
Dysoxylum fraseranum		+	+	+		
Didymocheton rufum	+		+			
Pseudocarapa nitidula		+	+	+		
Synoum glandulosum					+	+
Flindersia australis		+	+	+		
F. schottiana				+		
F. xanthoxyla	+			+		
Euphorbiaceae						
Breynia oblongifolia		+		+	+	+
Drypetes australasica				+		
Bridelia exaltata				+		
Cleistanthus cunninghamii				+		
Croton insularis				+		
C. verreauxii		+		+	+	
Claoxylon australe			+	+	+	+
Mallotus philippensis	+			+		
Coelebogyne ilicifolia				+		
Austrobuxus swainii					+	+
Baloghia lucida	+	+	+	+		
Excoecaria dallachyana				+		
Omolanthus populifolius		+	+			+

Family and Species	Mr. Pk.	T. Plat.	W' garie	Mt. Pik.	Br. Pk.	M' par.
<u>Anacardiaceae</u>						
Rhodosphaera rhodanthema	+					
Euroschinus falcatus			+	+		
<u>Celastraceae</u>						
Maytenus bilocularis		+		+		
Denhamia pittosporoides						+
Elaeodendron australe				+		
Siphonodon australe			+	+		
<u>Icacinaceae</u>						
Pennantiacunninghamii			+			
Citronella moorei		+				
<u>Sapindaceae</u>						
Diploglottis australis		+	+		+	+
Guioa semiglauca		+	+			+
Cupaniopsis parviflora				+		
C. serrata			+	+		
Alectryon subcinereus	+			+		
A. tomentosus	+			+		
A. subdentatus				+		
Sarcopteryx stipitata		+	+		+	+
Jagera pseudorhus				+	+	
Elattostachys xylocarpa				+		
E. nervosa			+			
Arytera divaricata		+		+		
Mischocarpus pyriformis					+	
Harpullia hillii		+				
<u>Akaniaceae</u>						
Akania lucens			+		+	
<u>Rhamnaceae</u>						
Alphitonia excelsa		+	+	+		
<u>Vitaceae</u>						
Cissus antarctica	+	+				+
C. hypoglauca						+
Cayratia clematidea		+	+			
<u>Elaeocarpaceae</u>						
Sloanea australis		+	+		+	
S. woollsii			+		+	+
Elaeocarpus reticulatus					+	+
E. obovatus	+					
E. kirtonii			+			
<u>Malvaceae</u>						
Hibiscus heterophyllus				+		
Abutilon spp.	+					
<u>Sterculiaceae</u>						
Brachychiton discolor				+		
B. acerifolius			+		+	+
Heritiera trifoliolatum			+		+	
H. actinophyllum		+	+	+	+	
<u>Flacourtiaceae</u>						
Casearia multinervosa				+		

Family and Species.	Mr. Pk.	T. Plat.	W'garie	Mt. Pik.	Br. Pk.	M'par
Thymeliaceae						
Wickstroemia indica		+				
Myrtaceae						
Tristania conferta					+	+
T. laurina					+	+
Backhousia myrtifolia					+	
Austromyrtus acmenioides				+	+	
A. hillii				+		
Rhodomyrtus beckleri						+
Rhodamnia trinervia					+	+
R. argentea	+		+			+
Acmena hemilampra			+			+
Syzygium francisii				+		
S. corynanthum					+	
Acmena australis		+	+			
Syzygium paniculatum	+					
S. crebrinerve		+	+		+	
S. coolminianum			+		+	
Araliaceae						
Polyscias murrayi					+	+
P. elegans	+		+	+	+	
P. sambucifolius						+
Epacridaceae						
Trochocarpa laurina					+	+
Myrsinaceae						
Rapanea variabilis		+	+			+
Embelia australiana		+	+		+	+
Sapotaceae						
Chrysophyllum pruniferum					+	
Planchonella australis		+	+		+	
P. myrsinoides				+		
Ebenaceae						
Diospyros australis		+				
D. pentamera		+	+	+	+	
Oleaceae						
Olea paniculata	+					
Apocynaceae						
Melodinus australis		+	+		+	
Alyxia ruscifolia				+		
Ervatamia angustisepala					+	
Alstonia constricta				+		
Parsonsia sp.	+	+	+	+		+
Asclepiadaceae						
Hoya australis				+		
Boraginaceae						
Ehretia acuminata	+	+		+		
Verbenaceae						
Spartothamnus junceus				+		

Family and Species	Mr. Pk.	T. Plat.	W' garie	Mt. Pik.	Br. Pk.	M' par
Verbenaceae continued						
Clerodendron tomentosum			+	+		
Gmelina leichhardtii					+	
Solanaceae						
Solanum mauritianum	+					
Duboisia myoporoides						+
Bignoniaceae						
Pandorea sp.	+	+	+	+		
Rubiaceae						
Randia benthamiana			+		+	+
Psychotria loniceroides						+
P. daphnoides			+			
Caprifoliaceae						
Sambucus sp.			+			
Compositae						
Helichrysum diosmifolium						+

APPENDIX II

ASH ANALYSIS

The sign (x) in Table 9 indicates that the sample so designated has been obtained from a locality not discussed in the present paper. A list of these localities is as follows:-

Berowra: depauperate *Ceratopetalum* rain-forest in sandstone gully near Sydney.

Bilgola: A very much dwarfed headland rain-forest near Sydney, related to the *Cupaniopsis* alliance.

Bola Creek: gully rain-forest near Sydney belonging to the *Ceratopetalum-Diploglottis* association.

Bulli: A coastal example of the *Ceratopetalum-Diploglottis* association south of Sydney.

Cockrow: *Nothofagus*-dominated rain-forest near the Barrington Tops.

Gosford: gully rain-forest near Sydney, belonging to the *Ceratopetalum-Diploglottis* association.

Robertson: *Ceratopetalum-Diploglottis* association south of Sydney.

St. Ives: *Eucalyptus pilularis-E. saligna* wet sclerophyll forest on shale near Sydney.

TABLE 9.

ASH ANALYSIS RESULTS.

Percentage of oven-dry weight of leaf material

Species and Location	Ash	Ca	Na	K	PO_4
Brachychiton acerifolius					
Lamington Nat. Park - Basalt	7.93	1.42	0.048	1.34	0.432
Bulli (x)	10.42	0.96	0.125	2.67	0.880
Wiangarie S.F.	9.30	0.52	0.056	3.05	0.811
Breynia oblongifolia					
St. Ives (x)	7.20	0.77	0.159	1.47	0.384
Bilgola (x)	5.92	0.63	0.302	1.22	0.183
Tooloom Plateau	14.03				
Mt. Pikapene	16.12				
Pine Creek - beach sands	8.98				
Casuarina torulosa					
St.Ives	3.18	0.34	0.130	0.36	0.126
Whian Whian	3.74	0.22	0.348	0.49	
Mt. Pikapene - Tall woodland	3.83	0.13	0.157	0.40	
Barcoongere - good quality pinus	4.21	0.12	0.408	0.47	
Toona australis					
Wiangarie State Forest	5.12	0.51	0.056	1.31	0.455
Koreelah	10.63	2.10	0.043	1.01	0.710
Ceratopetalum apetalum					
Lamington Nat. Park	7.86	0.59	0.047	0.45	0.108
Bulli	5.86	0.46	0.040	0.64	0.270

Species and Location	Ash	Ca	Ka	K	PO_4
Ceratopetalum apetalum cont.					
Berowra (x)	8.07	0.54	0.024	0.54	0.118
Bola Creek (x)	7.74	0.81	0.039	0.53	0.197
Whian Whian	6.06	0.24	0.067	0.63	0.146
Whian Whian	8.66	0.48	0.053	0.36	0.102
Dome Mountain - tree top	5.02	0.36	0.041	0.78	0.223
Dome Mountain - tree base	4.37	0.31	0.039	0.53	0.121
Claoxylon australe					
Gosford (x)	18.20	3.52	0.200	3.75	0.346
Wiangarie S.F.	15.43	2.87	0.154	2.95	0.593
Mt. Pikapene S.F.	14.75	2.99	0.118	1.83	0.488
Moonpar S.F.	14.02	2.69	0.070	2.31	0.376
Cryptocarya glaucescens					
Gosford - inside rain-forest	3.87	0.62	0.124	0.64	0.207
Gosford - rain-forest margin	5.67	0.75	0.136	1.49	0.201
Diploglottis australis					
Bola Creek	9.00	0.80	0.288	1.18	0.471
Robertson (x)	5.94	0.62	0.083	0.89	0.500
Lamington Nat. Park - basalt	4.53	0.33	0.045	1.13	0.415
Gosford	9.87	1.12	0.128	0.77	0.369
Clouds Creek - basalt	10.98	1.78	0.110	0.98	0.376
Moonpar S.F.	6.34	0.66	0.139	0.42	0.254
Doryphora sassafras					
Lamington Nat. Park - basalt	3.06	0.50	0.037	0.42	0.190
Whian Whian - coachwood rain-forest	6.01	0.99	0.042	0.57	0.312
Robertson	5.72	0.76	0.052	1.07	0.311
Bulli	7.52	1.31	0.090	0.72	0.394
Bola Creek	7.51	1.01	0.098	1.42	0.323
Dome Mountain	4.33	0.65	0.065	0.70	0.198
Wiangarie S.F.	5.22	0.70	0.177	0.74	0.267
Cockrow (x)	5.71	0.85	0.046	0.93	0.305
Mt. Lindsay	5.24	0.83	0.147	0.82	0.257
Eucalyptus gummifera					
Barcoongere - good quality Pinus	3.40	0.23	0.344	0.52	0.183
Barcoongere - poor quality Pinus	3.09	0.23	0.232	0.65	0.121
Wiangarie S.F. - rain-forest margin	4.77	0.41	0.129	1.06	0.644
Eucalyptus planchoniana					
Barcoongere - poor quality Pinus	4.34	0.62	0.256	0.22	0.077
Eucalyptus saligna					
St. Ives	5.61	0.53	0.264	1.08	0.419
Tooloom Plateau - rain-forest margin	3.41	0.17	0.075	0.78	0.539
Clouds Creek - basalt plain	4.92	0.66	0.226	0.67	0.458
Clouds Creek - shale	4.76	0.48	0.176	0.76	0.380
Acmena smithii					
Bulli	4.10	0.26	0.225	0.83	0.998
Robertson	3.62	0.44	0.163	0.41	0.184
Bola Creek	5.68	0.51	0.284	0.77	0.401
Berowra	4.91	0.65	0.206	0.66	0.153

Species and Location	Ash	Ca	Na	K	PO_4
Acmena smithii continued					
Bilgola	3.77	0.34	0.181	0.53	0.262
Pine Creek - beach sand	5.42	0.72	0.108	0.43	0.798
Pine Creek - gully	3.48	0.37	0.139	0.49	0.302
Omolanthus populifolius					
Bilgola	6.10	0.29	0.287	0.72	0.324
Whian Whian - basalt	7.09	0.43	0.050	2.58	0.940
Whian Whian - obsidian	7.25	0.71	0.044	1.03	0.354
Orara West S.F.	5.62	0.69	0.056	1.06	0.459
Neolitsea dealbata					
Lamington Nat. Park - basalt	4.47	0.09	0.031	1.31	0.067
Whian Whian - basalt	4.39	0.05	0.026	0.44	0.020
Whian Whian - acid rocks	3.30	0.46	0.043	0.42	0.213
Gosford	5.61	0.07	0.056	1.72	0.070
Tooloom Plateau	3.26	0.30	0.049	0.70	0.258
Brooklana	3.95	0.22	0.028	1.18	0.252
Nothofagus moorei					
Lamington Nat. Park	3.01	0.12	0.045	0.95	0.292
Brooklana	2.60	0.13	0.096	0.57	0.188
Dome Mountain	3.91	0.53	0.145	0.68	0.177
Cockrow	3.37	0.28	0.024	0.69	0.390
Orites excelsa					
Lamington Nat. Park - basalt	5.20	0.08	0.114	0.54	0.128
Whian Whian - acid rocks	4.86	0.18	0.083	0.30	0.120
Whian Whian - basalt	6.20	0.06	0.180	0.34	0.136
Dome Mountain	5.25	0.04	0.053	0.37	0.132
Cockrow	6.52	0.15	0.033	0.43	0.164
Pinus elliottii					
Clouds Creek - basalt plain	2.92	0.27	0.020	0.48	0.416
Brooklana	3.33	0.55	0.113	0.19	0.181
Barcoongere - good growth	3.68	0.58	0.026	0.23	0.219
Barcoongere - poor growth	2.33	0.33	0.033	0.24	0.112
Pittosporum undulatum					
St. Ives	8.01	0.74	0.072	2.36	0.278
Lamington Nat. Park - basalt	8.29	1.77	0.166	1.61	0.212
Dome Mountain - wet sclerophyll forest	6.92	0.43	0.097	2.39	0.177
Tooloom Plateau	10.36	1.75	0.145	2.58	0.255
Rhodamnia trinervia					
Gosford - inside rain-forest	5.33	0.68	0.053	0.34	0.214
Gosford - rain-forest margin	4.31	0.49	0.069	0.54	0.256
Whian Whian - basalt	5.38	0.31	0.064	0.69	0.545
Moonpar S.F.	4.65	0.35	0.074	0.76	0.226
Pine Creek - beach sand	6.57	0.28	0.039	0.54	0.898
Sloanea australis					
Lamington Nat. Park - basalt	4.15	0.66	0.099	0.72	0.240
Lamington Nat. Park - acid rocks	4.12	0.68	0.047	0.74	0.160
Whian Whian - basalt	6.11	1.20	0.098	0.66	0.251
Gosford	4.67	0.51	0.061	0.98	0.220
Bulli	5.40	0.79	0.102	1.15	0.387
Wiangarie S.F.	8.30	1.78	0.100	0.77	0.242

Species and Location	Ash	Ca	Na	K	PO_4
Smilax australis					
Gosford - rain-forest margin	5.51	0.83	0.099	1.08	0.152
Gosford - inside rain-forest	5.38	0.51	0.102	1.43	0.330
Whian Whian - acid rocks	6.59	0.63	0.138	2.21	0.190
Whian Whian - obsidian	5.47	0.94	0.109	0.97	0.287
Whian Whian - wet sclerophyll forest above basalt	5.33	0.88	0.149	1.06	0.298
Whian Whian - basalt	6.11	1.03	0.153	1.04	0.325
Trochocarpa laurina					
Gosford - inside rain-forest	3.95	0.82	0.122	0.26	0.126
Gosford - rain-forest margin	3.64	0.65	0.087	0.65	0.127
Moonpar S.F. - wet sclerophyll forest	7.12	0.72	0.064	0.56	0.159
Moonpar S.F. - rain-forest	4.08	0.68	0.127	0.51	0.113
Wilkiea huegeliana					
Whian Whian - acid rocks	8.74	0.27	0.236	0.69	0.177
Whian Whian - basalt	10.76	1.19	0.242	0.47	0.183
Coffs Harbour - headland	11.18	1.03	1.55	1.00	0.473
Syzygium spp.					
Wiangarie S.F. (Syzygium crebrinervis)	6.46	0.78	0.265	0.89	0.307
Wiangarie S.F. (Acmena australis)	3.76	0.05	0.034	1.39	0.632
(Acmena hemilampra)	3.62	0.30	0.181	0.52	0.212