Lands of the Port Moresby–Kairuku Area, Territory of Papua and New Guinea

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PART I. INTRODUCTION TO LANDS OF THE PORT MORESBY–KAIRUKU AREA

By J. A. Mabbutt* and J. R. McAlpine*

I. General

The area surveyed covers approximately 2750 sq miles in the Territory of Papua and has been designated the "Port Moresby–Kairuku area" from the two main administrative centres within it. It is a coastal strip between lat. 8° 15′ S. and lat. 9° 40′ S.

The immediate object of the survey was the mapping and description of the area at reconnaissance scale by a small team of scientists. As in previous surveys carried out by the Division of Land Research and Regional Survey, the basic descriptive unit is the land system, which is an area or group of areas with a recurring pattern of land forms, soils, and vegetation. The land system maps and descriptions provide a basis for an assessment of the potential of the area and for recommendations for further research.

The survey was mainly in the coastal lowlands, with limited incursions into the uplands where roads existed.

II. Administrative Divisions

The area consists of coastal parts of the following administrative divisions of the Territory of Papua (Fig. 1):

- Central District
  - Port Moresby subdistrict
  - Rigo subdistrict, administered from Kwikila
  - Kairuku subdistrict, administered from Kairuku at the time of the survey, now administered from Bereina
- Gulf District
  - Kerema subdistrict

III. Settlement

The survey area includes those parts of the Territory with the longest record of Australian settlement and administration. Following attempts to take possession by Yule in 1846 and by Moresby in 1873, annexation followed at Port Moresby on the initiative of the Queensland Government in 1883. Missionaries were already active along the Papuan coast at this time.

The distribution of villages (Fig. 1) shows a concentration of native settlement along the coast (Plate 12, Fig. 1). The sparseness of settlement inland is noteworthy;

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it is partly a result of difficult terrain, notably the extensive swamps, but in other areas lack of water may also be a cause, for this is one of the driest parts of the Territory. The large Mekeo villages near the Angabunga River are a notable exception to the lack of inland settlement. Small hamlets are scattered through the southern part of the area, including the Sogeri Plateau.

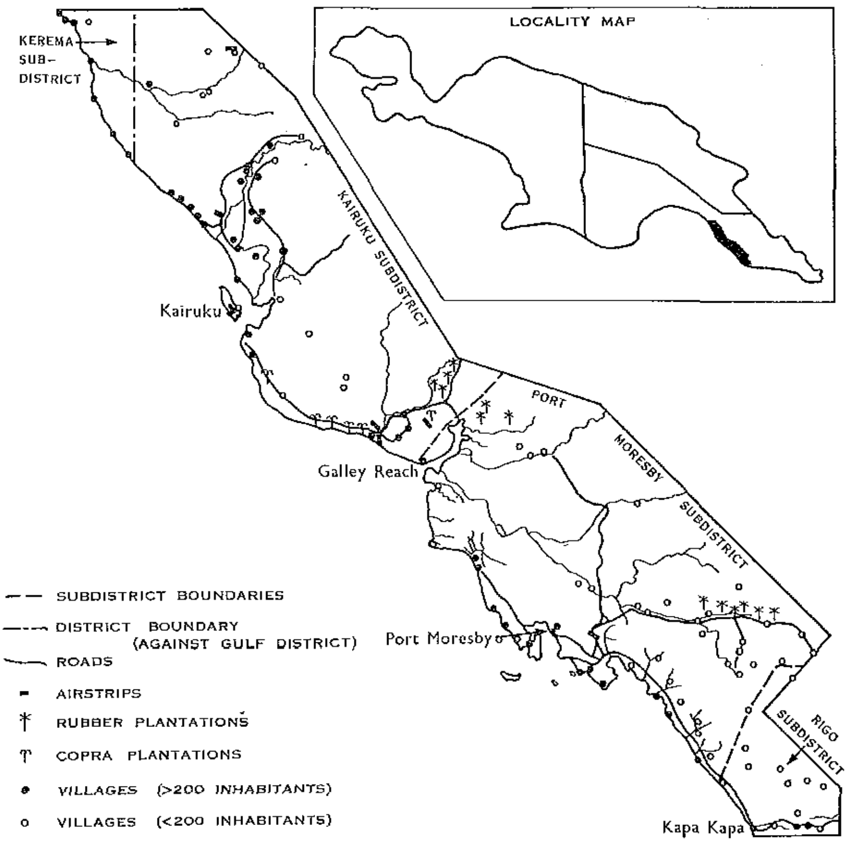

Fig. 1.—Settlement, communications, and land use in the Port Moresby–Kairuku area.

Population figures in Table 1 illustrate the pre-eminence of Port Moresby, not only as a centre of European settlement but also as a market for native labour (Plate 12, Fig. 2). However, the functions of Port Moresby relate to a wider sphere than the survey area, for it is the centre of administration in the Territory of Papua and New Guinea, the main commercial centre of Papua, and the main port linking the Territory with Australia by sea and air. Apart from government stations, white settlement outside Port Moresby is mainly associated with the rubber plantations at Kanosia and on the Sogeri Plateau (Plate 11, Fig. 2), and the coastal area of copra plantations near Hisiu. These mainly use indentured native labour from the New Guinea highlands.

IV. Communications

The area possesses a number of road nets (Fig. 1) mainly based on centres of non-indigenous settlement and enterprise and partly answering administrative needs. These are separated by rivers, swamps, or hilly terrain. Sealed or built roads are restricted to Port Moresby, but most of the roads shown in Figure 1 can be classed as all-weather roads for four-wheel-drive vehicles. Road maintenance is facilitated by low rainfall in much of the area.

With the emphasis on coastal settlement and development, and in the absence of a connected road system, coastal shipping plays an important part in the movement of plantation products and of native produce. "K" boats, mainly owned by plantation firms, ply regularly between plantation wharves, Kairuku, and Port Moresby.

Table 1

POPULATION OF THE PORT MORESBY–KAIRUKU AREA (1959–60 CENSUS)

Indigenous		Non-indigenous	
Port Moresby subdistrict	13,500	Port Moresby town	5,900
Port Moresby town	23,000	Other	500
Rigo subdistrict	2,500		
Kairuku subdistrict	13,000		
Kerema subdistrict	5,700		
Total	64,200	Total	6,400
Total population 70,600			

Apart from Port Moresby, there are strips for DC3 aircraft at Rogers (Kanosia) and at Bereina, and strips for light aircraft at Aroa and at Kairuku. In addition, a small strip has been cleared by native enterprise at Maipa, and native produce is flown into Bereina and Port Moresby.

V. Survey Procedure

The method of survey is based on the concept that each type of country, or land system, is expressed on aerial photographs by a distinctive pattern, so that a map of the land systems can be produced from air photographs. The method presupposes that a complete aerial photographic cover of the area is available.

Vertical air photos at a scale of 1 : 50,000 in the southern half of the area and 1 : 40,000 in the north, taken on flights by Adastra Airways in 1956 and 1957, gave complete coverage save for a very small area near Kubuna. These were supplemented by air photos of the Kubuna One-Mile Sheet, taken in 1961. The age of the air photos was a source of inconvenience at many points in the survey, as tracks, garden patterns, and plantation limits have changed in many areas, and notably the Angabunga River has undergone a major change of course with important consequences to land-system patterns.

The only large-scale topographic maps are the following sheets of the wartime 1 : 63,360 Standard Series, New Guinea, produced by the Australian Army and having generalized contours: Kapa Kapa, Gaile, Uberi, Port Moresby, Lea Lea Inlet, Vanapa, Galley Reach. Coastal features are shown on Admiralty Charts Nos. 1239 (Hall Sound), 2028 (Kerema Bay to Port Moresby), and 2029 (Port Moresby to Orangerie Bay), and on Australian Chart No. 1 (Approaches to Port Moresby).

Preliminary mapping of air photos was carried out in April and May 1962, and field work occupied 15 weeks during July–October 1962. Field work was governed by the availability of vehicular roads and waterways. The use of vehicles, which was

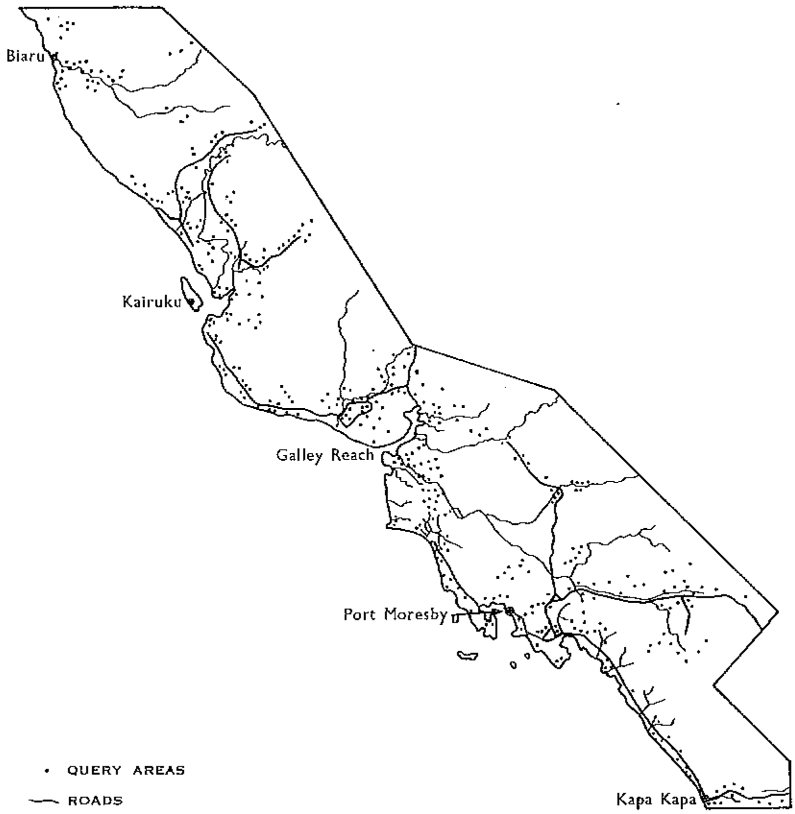

Fig. 2.—Query areas examined during the survey, and road network.

in any case necessitated by lack of carriers, gave greater mobility than in any previous survey in New Guinea. Instead of walking traverses, daily journeys were made from a small number of base camps. Further, routes could be planned in advance and areas for examination mainly selected before the party left Canberra. Two Land Rovers and a motor cycle were made available by the Administration.

Each road net was exploited in turn, from south to north, the vehicles being transported from one net to the next by boat or raft. Walking traverses and motor cycles were used to extend observations beyond road heads. Later the party used a K boat and powered dinghies to examine coasts and rivers near Lesi Inlet, Hall Sound, and Redscar Bay. Light aircraft were used to examine an isolated area around Maipa and in reconnaissance flights at the end of field work.

About 450 "query areas", each typically comprising three or four sites, were examined and plotted on air photos (Fig. 2). All observations were collated in the field into the framework of about 90 mapping types, and the boundaries of these types were placed on all air photos used during field work. When the team returned to Canberra, mapping of these types was extended over the whole survey area by the end of the year, and the mapping types were then grouped into 49 land systems. The period January to June 1963 was spent in describing the land systems and in the compilation of individual reports.

A base map scale 1 : 250,000 was compiled by the Division of National Mapping, Department of National Development, from preliminary detail plots at 1 : 50,000 assembled by the H. G. Jerie block assembly method.

VI. Acknowledgments

The cooperation of the Administration of the Territory of Papua and New Guinea in supplying transport and arranging for its transhipment is gratefully acknowledged, and work in the north of the area was greatly facilitated by the accommodation made available by the Administration at Bereina. The Department of Agriculture, Stock and Fisheries supplied unpublished information on soils.

Thanks are also due to many plantation managers for assistance and hospitality afforded to team members during the survey.

Identification of plants was undertaken by the Divisional herbarium staff under Dr. R. D. Hoogland.

The preparation of all maps, diagrams, illustrations, and the manuscript was done by the staff of the Division.

PART II. SUMMARY DESCRIPTION OF THE PORT MORESBY–KAIRUKU AREA

By J. A. Mabbutt*

I. Introduction

This Part summarizes the salient points of the specialized Parts of the report and is intended to be an introduction to the tabulated descriptions of the land systems in Part III. Together with the land systems and the photographs, it can be read as a shorter report in less technical form.

II. Description of the Area

(a) *General*

The survey area extends for 140 miles along the east coast of the Gulf of Papua with an average width of 20 miles, including the coastal lowland and extending a short distance into the outer part of the main range of New Guinea. Despite its narrowness, it contains six partly discontinuous zones parallel with the coast: in succession inland these are the littoral plains zone, coastal hill zone, swamp zone, fluvial plains zone, foothill zone, and upland zone.

Apart from the geomorphic differences implicit in these names, each zone has a distinctive geology and partakes in differing degree in the climatic transition from the coast inland; consequently, soils and vegetation also follow the same pattern. Zonal contrasts are naturally an important theme in most of the parts summarized below. It also follows that the land systems within each zone have a close relationship, and this is expressed in the zonal grouping of the land system descriptions in Part III and in the introductory remarks to each zonal group.

The zones are divided into sectors by virtue of discontinuities of relief and depositional patterns.

(b) *Climate*

The climate grades from tropical savannah or subhumid tropical type to tropical rain forest or wet tropical type (Part IV). Two wind systems control its main features. The rain-bearing north-west monsoon brings warmer, humid conditions between December and mid April, whilst the strong south-easterly trades, which prevail between June and mid October, bring cooler drier weather. These seasonal contrasts are modified by major relief, for the south-easters bring rain where they meet relief barriers. Orographic effects are lessened because of the parallelism of coast and ranges with the prevalent winds, but important rain shadows can occur, as on the Sogeri Plateau west of the Astrolabe Range.

Annual rainfall ranges from about 40 in. in sheltered coastal sites to 150 in. on exposed higher slopes, the larger amounts resulting from frequent moderate falls.

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Seasonal rainfall contrasts are marked in the drier coastal zone, where monthly rainfalls of less than 1 in. occur in the drier season and where significant dry spells are experienced, but dry seasonal effects decrease inland. Annual and monthly rainfalls vary considerably from year to year throughout the area.

Seasonal and diurnal temperature ranges are everywhere small, owing to maritime effects carried inland by sea breezes. At Port Moresby, mean monthly maximum temperatures range from 82°F to 90°F and minima from 73°F to 76°F; temperatures rarely fall below 65°F, even in the coolest months, and maximum temperatures above 95°F are uncommon. Temperature ranges may be expected to increase away from the coast, accompanied by a general decline of temperatures with altitude, but even at high altitudes inland there is no risk of frosts.

Mean relative humidity is high at all seasons, and heavy dew occurs throughout the year. Mean monthly cloudiness at Port Moresby ranges between five-tenths and seven-tenths, being only slightly lower in the dry season, but still cloudier conditions occur on the slopes of the higher ranges.

Mean annual evaporation at Port Moresby is about 70 in., but decreases inland.

The climate is generally favourable to plant growth, but contrasts in vegetation indicate a degree of adaptation according to the length and severity of the drier season. Analyses of weekly rainfall at Port Moresby indicate that rainfall has never been so inadequate that it could result in early termination of crops sown in late December, although some intra-seasonal water stress can be expected in the coastal zone. Duration of useful pasture growth at Port Moresby is 42 weeks compared with 22 weeks at Katherine, Northern Territory. At wetter inland stations there is no restriction of growth resulting from limited soil moisture.

Although the drier season would benefit many crops in the coastal lowlands, special agronomic problems may arise within the area as a whole because of prevailing high humidity, low radiation, lack of seasonal differences in day length, and heavy leaching from frequent and moderately heavy rainfalls.

(c) *Geology*

The survey area lies on the margin of the fold structures of the main range of New Guinea (Part V). Its structure is dominated by north-west-trending folds and faults which are of decreasing intensity on younger rocks, and by transverse warping. Since the Cretaceous period there has been almost continuous geosynclinal deposition, with a westward shift of axis of marine deposition about the beginning of the Miocene which left the coastline not far inland from its present position. Basic volcanism has been present from the beginning, but with shifting centres of activity, concluding with prominent, largely terrestrial outpourings in the Pliocene.

The older geosynclinal sediments, ranging from Cretaceous to Miocene in age, are mainly fine-grained, with cherty and calcareous members including coralline limestone, and are tuffaceous in large part. They are closely folded, particularly in the south-east of the area, where they have undergone low-grade metamorphism and concordant intrusion by gabbro and minor basic hypabyssal bodies in the Palaeogene. Where these rocks are heterogeneous, as in the coastal hill zone, cherts and limestones form narrow anticlinal strike ridges (Plate 3, Figs. 1 and 2) whilst mudstone underlies broad vales in synclinal tracts; where homogeneous, they form more massive relief, as on gabbro in the southern foothills (Plate 9, Fig. 1) and on phyllite in the south backing ranges (Plate 9, Fig. 2).

The succeeding volcanic pile consists of agglomerate, tuff, and lava in a succession known to exceed 1500 ft in thickness locally (Plate 10, Fig. 1). These Pliocene rocks are mainly gently folded, as in the basin structure of the Sogeri Plateau, and survive as a dissected volcanic apron in the north backing ranges. A contemporary succession of 5000 ft of mainly terrestrial gritty sandstone has locally undergone moderate folding in the Palipala hills.

Cross-warps in the coastal lowlands have controlled the distribution of unconsolidated Pleistocene and Recent sediments, which cover 40% of the survey area. Down-warps about Galley Reach and in the north of the area have been areas of accumulation of unknown thicknesses of sand, silt, and clay. Complementary upwarping has resulted in local emergence of Pleistocene coral reefs by as much as 100 ft, and in general subaerial dissection in the coastal hill zone.

Minerals are not at present of economic importance, but the area has produced 81,000 tons of copper ore and nearly 2000 tons of battery-grade manganese ore.

(d) *Geomorphology*

The six environmental zones have characteristic land forms and processes (Part VI).

(i) *Coastal Hill Zone.*—Parallel strike ridges are formed of chert and limestone (Plate 3, Fig. 1) and lowlands are mainly cut in mudstone (Plate 4, Fig. 2). Much of the zone forms a savannah landscape with smooth inselberg ridges, concave foot slopes, and erosional plains. Weathering of sedimentary rocks is now mainly shallow, although lateritic weathering formerly occurred on gentle slopes. Under the prevailing climate, mass movement is subordinate to slope wash, streams are ephemeral, and there is slow deposition of clay-grade alluvium, indicative of slow erosion of fine-grained rocks. Moderately dense drainage reflects high run-off from impermeable surfaces, with extensive sheet flow on gentle slopes.

(ii) *Foothill Zone.*—With increasing altitude and rainfall inland, weathering and mass movement become more important and there is a closer network of streams of which the larger ones are perennial. Where relief is strong, slopes tend to be uniformly steeper than in the coastal hill zone. Land forms range from plains to low hills and broad cuestas on agglomerate in the northern foothills, and include higher ridges eroded in gabbro in the southern foothills (Plate 9, Fig. 1).

(iii) *Upland Zone.*—This is a zone of greater altitude and fairly heavy rainfall, with deep rock weathering, more pronounced mass movement and colluviation, and a dense network of perennial streams. Characteristic land forms are ridges ranging from low hilly to massive, with deep gully re-entrants. The north backing ranges are ridge and plateau remnants of the agglomerate sheet which also forms the Sogeri Plateau (Plate 10, Fig. 1); phyllite ridges of the south backing ranges constitute the third sector (Plate 9, Fig. 2).

(iv) *Fluvial Plains Zone*.—These plains occur about valley exits of large perennial rivers, and contain many prior meandering channels. Except for red clays derived locally from volcanic rocks in piedmont tracts, most of the alluvial cover consists of silty clay, with stratified sand on prior levees and clay in back swamps. Stable plains are distinguished from unstable flood-plains subject to fluvial re-working. Differences between land systems of the stable plains relate to water-table levels and liability to flooding, which is least in prior meander tracts and increases downslope towards the swamp zone and towards back plains. The unstable flood-plains (Plate 8, Fig. 1) have valley reaches with braiding channels, upper plain reaches dominated by shifting meanders, and lower plain reaches traversing swamps or low-lying plains and subject to major changes of course.

(v) *Swamp Zone*.—Extensive areas of permanent or seasonal standing water moderate river discharge in the lowlands. Seasonal fluctuations of water level range between 3 and 6 ft. Distinction is made between mainly permanent and mainly seasonal swamps, with differentiation of permanent swamps according to amount of through-going drainage and hence degree of infilling. Swamps are areas of clay deposition with minor peat formation, but through-going rivers deposit silty clays.

(vi) *Littoral Plains Zone*.—Sandy beach ridges of combined littoral and foredune origin occur as beach plains, spits, and barrier beaches (Plate 2, Fig. 2). Tidal flats (Plate 1, Figs. 1 and 2; Plate 2, Figs. 1 and 2) are differentiated on the basis of frequency of tidal inundation; related sediments range from sandy near the coast to clays inland, and are generally peaty. An estuarine land system comprises zones of mixed river and tidal influence, with levees backed by swampy plains ranging from freshwater inland to brackish near the coast. Coastal shifts, sea-level movements, and changes in river course commonly result in complex arrangements of river silts, mangrove clays, and stranded beach ridges.

(*e*) *Soils*

The soils have been separated into 13 groups based on profile form and wetness, and these have been subdivided into families based on differences of texture, colour, and soil reaction (Part VII). Soil groups are here numbered as in Parts III and VII.

(1) Beach soils are wholly sandy and generally well sorted. The younger sands are grey, but older sands are brown with incipient profiles.

(2) Mangrove soils are grey peats with a subsurface mangrove peat layer, subject to tidal inundation and poorly drained (Plate 1, Fig. 2). They range from sandy peat near the coast to clayey peat inland.

(3) Intertidal alluvial soils range from alkaline to neutral silty clay inland along river estuaries. Very strongly alkaline sticky clay characterizes the highest-lying tidal flats.

(4) Very poorly drained alluvial soils are grey and permanently waterlogged. Sticky clay with surface peat characterizes the swamp zone, whilst grey loam occupies swampy parts of the fluvial plains zone.

(5) Imperfectly drained alluvial soils are olive grey, are flooded seasonally or for shorter periods, and occupy lower parts of the stable fluvial plains. They include

stratified sandy soils on prior levees, silty clay in back plains, and sticky clay in back swamps. Across this textural division is that of alkalinity, attributed to cyclic salts, which is more pronounced near the coast.

(6) Moderately well-drained alluvial soils, with an olive colour, are characteristic of fluvial plains subject to flooding for short periods only. Subdivision is based on texture and alkalinity as in the preceding group.

(7) Dark cracking clay soils are typical on alluvial plains formed by minor streams in the coastal hill zone. Texture, self-mulching, and low rainfall preclude significant leaching, and there is normally a subsurface horizon of lime concretions.

(8) Lithosols, formed on steep slopes everywhere, are characteristically shallow and show strong affinity with the weathering rock beneath. Lithologic control of soil reaction and colour is pronounced in the drier areas, e.g. alkaline dark lithosols on limestones. Heavier rainfall leads to acid brown lithosols in the upland zone.

(9) Acid red to brown clay soils are deep, uniform, friable clays with rapid permeability. They are subdivided on the basis of colour and soil reaction as controlled by increasing rainfall, with range from dark reddish brown to dark yellow-brown and from moderately to extremely acid.

(10) Red gravelly clay soils have stony upper horizons which may be transported, and they characterize lowlands of the coastal hill zone. They range from neutral to alkaline, depending on subjacent or adjacent rocks.

(11) Brown clay soils are sedentary soils of moderate depth and permeability on soft-weathered rock. They vary from neutral to moderately alkaline, according to parent rock.

(12) Texture-contrast soils have coarse-textured surface horizons which pass abruptly into fine-textured subsurface horizons, and they typify gentle foot slopes. They are subdivided into solodic and solonetzic types on the basis of soil reaction, with further division on the presence or absence of a bleached A_2 horizon. Gravelly and non-gravelly phases of each family are distinguished.

(13) *Alkaline reddish clay soils overlie coral locally.*

The environmental zones are clearly reflected in the distribution of soils. Geologic control of soils is strongest in the dry coastal hill zone, where fine-grained sedimentary rocks give fine-textured soils, with widespread alkaline soils on limestone. Ridges and hills in this zone have lithosols, lowlands have texture-contrast or brown clay soils, and minor alluvial plains and valley flats have dark cracking clay soils. Increasing rainfall inland through the foothill and upland zones is shown in greater leaching, increasing acidity, and a transition from 2 : 1 to 1 : 1 clay minerals. The southern foothills have neutral brown lithosols and the central foothills have acid red to brown clay soils on volcanic rocks, whilst the upland zone is characterized by slightly acid to extremely acid red to brown clay soils. The fluvial plains and swamp zones have alluvial soils ranging from poorly drained grey sticky clays in permanent swamps to moderately well-drained olive silty clays and stratified soils on higher plains. In the littoral plains zone, mangrove soils on tidal flats are dominant, with smaller areas of beach soils.

(*f*) *Vegetation*

The vegetation pattern closely follows the environmental zonation seen in climate, land forms, and soils. The vegetation (Part VIII) has been divided into six main structural types: mixed herbaceous vegetation, grassland, savannah, palm and pandanus vegetation, scrub and thicket, and forest. Grassland, forest, and scrub and thicket types are further subdivided into groups on the basis of height or deciduousness, and a number of floristic communities have been recognized within each group. The main vegetation types have been mapped.

The relationships between vegetation groups and the main environmental zones are as follows:

(i) *Coastal Hill Zone.*—Low rainfall in this zone is emphasized by edaphic drought due to mainly shallow or fine-textured soils; hence savannah (Plate 3, Fig. 1; Plate 4, Figs. 1 and 2), semi-deciduous thicket, and strongly deciduous forest (Plate 3, Fig. 2) are prominent.

(ii) *Foothill Zone.*—Vegetation shows the influence of increasing rainfall with increasing altitude inland, with a transition from savannah and strongly deciduous forest to slightly deciduous forest (Plate 9, Fig. 1).

(iii) *Upland Zone.*—Rainfall is generally abundant here and tall evergreen forest prevails (Plate 9, Fig. 2) except for edaphically determined areas of slightly deciduous forest on stony crests of the north backing ranges and for the savannah of the Sogeri Plateau in the rain shadow of the Astrolabe Range (Plate 10, Fig. 1). At higher altitudes within the zone there are extensive oak forests.

(iv) *Fluvial Plains Zone.*—The vegetation of this zone shows the effects of increasing rainfall inland and of wetness and liability to flooding as determined by local relief. In the grasslands of the northern plains, for instance, tall grassland (*Saccharum spontaneum–Imperata*) (Plate 7, Fig. 1) gives place to mid-height grassland (*Ophiuros–Imperata*) (Plate 6, Fig. 2) inland. In the forested southern plains, mid-height forest gives place in ill-drained situations to tall evergreen and slightly deciduous forest (Plate 7, Fig. 2; Plate 8, Fig. 2) in drier sites.

(v) *Swamp Zone.*—The vegetation is edaphically determined. The permanent swamps show a succession from open water through mixed herbaceous vegetation to tall grasslands (*Phragmites–Saccharum robustum*) (Plate 5, Fig. 2), and the seasonal swamps largely bear mid-height evergreen forest (Plate 6, Fig. 1) or low evergreen thicket.

(vi) *Littoral Plains Zone.*—The vegetation reflects low rainfall and droughty soils, as in the semi-deciduous thicket of the sandy beach ridges (Plate 2, Fig. 2), or physiological drought of the saline mangrove flats, where mid-height and low evergreen forests occur (Plate 1, Figs. 1 and 2; Plate 2, Fig. 1).

(*g*) *Present Land Use*

The two main types of farming in the area (Part IX) are native gardening and plantation agriculture with large non-indigenous units. The latter shows a zonal distribution, mainly with rubber plantations in the upland zone (Plate 11, Fig. 2) and copra plantations in the littoral plains zone, both using indentured labour from outside the area, and cattle ranching in the coastal hill zone. The natives practise subsistence cropping on a family basis, by shifting cultivation, mainly in forest clearings, using digging stick or spade (Plate 10, Fig. 2), and the chief crops are taro and bananas. Native cash crops of growing importance are copra, cocoa, and coffee, and these may involve communal enterprise (Plate 11, Fig. 1). Betel nut and food crops from a wide area are also marketed in Port Moresby.

(*h*) *Land Capability Classes*

Land units have been put into eight capability classes based on the system of the United States Soil Conservation Service (Part IX), the classes being determined by specific hazards. Class I land has no limiting hazards, class II and class III lands are suitable for cultivation but require moderate and intensive measures respectively to maintain production, and class IV land is marginal for cultivation owing to major limiting factors. Class V and class VI lands are suitable for improved pastures, although with moderate limitations in class VI. Class VII land is restricted to native pastures, forests, or tree crops by severe limitations, whilst class VIII land is unsuited for commercial land use. Class I and class V lands do not occur on a land-unit scale in the survey area.

The coastal hill zone has mainly class VII land on hill slopes, with shallow and erodable soils, but the steepest, rockier sectors are class VIII land. The lowlands of this zone consist of class III land on upper foot slopes and on less stable interfluves, and class IV land where erodable, droughty, texture-contrast soils occur on gentle foot slopes and stable interfluves. The heavy dark cracking clays on valley flats and minor alluvial plains are class III land.

The upland zone has predominantly class VII and VIII lands, the latter occurring on steeper slopes and also on bouldery soils on agglomerate, but important albeit small areas of well-drained class II land occur on river terraces and also on undulating terrain on the Sogeri Plateau.

In its land classes, the foothill zone is intermediate between the coastal hill zone and the upland zone; the steep southern foothills are predominantly class VII and class VIII lands, but the central foothills also include class III and class IV lands in the lower western areas of plains and undulating terrain.

The drier parts of the fluvial plains zone are mainly class III land, with coastal areas of class IV land because of alkaline soils, but the lower parts, subject to frequent or seasonal flooding, are class VI land.

Most of the swamp zone is class VIII land because of waterlogging, but higher-lying areas subject only to seasonal or periodic flooding are regarded as class VI land.

In the littoral plains zone the sandy beach ridges consist of class IV lands, for they are droughty, saline, and infertile, and the tidal flats are class VIII land.

(*i*) *Photographs*

Plates 1–12 have been arranged in sequence to give a descriptive account of the survey area, arranged under the six main environmental zones from the coast inland, with examples of agriculture and settlements.

PART III. LAND SYSTEMS OF THE PORT MORESBY–KAIRUKU AREA

By J. A. Mabbutt,* P. C. Heyligers,* R. Pullen,* R. M. Scott,* and J. G. Speight*

I. Introduction

The area has been mapped into 49 land systems, which are composite mapping units defined by Christian and Stewart† as "an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation".

The land systems and their component land units are described in tabulated form, and the descriptions are illustrated with block diagrams and sketch plans, with land units numbered. The land systems are arranged in six groups representing the environmental zones briefly described in Part II, and each group of land systems is prefaced by a short description of the salient characteristics of the zone, illustrated by a typical aerial view, with a table setting out the diagnostic features of each land system. The order of the groups and of the land systems within each group is essentially based on geomorphic criteria and is that used on the land system map. Individual land systems can also be located by reference to the index.

The stated areas of land systems have been obtained by dot counts and are approximate only, and the relative areas of land units are based on independent estimates by team members on the following scale:

Very large	More than 50% of the total area
Large	30–50% of the total area
Moderate	15–30% of the total area
Small	5–15% of the total area
Very small	Less than 5% of the total area

Scales shown on block diagrams and sketch plans are relative only, and areas of land units may not be shown in true proportion. The geological sections on the block diagrams are generalized.

More detailed information about particular characteristics of the land systems can be obtained from Parts V–VIII and some reference is made in the land system descriptions to data given more fully in those parts of the report. For instance, the soils are described in groups and families treated more fully in Part VII and are numbered similarly. The vegetation is given in groups and types as described in Part VIII; in the land system descriptions the group is named first, followed by the name of the vegetation type in brackets.

Description of the soils of each land unit is followed by an assessment of land capability in terms of the hazards listed in Table 2, the land capability class of a land unit being determined by the highest individual hazard. Land capability classes are discussed more fully in Part IX.

* Division of Land Research and Regional Survey, CSIRO, Canberra, A.C.T.

† Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. CSIRO Aust. Land Res. Ser. No. 1.

TABLE 2

LAND CAPABILITY CLASSES*

Class	Limiting Factors							
	Erosion Hazard	Soil Moisture	Drainage	Flooding	Surface Stones	Fertility	Erodability	Alkalinity
I—Land suitable for cultivation; no limiting factors	e_1. Level or sloping at less than 1·5°; no hazard	so_1. Deep soils, not subject to drying out	d_1. Well drained	f_1. Not subject to flooding	st_1. No stones on surface	s_1. Apparently relatively fertile	w_1. Easily worked	a_1. No alkalinity hazard
II—Land suitable for cultivation; some limiting factors requiring moderate measures to maintain or reach optimum productivity	e_2. Slopes 1·5–5°; minor hazard when cultivated	so_2. Possible drying out of upper horizons of profile for short periods	d_2. Imperfectly drained		st_2. Surface stones cover 0·1–1% of land	s_2: Appears to have low fertility, either inherently or through leaching	w_2. Not easily worked	
III—Land suitable for cultivation; some limiting factors requiring intensive measures to maintain or reach optimum productivity	e_3. Slopes 5–9°; moderate hazard when cultivated		d_3. Poorly drained, easily improved	f_3. Subject to short seasonal flooding in most years	st_3. Surface stones cover 1–3% of land			a_3. Mild to moderate alkalinity
IV—Marginal lands for cultivation because of major limiting factors	e_4. Severe hazard when cultivated because of erodability of soil	so_4. Profile dries out for indefinite periods (climate, shallowness, or coarse texture)						a_4.Strong to very strong alkalinity

V—Land suitable for improved pastures			d_5. Poorly drained, not easily improved		st_5. Surface stones cover 3–15% of land			
VI—Land suitable for improved pastures but with moderate limitations	e_6. Slopes 9–17°; hazard moderate			f_6. Subject to frequent and irregular flooding or prolonged seasonal flooding	st_6. Surface stones cover 16–90% of land			
VII—Land with severe limitations restricting use to native pastures, forests, and tree crops	e_7. Slopes 17–33°; hazard severe		d_7. Slightly swampy					
VIII—Unsuitable for commercial land use	e_8. Slopes >33°; hazard very severe		d_8. Swampy	f_8. Frequent devastating floods or tidal inundation	st_8. Surface stones cover >90% of land			

*Under each land capability class the maximum permissible hazard is listed where applicable. Class I land has no hazards; elsewhere, the land capability class is determined by the highest hazard present.

II. Coastal Hill Zone (700 sq miles) (Fig. 3)

This zone is underlain by various sedimentary rocks, with ridges, mainly formed by limestone and cherty beds, more developed near the coast, and lowlands cut largely in mudstone on the inland side. It ranges from sea level to about 1400 ft, with relief mainly not exceeding 500 ft but locally attaining 1000 ft. Rainfall is mainly between 40 and 50 in. and streams are ephemeral. The main soils are shallow lithosols on hill slopes, texture-contrast soils and brown clay soils on lowlands,

Fig. 3.—North-west-trending parallel ridges and lowlands of the coastal hill zone north-east of Port Moresby. Relief approaches 800 ft in the west of the area shown.

and dark cracking clay soils on valley floors and minor alluvial plains. Much of the zone is covered with eucalypt savannah and derived grassland, with strongly deciduous forest or semi-deciduous thicket in gullies and on remote hills, and tall grassland and gallery forest in valleys and plains.

In Table 3 and in the tabulated descriptions which follow, the land systems of the coastal hill zone are arranged according to major land forms, namely ridges, lowlands, and minor alluvial plains, and are listed in order of decreasing relief.

TABLE 3

DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE COASTAL HILL ZONE

Land System	Lithology	Land Form	Relief	Predominant Soil	Predominant Vegetation
Ridges					
Tovobada	Cherty limestone	Strike ridges	Up to 800 ft	Alkaline dark lithosols	Strongly deciduous forest
Hanuabada					Savannah and derived grassland
Kopu	Mudstone, muddy tuff	Branching ridges and hills		Neutral brown lithosols	Savannah, semi-deciduous forest
Palipala	Coarse sandstone		Up to 500 ft	Alkaline dark lithosols	Savannah
Pokama	Limestone	Strike ridges	Up to 400 ft		Semi-deciduous thicket
Kabuka	Cherty mudstone		Up to 200 ft	Red lithosols	Savannah
Lowlands					
Fairfax	Limestone, conglomerate	Low plateaux and undulating terrain	Mainly < 100 ft	Neutral brown lithosols	Savannah and derived grassland
Diumana	Sandstone, siltstone, claystone, limestone	Undulating terrain	Mainly < 50 ft	Alkaline dark lithosols	Semi-deciduous thicket
Bomana Creek	Muddy tuff	Undulating, with minor hills and ridges		Brown clay soils	Savannah, tall grassland
Nikura	Sandy and muddy tuff, gabbro	Undulating terrain		Texture-contrast soils	Savannah, semi-deciduous thicket
Ward	Muddy tuff	Foot slopes	Mainly < 20 ft		Savannah
Ouou	Sandy limestone	Coastal platform			
Tsiria	Coral limestone	Raised reef		Dark cracking clay soils	Semi-deciduous thicket
Minor alluvial plains					
Boroko	Fine-textured alluvium	Plains	< 5 ft	Dark cracking clay soils	Savannah, tall grassland

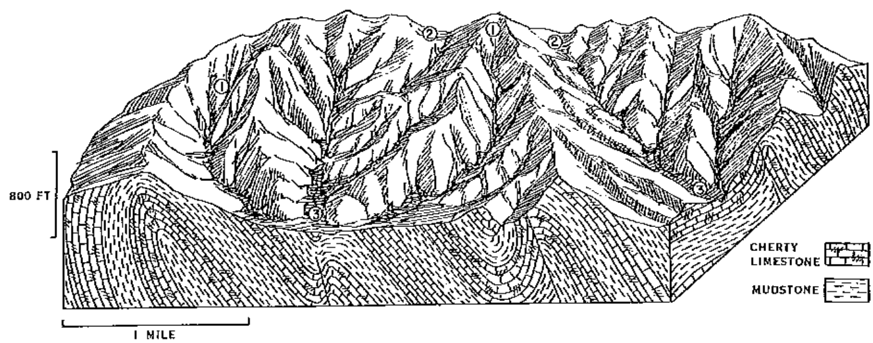
TOVOBADA LAND SYSTEM (20 SQ MILES)

High limestone ridges largely with deciduous forest, north of Port Moresby.

Geology.—Cherty limestone; thin-bedded and intercalated with mudstone; striking NW. with steep dips; Eocene (Port Moresby group).

Geomorphology.—A belt up to 5 miles wide, with strike ridges converging in prominent summits; relief up to 800 ft; strike drainage with close pinnate tributary systems; ephemeral streams except for a few larger channels; slumping common in steep valley heads formed in shale.

Altitude.—200–1250 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: fairly straight dip slopes, up to 35°, with chevron spurs; concave escarpments, dissected into short rounded spurs, exceeding 38° on heads and margins of valleys; many slump scars on slopes above 35°; undulating, narrowly rounded crests	Alkaline dark lithosols (8*a*)—VIII.e_8.st_8.so_4.a_1	Strongly deciduous forest (*Bombax–Celtis*); smaller tracts of savannah (*Themeda australis–Eucalyptus*), with derived grassland on crests and upper slopes
2	Very small	Perched valley floors and benches: hummocky slopes, 5–10° and up to 50 yd long; ill-defined drainage	Red gravelly clay soils: Nebire family (10*a*)—III–VI.e_{3-6}.so_2.a_3	
3	Small	Main valley floors: discontinuous, up to 100 yd wide, with cross slopes up to 0°30′ and longitudinal gradients about 2°; locally slightly terraced	Mainly gravel and sand —VI.so_4.st_6	Slightly deciduous forest (*Planchonia–Adenanthera*)

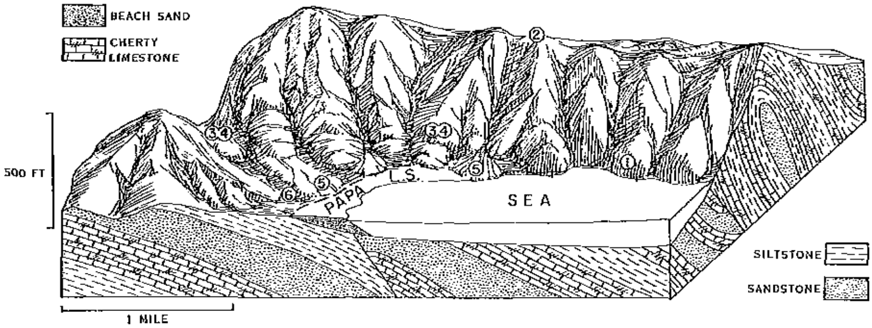
Hanuabada Land System (70 sq miles)

Limestone ridges with extensive grasslands, along the southern half of the coast.

Geology.—Thin-bedded limestone, siltstone, and sandstone, very cherty except in the north-west; striking NW. and dipping steeply NE.; Upper Cretaceous to Lower Miocene (including Bogora limestone, Barune sandstone, Port Moresby group, Boira limestone).

Geomorphology.—Coastal hill range up to 2 miles wide, relief up to 800 ft; coastal escarpment, commonly oversteepened and subject to slumping and rock falls, with fairly closely spaced, incised valleys and rounded salients; inland dip slopes with sparser, less incised drainage; locally with narrow coastal plain, elsewhere cliffed and embayed; ephemeral streams.

Altitude.—0–900 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	*Coastal cliffs: up to 200 ft high; slopes 35–60°,* with sheer faces	*Rock*	Bare *or with semi-deciduous thicket* (*Gyrocarpus–Harpullia, Garuga–Rhodomyrtus*)
2	Very large	Ridges: fairly straight slopes, 20–35° and 100–300 yd long; well-spaced, open gullies; narrowly rounded crests and summits	Alkaline dark lithosols (8*a*)—VII.e_7.st_6.so_4.a_3	Savannah or derived grassland (*Themeda australis–Eucalyptus*; in re-entrants and on some crests also *Themeda novoguineensis–Eucalyptus*); gullies with semi-deciduous thicket (*Gyrocarpus–Harpullia*) or strongly deciduous forest (*Bombax–Celtis*)
3	Very small	Foot slopes and spurs: smooth, concave or gently undulating slopes, attaining 15° and up to ½ mile long	Texture-contrast soils: Ouou family (12*a*), gravelly phase, and Ward family (12*b*), gravelly and non-gravelly phases—IV.e_4.so_4.w_2.d_3.a_3	Savannah or derived grassland (*Themeda australis–Eucalyptus* on spurs, *Ophiuros–Eucalyptus alba* on lower slopes, *Themeda novoguineensis–Eucalyptus* in re-entrants and on valley margins); patches of semi-deciduous thicket (*Gyrocarpus–Harpullia, Garuga–Rhodomyrtus*) or strongly deciduous forest (*Bombax–Terminalia*)
4	Very small		Mainly on upper foot slopes, brown clay soils: Fairfax family (11*a*)—III.e_3.so_2.a_3, and Bomana family (11*b*)—III.e_3.so_2. Locally, red gravelly clay soils: Nebire family (10*a*)—III–VI.e_{3-6}.so_2.a_3	
5	Small	Valley margins and fans: slopes 2–8°; up to 300 yd long on fans, <50 yd long in valleys	Dark cracking clay soils: Boroko family (7*a*)—III.d_3.a_3.w_2.so_3	
6	Very small	Drainage flats: up to 50 yd wide, slopes <1°; small, ill-defined channels	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.a_3.w_2.so_2	Tall grassland (*Saccharum spontaneum–Imperata*) or slightly deciduous forest (*Planchonia–Adenanthera*)

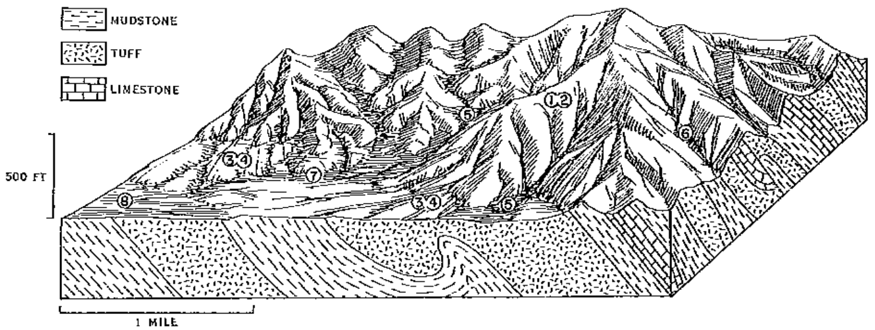
Kopu Land System (70 sq miles)

Short branching ridges with savannah or semi-deciduous thicket, in the south of the area.

Geology.—Thin-bedded mudstone and tuff, and intercalated, locally siliceous thin-bedded limestone; steeply dipping; Palaeogene (Port Moresby group). In the extreme south-east, dolerite and tuff with an included thick-bedded limestone member; dips apparently low; Miocene (Gidobada series).

Geomorphology.—Strike belt up to 3 miles wide, with close-branching ridges up to 800 ft high, and minor lowlands; moderately dense dendritic drainage with larger perennial streams; slumping common on steeper slopes.

Altitude.—0–1000 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	Ridges: mainly concave slopes, 10–30° and up to 500 yd long, commonly with straight upper sectors, 25–30°; generally deeply embayed, with rounded spurs 50–100 ft high and incised small gullies; narrowly to moderately rounded crests; slump scars on escarpment and valley-head slopes above 33°; generally stone-free	Neutral brown lithosols (8*b*)—$\mathrm{VII.e_7.so_4}$	Southern part: semi-deciduous thicket (*Garuga–Rhodomyrtus*) or slightly deciduous forest (*Intsia–Celtis*)
2	Large			Northern part: savannah (*Ophiuros–Eucalyptus alba*)
3	Small	Foot slopes: broad concave slopes, mainly 2–8° and up to 300 yd long; gently undulating in cross section, with cross slopes generally less than 2° and relief less than 10 ft	Northern part: red gravelly clay soils: Nebire family (10*a*)—$\mathrm{III.e_3.so_2.a_3}$; Bom family (10*b*)—$\mathrm{III.e_3.so_3}$. Locally, brown clay soils: Bomana family (11*b*)—$\mathrm{III.e_3.so_2}$	Semi-deciduous thicket (*Garuga–Rhodomyrtus*)
4	Small		Southern part: texture-contrast soils: Ward family (12*b*), gravelly phase—$\mathrm{IV.e_4.so_4.w_2.d_2.a_3}$; and Nikura family (12*c*), gravelly phase—$\mathrm{IV.e_4.so_4.w_2.d_2}$	Savannah (*Ophiuros–Eucalyptus alba*)
5	Very small	Tributary valley floors: up to 50 yd wide, gradients less than 5° and cross slopes about 2°; very small, ephemeral channels	Dark cracking clay soils: Boroko family (7*a*) in larger valleys and Inapi family (7*c*) in smaller valleys—$\mathrm{III.d_3.w_2.so_2.a_3}$	Savannah (*Ophiuros–Eucalyptus alba*) or semi-deciduous thicket (*Garuga–Rhodomyrtus*)
6	Very small	Margins and heads of larger valleys: concave slopes, mainly 2–5° and 50–100 yd long, locally attaining 200 yd	Brown clay soils: Fairfax family (11*a*)—$\mathrm{III.e_2.so_2.a_3}$	Savannah (*Ophiuros–Eucalyptus alba*) or tall grassland (*Saccharum spontaneum–Imperata*)
7	Very small	Larger valley flats: discontinuous and generally less than 50 yd wide, with slopes up to 2°; 10–20 ft above larger channels	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*)—$\mathrm{IV.d_2.f_3.a_4}$	Strongly deciduous forest (*Bombax–Terminalia*) or tall evergreen forest (*Casuarina–Dysoxylum*)
8	Very small	Alluvial plains: up to $1\frac{1}{2}$ miles wide, with slopes mainly less than 0°30′; numerous winding perennial streams, with channels up to 20 ft wide and 10 ft deep	Dark cracking clay soils: Boroko family (7*a*)—$\mathrm{III.d_3.w_2.so_2.a_3}$	Semi-deciduous thicket (*Garuga–Rhodomyrtus*)

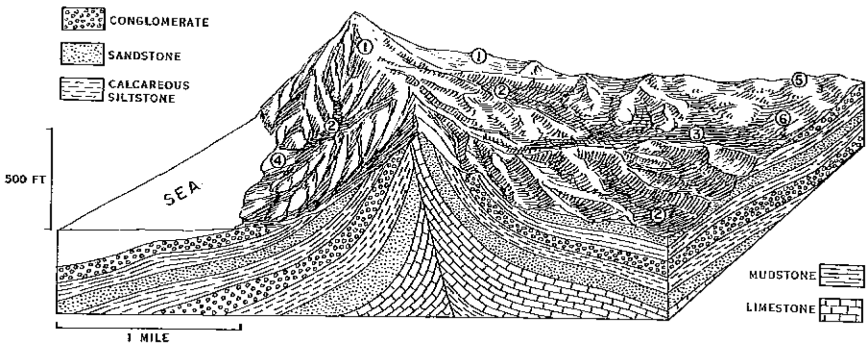
PALIPALA LAND SYSTEM (150 SQ MILES)

Savannah-covered coastal hills, in the north of the area.

Geology.—Thin-bedded brown to yellow gritty sandstone and conglomerate with subordinate sandy shale and calcareous siltstone of Pliocene age, locally underlain by 1200 ft of limestone and 600 ft of mudstone of Upper Miocene age; strike NW., dips gentle to moderate.

Geomorphology.—Hill belt, generally with higher crest and watershed near coast and long branching hill ridges descending inland; relief mainly less than 500 ft, with area of lower, rounded spurs in extreme south-east; close, dendritic pattern of rather straight-sided valleys with many shallow tributary re-entrants; mainly ephemeral streams.

Altitude.—0–800 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: slopes, concavo-convex and 10–25° on lower ridges, concave and attaining 35° on higher ridges, with shallow valley alcoves; locally incised valleys with amphitheatral valley heads; discontinuous coastal cliffs up to 150 ft high; narrowly rounded, undulating crests connecting in pyramidal summits	Alkaline dark lithosols (8*a*) on soft-weathering rock—$VII.e_7.so_4.a_3$	Savannah (*Themeda australis–Eucalyptus, Ophiuros–Eucalyptus alba, Imperata–Eucalyptus*); in re-entrants, semi-deciduous thicket (*Gyrocarpus–Harpullia*), strongly and slightly deciduous forest (*Bombax–Celtis, Garuga–Brachychiton,* and *Intsia–Celtis*)
2	Very small	Valley floors: up to 300 yd wide, axial gradients up to 10°, cross slopes mainly less than 2° but attaining 10°; mainly small channels	Dark cracking clay soils: Inapi family (7*c*)—$III.d_3.w_2.so_2.a_3$	Savannah (*Ophiuros–Eucalyptus alba, Ophiuros–Eucalyptus papuana*) or strongly deciduous forest (*Bombax–Terminalia*)
3	Small	Main valley plains: up to ½ mile wide, slopes mainly less than 1° but attaining 2° at margins and in upper parts; uneven axial tracts with mainly small, intermittent channels up to 20 ft wide and 6 ft deep		Tall evergreen forest (*Alstonia–Kleinhovia*)
4	Very small	Coastal fans: smooth, concave slopes up to 400 yd long, mainly 0°15′ to 2°30′, but attaining 5° at inner margin	Texture-contrast soils: Ward family (12*b*)—$IV.e_4.so_4.w_2.d_2.a_3$	Mid-height grassland (*Ophiuros–Imperata*)
5	Small	Low, rounded spurs: up to 100 ft high, crests up to 100 yd wide; straight or convex marginal slopes up to 20°; shallow valley alcoves	Neutral brown lithosols (8*b*) or red lithosols (8*c*)—$VII.e_7.st_6.so_4$	Savannah (*Ophiuros–Eucalyptus alba*) or semi-deciduous thicket (*Gyrocarpus–Harpullia*)
6	Very small	Foot slopes: below unit 5: concave slopes attaining 5° and up to 100 yd long	Texture-contrast soils: Nikura family (12*c*)—$IV.e_4.so_4.w_2.d_2$	

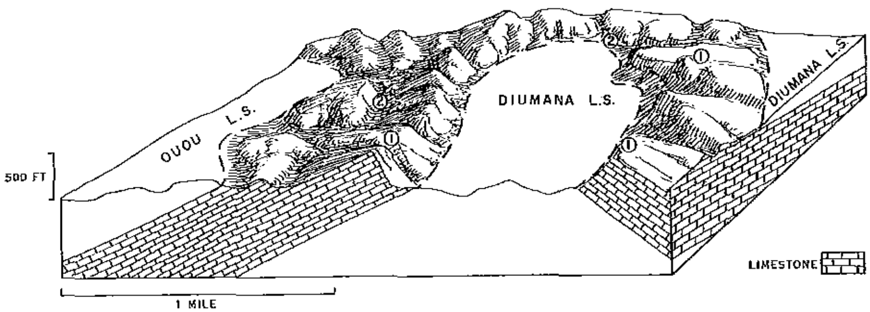
POKAMA LAND SYSTEM (25 SQ MILES)

Limestone ridges with savannah and semi-deciduous thicket, south-east of Kairuku.

Geology.—Thick-bedded, resistant crystalline and coralline limestone; NW. strike and moderate dips; Middle Miocene (Bokama limestone).

Geomorphology.—Cuestas and homoclinal ridges up to 400 ft high; fine-textured, trellis to dendritic drainage pattern of steep ephemeral streams.

Altitude.—0–500 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: straight dip slopes 15–25° and up to $\frac{1}{4}$ mile long; escarpment slopes 20–35°, with steeper rock faces; lower slopes broken into spurs with slopes up to 20° and up to 100 yd long	Alkaline dark lithosols (*8a*)—VII.e_7.st_6.so_3.a_3	Savannah (*Ophiuros–Timonius*), semi-deciduous thicket (*Gyrocarpus–Harpullia*), strongly and slightly deciduous forest (*Bombax–Celtis*, *Intsia–Celtis*)
2	Small	Foot slopes and valley floors: stony slopes, 2–5° and up to 200 yd long, as undulating spurs and as fans and valley flats associated with small streams	Stony slopes as unit 1. Valley flats, dark cracking clay soils: Inapi family (*7c*)—III.d_3.w_2.so_2.a_3	Savannah (*Ophiuros–Timonius*) and slightly deciduous forest (*Intsia–Celtis*)

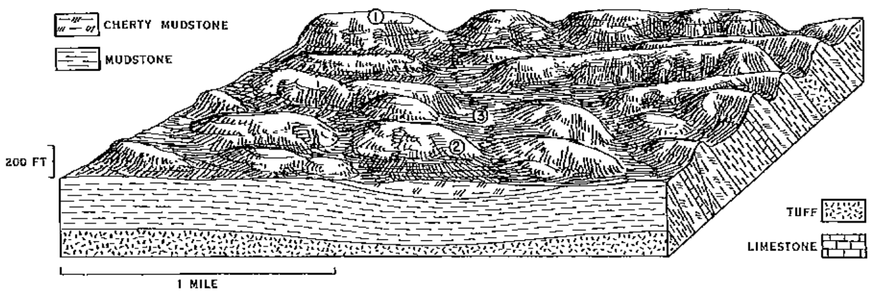
Kabuka Land System (30 sq miles)

Parallel low rounded ridges inland from Port Moresby, with red stony clay slopes.

Geology.—Cherty mudstone intercalated with soft mudstone, thin-bedded limestone, and dark tuff; strike NW., dips steep, Palaeogene (Port Moresby group). Thick mantles of weathered, shattered chert.

Geomorphology.—Strike belts up to 1 mile wide, with short parallel ridges, generally less than 1½ miles long and about ¼ mile apart; rounded outlines, with relief generally less than 200 ft; main drainage transverse, with small gullies and unchannelled sectors in strike valleys; ephemeral streams.

Altitude.—150–650 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Rounded ridges:** fairly straight slopes, 15–25° and mainly about 100 yd long, rarely up to 300 yd; lower parts locally dissected into spurs up to 50 ft high; valley embayments with steep, shallow heads, up to 32°; locally, prominent valley re-entrants with narrow floors	On main slopes and crests, red lithosols (8*c*)—VII.e_7.st_6.so_4. Valley heads and re-entrants, brown clay soils: Bomana family (11*b*)—III. e_3.so_2	Savannah (*Themeda australis–Eucalyptus*; *Ophiuros–Eucalyptus alba* in valley-head embayments)
2	Small	**Foot slopes:** concave, 3–8° and 100–600 yd long; even, or undulating with up to 20 ft of relief	On uppermost parts, red gravelly clay soils: Bom family (10*b*)—III–VI. e_{3-6}.so_2. On main foot slopes, texture-contrast soils: Nikura family (12*c*), gravelly phase—IV.e_4.so_4.w_2.d_2	Savannah (*Themeda australis–Eucalyptus*)
3	Very small	**Drainage floors:** up to 200 yd wide, slopes up to 5°; unchannelled or with small gullies	Dark cracking clay soils: Boroko family (7*a*)—III.d_3.so_2.w_2.a_3	Tall grassland (*Saccharum spontaneum–Imperata*) or slightly deciduous forest (*Planchonia–Adenanthera*)

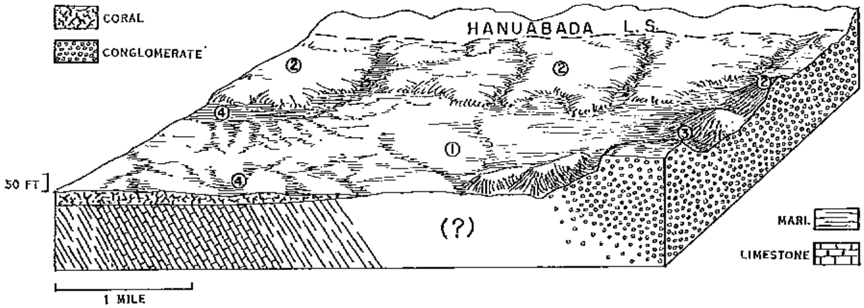
Fairfax Land System (25 sq miles)

Low savannah-covered plateaux and undulating grasslands, north-west of Port Moresby.

Geology.—In the south-west, thick-bedded, crystalline limestone and soft marl, with steep dips; in the north-east, coarse conglomerate of mixed rocks, generally intensely silicified; both of Neogene age (?Siro beds). Extensive coral rubble of Pleistocene age.

Geomorphology.—Raised marine plain dissected into low plateaux and undulating terrain, with relief mainly less than 100 ft; minor hill ridges up to 350 ft high in the north; sparse, slightly entrenched drainage in plateaux, closer dendritic pattern of shallow valleys in undulating terrain; ephemeral streams.

Altitude.—0–350 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Medium	**Gently undulating terrain**: relief up to 50 ft; concave lower slopes mainly less than 3° and up to ½ mile long, and gently rounded or flattish crests up to ¼ mile wide	Brown clay soils: Fairfax family (11*a*)—III. $e_2.so_2.a_3$. Near Papa village, red gravelly clay soils: Bom family (10*b*) —$II.e_2.so_2$	Savannah (*Themeda australis–Eucalyptus*); large areas of derived grassland
2	Large	**Low plateaux and hills**: in the south, moderately to strongly undulating surfaces, relief up to 50 ft, with short slopes mainly below 10° but attaining 20° on low hills and plateau margins; in the north, hills up to 350 ft high, with concave or irregular slopes mainly up to 30°, but with rocky and locally cliffed sectors exceeding 35°	Neutral brown lithosols (8*b*)—$VII.e_7.st_6.so_4$	Savannah (*Themeda australis–Eucalyptus*), with patches of semi-deciduous thicket (*Gyrocarpus–Harpullia, Adenanthera–Colona*)
3	Small	**Foot slopes**: smooth, concave slopes, mainly <5° and up to 200 yd long	Red gravelly clay soils: Bom family (10*b*)—$II.e_2.so_2$	
4	Small	**Drainage floors**: up to 100 yd wide, slopes mainly <0°30′ but attaining 2° at margins; partly unchannelled, mainly with small gullies, but locally with larger channels flanked by minor flood-plains	Dark cracking clay soils: Boroko family (7*a*)—$III.d_3.w_2.so_2.a_3$. Locally, on flood-plains, moderately well-drained alluvial soils: neutral olive silty clays (6*b*)—$III.d_2.f_3$	Savannah (*Themeda australis–Eucalyptus, Ophiuros–Eucalyptus alba*)

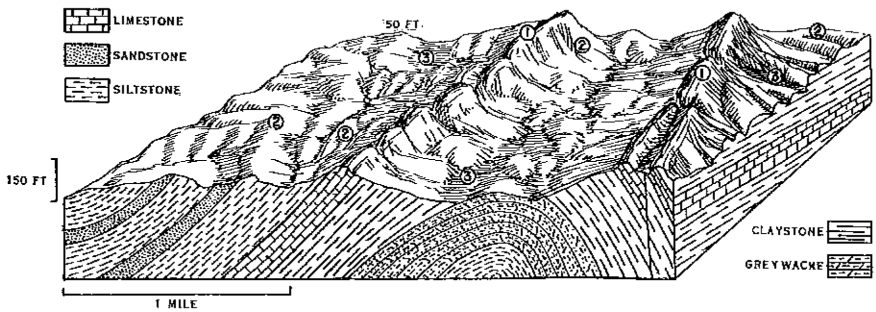
DIUMANA LAND SYSTEM (35 SQ MILES)

Strongly undulating lowlands with mainly shallow calcareous soils, south-east of Kairuku.

Geology.—Greywacke, claystone, and siltstone (Kaieu greywacke, Dumana greywacke); coral limestone, calcarenite, and chert (Bokama limestone); siltstone and sandstone (Vanuamai siltstone); all with NW. strike and moderate dips; Miocene.

Geomorphology.—Strike vales about 2 miles wide, strongly undulating and with 50 ft of relief, separated by narrow limestone ridges rising to 200 ft; fine-textured, incised dendritic drainage, with ephemeral or intermittent streams.

Altitude.—0–250 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**Ridges:** slopes 10–30° and up to 100 yd long; lower slopes dissected into widely spaced spurs; moderately rounded, rocky crests	Alkaline dark lithosols (8*a*)—VII.e_7.a_3	Semi-deciduous thicket (*Gyrocarpus–Harpullia*) and strongly or slightly deciduous forest (*Bombax–Celtis, Intsia–Celtis*), with minor savannah (*Ophiuros–Timonius, Imperata–Eucalyptus*)
2	Very large	**Low spurs and interfluves:** side slopes 5–20° and up to 200 yd long; moderately to broadly rounded crests, slopes 2–10°		Semi-deciduous thicket (*Eucalyptus–Acacia*) and savannah (*Themeda australis–Timonius, Ophiuros–Timonius, Imperata–Eucalyptus*)
3	Small	**Valley floors:** up to 100 yd wide; concave cross slopes, 2–5°, descending to small channels up to 25 ft wide; in lower parts, valley flats up to 200 yd wide, gradients less than 2°	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.w_2.so_2.a_3	Tall grassland (*Saccharum spontaneum–Imperata*), semi-deciduous thicket (*Adenanthera–Colona, Eucalyptus–Acacia*), and strongly and slightly deciduous forest (*Albizia–Maniltoa, Bombax–Terminalia, Intsia–Celtis*)

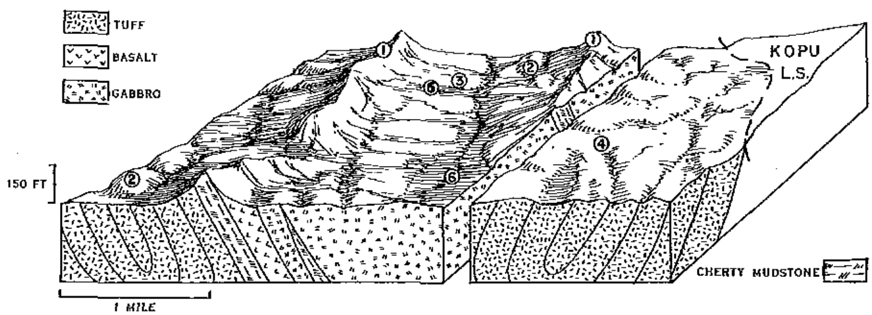
Bomana Creek Land System (40 sq miles)

Plains traversed by short rocky ridges, in the south half of the area.

Geology.—Unresistant green and dark tuffs (Dokuna tuff), basalt, and fine-grained gabbro, and resistant cherty mudstone (Port Moresby group), strike NW., steeply dipping; Palaeogene age.

Geomorphology.—Strike belt up to 4 miles wide, east of Port Moresby, with many parallel narrow ridges up to ½ mile long and 150 ft high, and vales and valley flats up to ½ mile wide with small areas of rounded low hills; branching intermont plains up to 1½ miles wide in the south of the area; moderately dense dendritic pattern of small ephemeral streams.

Altitude.—0–400 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**Ridges:** concave stony slopes, 10–30° and up to 200 yd long, locally dissected into rounded spurs up to 50 ft high; shallow gully-head embayments, with short slopes up to 35°, with small slump scars; narrow, rocky crests	Neutral brown lithosols (8*b*)—VII.$e_7.st_6.so_4$, or red lithosols (8*c*)—VII.$e_7.st_6.so_4$	Savannah (*Themeda australis–Eucalyptus*)
2	Medium	**Rounded hills and rises:** up to 50 ft high, with straight or convex marginal slopes up to 15°, and convex crest slopes, mainly 1–5° and up to 75 yd long	Brown clay soils: Fairfax family (11*a*)—III. $e_3.so_2.a_3$, locally passing into soft weathering gabbro	Savannah (*Themeda australis–Eucalyptus, Ophiuros–Eucalyptus alba*)
3	Medium	**Foot slopes:** concave, mainly 2–8° and up to 400 yd long; broadly undulating in cross section, as flattish-crested interfluves up to 15 ft high, with short marginal slopes mainly <5°, locally steepened to 15°	As in unit 2, and also Bomana family (11*b*) —II–III.$e_{2-3}.so_2$	
4	Medium	**Undulating plains:** up to 10 ft of relief, with slopes <5°; flattish-crested interfluves, and drainage floors up to 50 yd wide with very small drainage channels		Tall grassland (*Saccharum spontaneum–Imperata*) with patches of strongly deciduous forest (*Bombax–Terminalia*)
5	Very small	**Drainage floors:** up to 100 yd wide, gradients 1–5°, cross slopes mainly <2°; mostly with very small drainage channels, locally unchannelled	Dark cracking clay soils: Inapi family (7*c*) —III.$d_3.w_2.so_2.a_3$	Mid-height grassland (*Ophiuros–Imperata*) with remnants of slightly deciduous forest (*Planchonia–Adenanthera*) along channels
6	Very small	**Alluvial plains:** very gentle, even slopes up to 400 yd long	Dark cracking clay soils: Boroko family (7*a*)—III.$d_3.w_2.so_2.a_3$, or Jackson family (7*b*) —III.$d_3.w_2.so_2$	

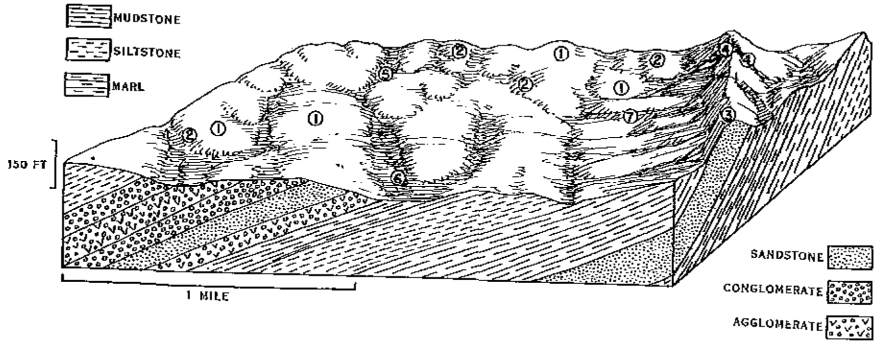
Nikura Land System (140 sq miles)

Broadly undulating lowlands with texture-contrast soils, south-east from Kairuku.

Geology.—South of Brown River: eastern part, dolerite and fine-grained gabbro intruding altered sediments of Palaeogene age (Port Moresby group); western part, argillaceous tuff, presumed strike NW., dipping steeply and of Palaeogene age (Dokuna tuff). North of Galley Reach: well-bedded rocks including mudstone, siltstone, marl, sandstone, quartzose conglomerate, and andesitic conglomerate and agglomerate, volcanic component increasing to NE.; gently dipping; Pliocene (Kaufana beds). Local ferruginous duricrust.

Geomorphology.—Broadly undulating strike lowlands with 10–50 ft of relief, locally with short strike ridges up to 150 ft high; open, branching drainage pattern, shallowly incised in lower parts and with small valley plains in lowermost sectors; mainly ephemeral streams.

Altitude.—0–250 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	**Relatively stable interfluves:** flat or gently undulating crests, including gentle valley-head slopes; slopes mainly below 3°, locally attaining 5°, and up to 400 yd long; locally, dissected foot slopes up to 1 mile long	Texture-contrast soils: Ward family (12*b*), gravelly and non-gravelly phases—IV.e_4.so_4.w_2.d_2.a_3, Nikura family (12*c*), Laloki family (12*d*)—IV.e_4.so_4.w_2.d_2	Savannah (*Themeda australis–Eucalyptus, Ophiuros–Eucalyptus alba, Themeda novoguineensis–Eucalyptus, Imperata–Eucalyptus*); semi-deciduous thicket (*Eucalyptus–Acacia*) particularly extensive north of Hisiu; minor strongly and slightly deciduous forest (*Bombax–Celtis, Garuga–Brachychiton*)
2	Medium	**Stripped interfluves:** marginal slopes of unit 1, up to 200 yd long, generally about 5° but commonly stepped, with short bouldery sectors up to 10°; also, more strongly undulating crests, narrower and higher than in unit 1, locally with cappings of ferruginous duricrust	Neutral brown lithosols (8*b*)—VI.e_3.st_6.so_4	Savannah as in unit 1, or semi-deciduous thicket (*Gyrocarpus–Harpullia, Adenanthera–Colona, Eucalyptus–Acacia*)
3	Very small	**Low ridges:** up to 150 ft high, with irregular slopes up to 400 yd long, locally attaining 20°; narrowly rounded crests		Savannah (*Themeda australis–Eucalyptus, Imperata–Eucalyptus*)
4	Very small	**Incised valleys in unit 3:** V-shaped and incised 25–35 ft; slopes up to 30°		Semi-deciduous thicket (*Adenanthera–Colona*) and strongly deciduous forest (*Bombax–Celtis, Albizia–Maniltoa*)
5	Small	**Tributary valley floors:** gradients mainly 0°30′ to 2°, concave side slopes up to 4° and up to 50 yd long; upper sectors may be unchannelled, with hummocky floors; lower parts have winding ephemeral channels up to 15 ft wide and irregularly incised up to 10 ft	Texture-contrast soils: Ouou family (12*a*)—IV.e_4.so_2.w_2.d_2.a_3, and Laloki family (12*d*), gravelly phase—IV.e_4.so_4.w_2.d_2	Savannah (*Ophiuros–Eucalyptus alba, Themeda novoguineensis–Eucalyptus*) and slightly deciduous forest (*Garuga–Brachychiton*); or as unit 4
6	Small	**Larger river flats:** up to ½ mile wide, slopes less than 0°30′; commonly with levees, and locally with ill-drained back-plain depressions; ephemeral channels up to 50 ft wide and 15 ft deep, with permanent water-holes	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.w_2.so_2.a_3	Tall evergreen forest (*Alstonia–Kleinhovia*, minor *Octomeles–Artocarpus*)
7	Very small	**Drainage floors in foot slopes:** up to 100 yd wide, axial gradients and cross slopes up to 3°; small ephemeral channels	Dark cracking clay soils: Jackson family (7*b*)—III.d_3.w_2.so_2	Savannah (*Themeda novoguineensis–Eucalyptus*)

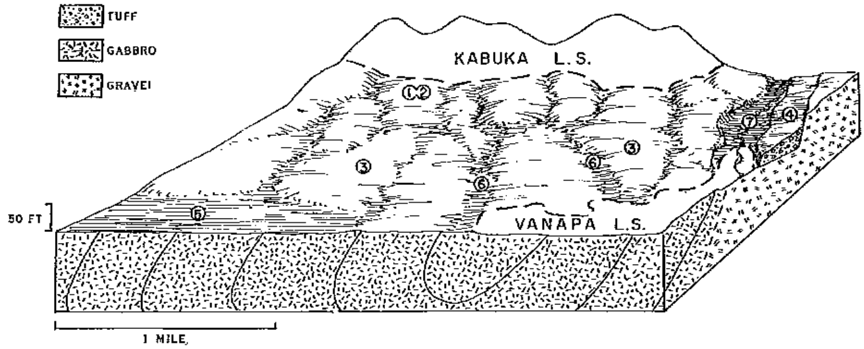
Ward Land System (40 sq miles)

Savannah-covered plains sloping from low ridges, north-east of Port Moresby.

Geology.—Uniform fine-grained tuff, apparently steeply dipping (Dokuna tuff); fine-grained gabbro intruding Port Moresby group; all of Palaeogene age; locally, terrace gravel and cherty colluvium of Quaternary age.

Geomorphology.—Piedmont plains up to 2 miles wide, and terraces 20 and 45 ft above the Laloki River; moderately sparse, parallel transverse drainage, commonly becoming ill defined in the lower plains; ephemeral or intermittent streams.

Altitude.—0–200 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	Upper foot slopes: broadly undulating slopes, 3–10° and up to 400 yd long, including rounded spurs up to 50 ft and isolated rocky hills up to 100 ft high	On steeper slopes, neutral brown lithosols (8*b*)—VII.e_7.st_4.so_4	Savannah (*Themeda novoguineensis–Eucalyptus*)
2	Very small		On gentler slopes, brown clay soils: Fairfax family (11*a*)—III.e_3.so_2.a_3, or Bomana family (11*b*)—III.e_3.so_2; minor Bom family (10*b*)—III.e_3.so_2	Savannah (*Ophiuros–Eucalyptus alba*)
3	Very large	Lower foot slopes: very broad, concave slopes, 0°30′–3° and up to 1 mile long	Texture-contrast soils: gravelly and non-gravelly phases of Ward family (12*b*)—IV.e_4.so_4.w_2.d_2.a_3, Nikura family (12*c*), and Laloki family (12*d*)—IV.e_4.so_4.w_2.d_2	Savannah (*Themeda australis–Eucalyptus*)
4	Very small	River terraces: undulating, channelled surfaces up to ¼ mile wide, with local slopes up to 3°, short, stony marginal slopes up to 10°	Terrace surfaces as unit 3. Marginal slopes, red gravelly clay soils: Bom family (10*b*)—III.e_3.so_2	Savannah (*Themeda australis–Eucalyptus*, *Ophiuros–Eucalyptus alba*)
5	Medium	Plains: slopes in extension of unit 3, 0°15′–0°45′ and up to ½ mile long	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.so_2.w_2.a_3	Savannah (*Ophiuros–Eucalyptus alba*) or semi-deciduous thicket (*Eucalyptus–Acacia*)
6	Small	Drainage floors: shallow depressions up to 200 yd wide, axial slopes up to 2°	Dark cracking clay soils: Boroko family (7*a*)—III.d_3.w_2.so_2.a_3, and Jackson family (7*b*)—III.d_3.w_2.so_2	In upper sectors, savannah as in unit 4. In lower sectors, mid-height and tall grassland (*Ophiuros–Imperata*, *Saccharum spontaneum–Imperata*). Slightly deciduous forest (*Planchonia–Adenanthera*) along channels
7	Very small	Laloki River channel and flats: steep-sided channel 20 ft deep, 200 ft wide at bank level narrowing to 100 ft at low-water level; discontinuous riparian flats up to 50 yd wide, with perched flood channels	On river flats, moderately well-drained alluvial soils: neutral olive stratified soils (6*d*)—III.d_2.f_3	On flats, tall grassland (*Saccharum spontaneum–Imperata*). On banks, tall evergreen forest (*Octomeles–Artocarpus*)

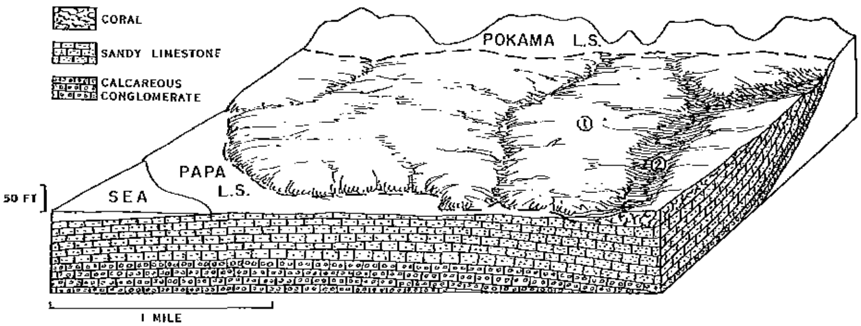
Ouou Land System (5 sq miles)

Narrow plain along the coast south of Kairuku.

Geology.—Silty and sandy limestone, calcareous grit, and calcareous quartz-pebble conglomerate; strike NW., dips moderate; Middle Miocene; overlain in places by Pleistocene reef coral.

Geomorphology.—Slightly dissected coastal platform less than 1 mile wide; relief mainly less than 30 ft; shallowly entrenched, transverse valleys with many short tributaries; streams ephemeral or intermittent.

Altitude.—0–100 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Foot slopes:** concave, 0°30′ to 4° and up to $\frac{3}{4}$ mile long; generally dissected to 15 ft, locally to 30 ft into mainly flattish-crested spurs up to $\frac{1}{2}$ mile wide, cross slopes $<1°$; minor uneven, locally rocky crests; short marginal slopes with shallow gully re-entrants, mainly $<5°$ but steepening to 10° on coastal margin and in more strongly dissected areas	Texture-contrast soils: gravelly and non-gravelly phases of Ouou family (12*a*), Ward family (12*b*)—IV.e_4.so_1.w_2.d_2.a_3, and Laloki family (12*d*)—IV.e_4.so_1. w_2.d_2	Savannah (*Themeda australis–Eucalyptus*, *Themeda australis–Timonius*, *Imperata–Eucalyptus*); remnants of semi-deciduous thicket (*Eucalyptus–Acacia*)
2	Small	**Drainage floors:** gently sloping, up to 50 yd wide, with small gullies, tributary to larger valley flats up to $\frac{1}{4}$ mile wide, slopes generally less than 0°30′, with winding channels up to 15 ft wide and 10 ft deep; locally these open into small coastal alluvial plains	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.w_2.so_2.a_3	Evergreen thicket (*Hibiscus–Flagellaria*), strongly deciduous forest (*Bombax–Terminalia*), and tall evergreen forest (*Alstonia–Kleinhovia*); fringing tall grassland (*Saccharum spontaneum–Imperata*)

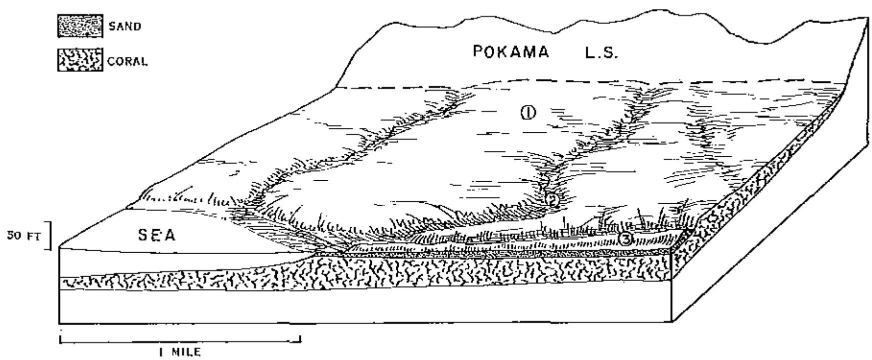
Tsiria Land System (5 sq miles)

Narrow coastal platforms on Yule Island and west of Hisiu.

Geology.—Coral limestone; Pleistocene.

Geomorphology.—Raised coral reef platform up to 2 miles wide, between 10 and 50 ft above sea level; commonly with outer sand beach; featureless surface traversed by a few incised narrow valleys without tributaries and with small intermittently flowing channels.

Altitude.—0–50 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Reef platform:** rising inland at 0°15′–1°30′, increasing to near 3° near inner margin; locally uneven, with up to 5 ft of local relief and with short slopes up to 2°; seaward bluff and incised valley margins 10–20 ft high, slopes 5–10°	Mainly dark cracking clay soils: Boroko family (*7a*)—III.d_3.w_2.so_2.a_3. Small areas of alkaline reddish clay soils: Obu family (13)—IV.so_4	Semi-deciduous thicket (*Eucalyptus–Acacia*) and strongly or slightly deciduous forest (*Bombax–Terminalia, Intsia–Celtis*); patches of tall grassland (*Saccharum spontaneum–Imperata*)
2	Very small	**Valley flats:** mainly up to 100 yd wide, opening into coastal flats up to 200 yd wide; irregular small channels	Dark cracking clay soils: Inapi family (*7c*)—III.d_3.w_2.so_2.a_3	Strongly deciduous forest (*Albizia–Maniltoa*)
3	Very small	**Beach:** tidal reef flat; sand beach up to 50 yd wide, mainly below 2° and steepening to 5° below discontinuous hummocky foredune up to 10 ft high; commonly backed by sand swale up to 50 yd wide	Beach soils: on foredune, grey fine sands (1*a*)—IV.so_4.s_2.a_4; on beach, grey sands (1*c*)—VIII.d_8.f_8.a_4	Above high-water mark: mixed herbaceous vegetation (*Spinifex–Canavalia*) and scrub (*Premna–Scaevola*)

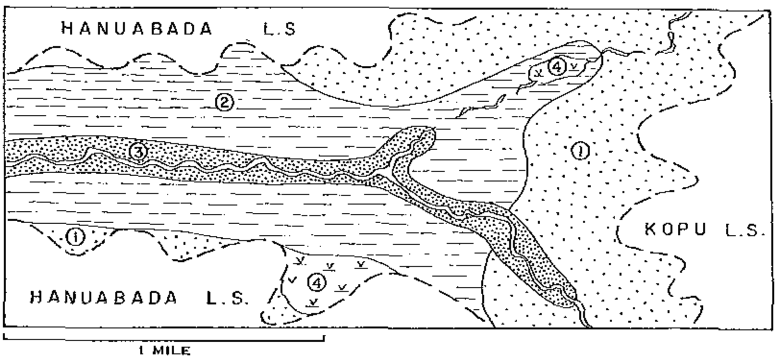
Boroko Land System (30 sq miles)

Small plains with dark cracking clay soils, near the coast in the south of the area.

Geology.—Fine-textured alluvium; Quaternary.

Geomorphology.—Alluvial plains up to 1½ miles wide, occurring as branching valley tracts, gradients 1 : 100 to 1 : 500, in the south of the area, and as strike vales and locally as a narrow coastal plain near Port Moresby; perennial channels in main valleys, but ill-defined or impeded drainage elsewhere.

Altitude.—0–200 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	**Higher plains**: slopes mainly less than 0°30′, but attaining 5° at gently undulating margins; extending up to ¾ mile from drainage lines	Dark cracking clay soils: Boroko family (*7a*)—III.d_3.w_2.so_2.a_3, or Jackson family (*7b*)—III.d_3.w_2.so_3	Savannah (*Themeda australis–Eucalyptus*, *Ophiuros–Eucalyptus alba*); extensive derived grasslands north-west of Port Moresby
2	Large	**Lower plains**: slopes less than 2°, otherwise as unit *1*; subject to impeded drainage	Dark cracking clay soils: Inapi family (*7c*)—III.d_3.w_2.so_2.a_3	Tall grassland (*Saccharum spontaneum–Imperata*) and slightly deciduous forest (*Planchonia–Adenanthera*)
3	Medium	**Flood-plains**: mainly about 50 yd wide, locally attaining 300 yd; meandering channels up to 40 ft wide and 15 ft deep	Moderately well-drained alluvial soils: alkaline olive silty clays (*6a*)—IV.d_2.f_3.a_4, or neutral olive silty clays (*6b*)—III.d_2.f_3	Tall evergreen forest (*Octomeles–Artocarpus*); tall grassland (*Saccharum spontaneum–Imperata*, *Phragmites–Saccharum robustum*)
4	Very small	**Swamps**: up to 300 yd in extent	Very poorly drained alluvial soils: grey sticky clays (*4a*)—VIII.d_8	Open water with patches of mixed herbaceous vegetation (*Nymphaea–Azolla*); bordered by tall grassland (*Phragmites–Saccharum robustum*) and patches of mid-height evergreen forest (*Melaleuca–Nauclea*)

III. Foothill Zone (350 sq miles) (Fig. 4)

This zone is transitional between lowlands and uplands, with rainfall increasing eastwards from 50 to 100 in. The central foothills range from plains to broad ridges, with acid red to brown clay soils and minor lithosols on gently dipping volcanic

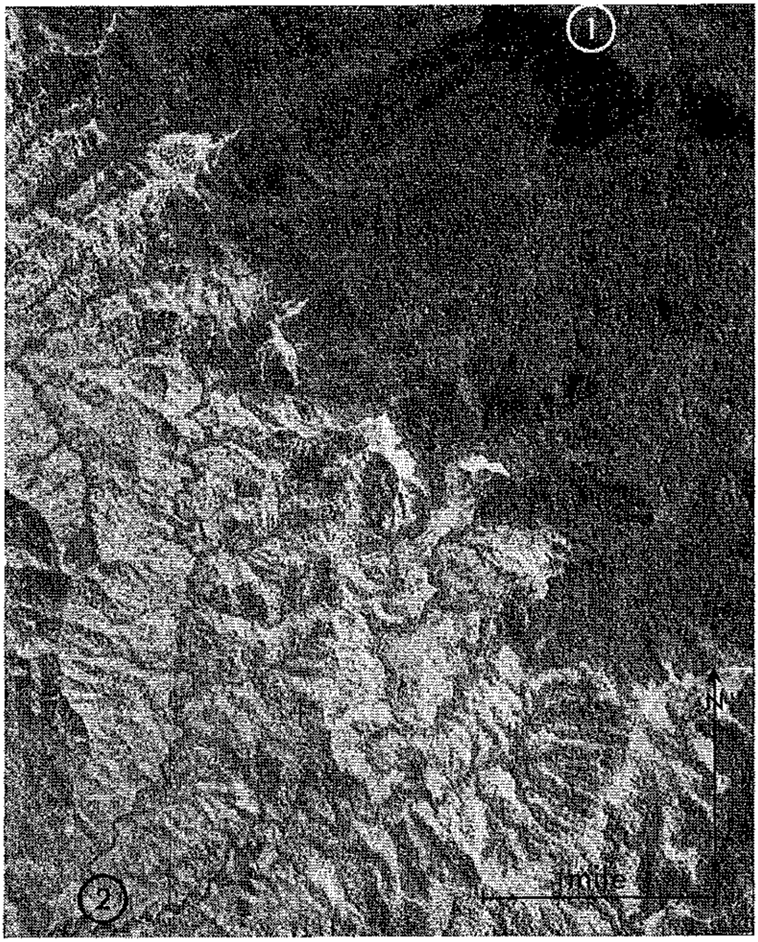


Fig. 4.—The southern foothills here extend between the Sogeri Plateau, above the escarpment of the Astrolabe Range (1), and the plains of the coastal hill zone (2). The contrast between a mainly savannah-covered western part and a forested eastern part is very marked.

rocks; they lie between sea level and 700 ft, with up to 500 ft of relief. The southern foothills are hills and narrow ridges, mainly of gabbro with neutral brown lithosols, with altitudes between 200 and 3500 ft and relief mainly up to 800 ft but including the prominent escarpment of the Astrolabe Range. The lower, drier western parts of the zone are covered with savannah and strongly deciduous forest, and the higher, wetter eastern parts have extensive slightly deciduous forest.

In Table 4 and in the tabulated descriptions which follow, the land systems of the central foothills precede those of the southern foothills.

TABLE 4

DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE FOOTHILL ZONE

Land System	Lithology	Land Form	Relief	Predominant Soil	Predominant Vegetation
Central foothills					
Aropokina	Sandy tuff and volcanic conglomerate	Strike ridges	Up to 500 ft	Lithosols and acid red to brown clay soils	Savannah and deciduous forest
Diulu		Undulating terrain with minor ridges	Up to 100 ft	Acid red to brown clay soils	
Kanosia		Undulating terrain and plains	Up to 50 ft	As above, and texture-contrast soils	As above, but extensively planted to rubber
Southern foothills					
Rouna	Gabbro, partly capped with agglomerate	Branching ridges and an escarpment	Up to 2000 ft	Neutral brown lithosols	Slightly deciduous forest
Dubuna	Gabbro and minor limestone	Branching ridges	Up to 1400 ft		Savannah
Edebu	Muddy tuff		Up to 500 ft		Slightly deciduous forest and semi-deciduous thicket

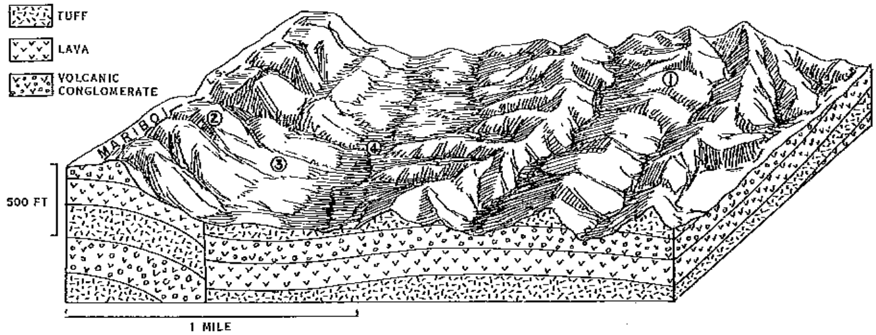
Aropokina Land System (35 sq miles)

Higher foothill ridges east of Hall Sound.

Geology.—Calcareous sandy tuff, volcanic conglomerate, agglomerate, lava and other basic volcanic rocks; gently folded and faulted along NW. axes; Pliocene.

Geomorphology.—Strike belt up to 4 miles wide, with prominent west-facing escarpments broken into hill ridges; strike-controlled main valleys with restricted lowlands, and a pinnate pattern of incised tributaries, denser in the west; relief up to 500 ft; slumping on steepened slopes; ephemeral tributary streams, perennial main streams.

Altitude.—0–700 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	Ridges: concave escarpments, mainly attaining 20–30° but exceeding 35° locally in valley heads and margins, where small rock faces and slump scars occur; deeply incised gullies in middle parts; also, fairly straight structurally controlled slopes, generally not exceeding 25°; crests mainly narrowly rounded, with minor crest and upland valley slopes below 10° and up to 100 yd long	Western part: Neutral brown lithosols (8*b*)—$\mathrm{VII.e_7.st_6.so_4}$	Savannah (*Themeda australis–Eucalyptus*) and strongly deciduous forest (*Bombax–Celtis*)
2	Large		Eastern part: On steeper slopes on agglomerates, acid brown lithosols (8*d*)—$\mathrm{VII.e_7.st_6}$. On gentler slopes elsewhere, acid red to brown clay soils: Diulu family (9*a*)—$\mathrm{III.e_3.so_2}$	Savannah (*Themeda novoguineensis–Eucalyptus*) and slightly deciduous forest (*Garuga–Brachychiton*, *Albizia–Canarium*)
3	Very small	Foot slopes: concave stony slopes, 2–10° and up to 300 yd long; minor gullies	On drier sites on volcanic conglomerate in west of land system, texture-contrast soils: Laloki family (12*d*)—$\mathrm{IV.e_4.so_4.w_2.d_2}$. On wetter sites on agglomerate in east of land system, acid red to brown clay soils: Koitaki family (9*e*)—$\mathrm{II.e_2.s_2}$	Savannah (*Ophiuros–Eucalyptus alba*) or slightly deciduous forest (*Garuga–Brachychiton*)
4	Very small	Valley plains: up to 200 yd wide, slopes less than 2° and mainly below 0°30′; upper sectors with small channels, lower parts with ill-defined drainage	Texture-contrast soils: Laloki family (12*d*)—$\mathrm{IV.e_4.so_4.w_2.d_2}$. Imperfectly drained alluvial soils: acid brown clays (5*g*)—$\mathrm{VI.d_3.f_6}$	Slightly deciduous forest (*Spondias–Celtis*); savannah (*Ophiuros–Eucalyptus papuana*)

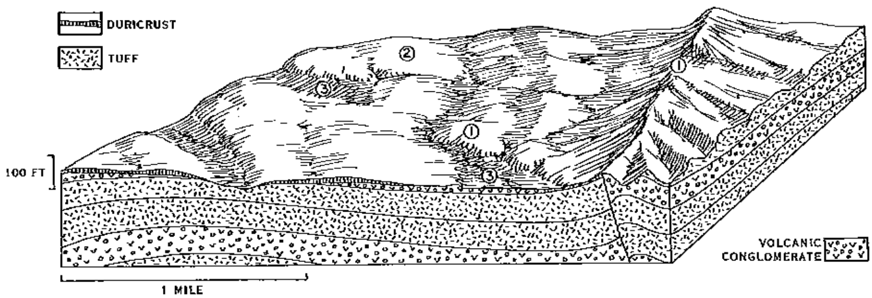
DIULU LAND SYSTEM (35 SQ MILES)

Undulating or low hilly tract with reddish soils, extending north-west from Galley Reach.

Geology.—Tuff interbedded with volcanic conglomerate, mainly of basic lava; gently folded and faulted on NW. axes; Pliocene. Pleistocene ferruginous duricrust locally.

Geomorphology.—Gently undulating terrain broken by low ridges and commonly fringed by low escarpments, in a discontinuous strike belt up to 3 miles wide; relief up to 100 ft; sparse, shallow upland valleys, with close tributary gullies on steeper slopes, and minor fringing valley plains; streams mainly ephemeral.

Altitude.—0–200 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**Hill ridges and escarpments**: straight or convex slopes, mainly up to 15° but locally up to 25°, and up to 200 yd long; rounded stony crests	Acid brown lithosols (8*d*)—$VI.e_6.st_6$	Savannah (*Themeda australis–Eucalyptus*)
2	Very large	**Undulating terrain**: flattish crests, and concave valley-side slopes 3–10° and up to ½ mile long, leading to small drainage channels	Acid red to brown clay soils: Diulu family (9*a*)—$III.e_3.so_2$	Savannah (*Themeda australis–Eucalyptus*, *Ophiuros–Eucalyptus alba*) and strongly deciduous forest (*Bombax–Terminalia*)
3	Small	**Alluvial plains**: up to ½ mile wide, slopes less than 1°; partly ill-drained, but generally with meandering small channels	Imperfectly drained alluvial soils, including acid brown clays (5*g*)—$VI.d_3.f_6$	Slightly deciduous forest (*Spondias–Celtis*)

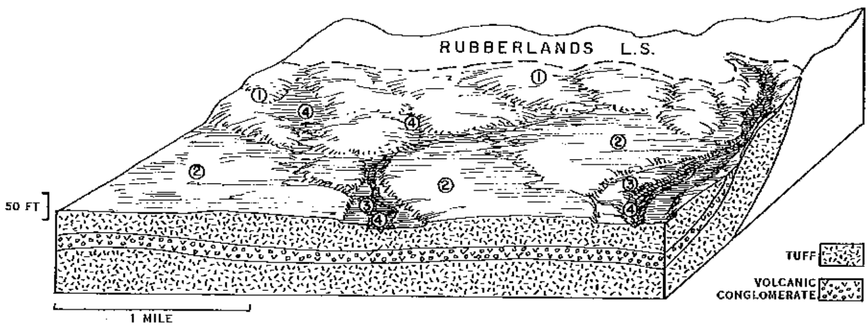
KANOSIA LAND SYSTEM (20 SQ MILES)

Plains and undulating country extensively under rubber at the head of Galley Reach.

Geology.—Sandy and argillaceous tuff (calcareous in part), volcanic conglomerate, agglomerate, lava and other basic volcanic rocks; gently folded and faulted along NW. axes; Pliocene.

Geomorphology.—An erosional plain 25–50 ft above sea level, with abrupt seaward margin, continued inland as undulating terrain to foot of backing hills; 25–50 ft of relief; a few entrenched small winding rivers, with close, branching tributary valleys in higher part; main streams perennial, minor streams intermittent.

Altitude.—0–100 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	Undulating terrain: convex slopes, locally bouldery, mainly less than 5° and up to 100 yd long, commonly steepened basally to 10°; somewhat gullied margins of unit 2, with stony slopes, 5–15°	Acid red to brown clay soils: Sogeri family (9*b*)—III.e_3	Under rubber; original vegetation presumably slightly deciduous forest (*Albizia–Canarium*)
2	Large	Plains: less than 5 ft of relief, with long slopes less than 1°; locally with very shallow, unchannelled drainage depressions about 50 yd wide	Texture-contrast soils: Nikura family (12*c*), Laloki family (12*d*)—IV.e_4.w_2.d_3, and brown clay soils: Bomana family (11*b*)—II.e_2	Savannah (*Themeda novoguineensis–Eucalyptus*), semi-deciduous thicket (*Eucalyptus–Acacia*), and strongly deciduous forest (*Bombax–Terminalia*)
3	Small	Alluvial terraces: 10–15 ft above river level; discontinuous, up to 200 yd wide, with cross slopes less than 1°	Acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	Slightly deciduous forest (*Planchonia–Adenanthera*) and tall grassland (*Saccharum spontaneum–Imperata*)
4	Small	Valley floors and flood-plains: discontinuous minor valley floors less than 50 yd wide, with slopes mainly less than 0°30′; commonly ill-drained, with sluggish winding small channels; slightly uneven flood-plains up to 100 yd wide, about 5 ft above larger channels, up to 30 ft wide and 10 ft deep	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6	

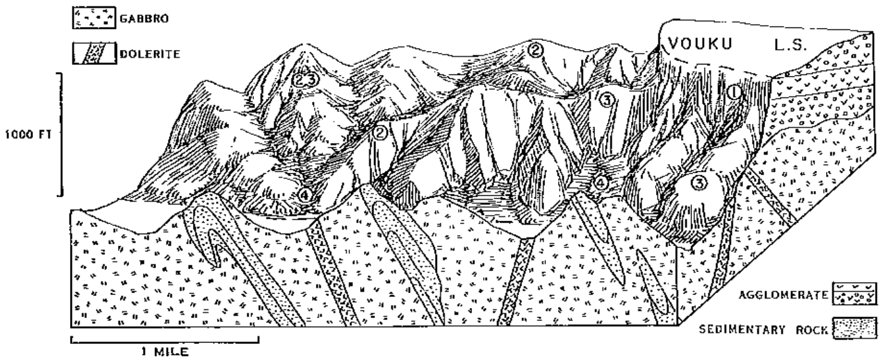
ROUNA LAND SYSTEM (120 SQ MILES)

Mainly forested higher ridges in a belt south-east from the Vanapa River, including the Astrolabe Range escarpment.

Geology.—Fine-grained gabbro and dolerite and remnants of the intruded sediments, including tuff, marl, and limestone which probably dip steeply and strike NW. and are of Eocene age (Port Moresby group); overlain by Pliocene andesitic agglomerate and locally by Miocene conglomerate (Siro beds).

Geomorphology.—Escarpment of the Sogeri Plateau, mainly up to 2000 ft high, continued NW. and SE. as a strike zone, 2–4 miles wide, of parallel massive ridges up to 800 ft high; trellis drainage of moderate density including several large through-going rivers; rock falls common on escarpment, slumping active on steep slopes; larger streams perennial.

Altitude.—200–3500 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Rock faces:** mainly up to 200 ft high, with irregular, stepped slopes 50–90° and widely spaced joint clefts; with narrow re-entrants at valley heads	Rock	Bare or with some rock plants; in re-entrants, tall evergreen forest (*Casuarina–Dysoxylum*)
2	Very large	**Ridges and spurs:** fairly straight slopes commonly up to 35° and up to ½ mile long; widely spaced major spurs and more numerous weakly developed foothill spurs, and prominent gullies with head slopes attaining 40° and incised lower parts; locally with a bench up to ⅓ mile wide, with irregular rocky slopes 5–15°; commonly mantled with fallen agglomerate blocks	Neutral brown lithosols (8*b*)—VII.e_7.st_8.so_3	Slightly deciduous forest (*Albizia–Canarium*)
3	Medium			On north-west escarpment of Sogeri Plateau, savannah (*Ophiuros–Eucalyptus tereticornis*); some valleys with slightly deciduous forest (*Albizia–Canarium*)
4	Very small	**Valley floors:** discontinuous and narrow, with incised stream channels	Imperfectly drained alluvial soils: acid brown clays (5g)—VI.d_3.f_6	Savannah (*Themeda novoguineensis–Eucalyptus*) or tall evergreen forest (*Casuarina–Dysoxylum*)

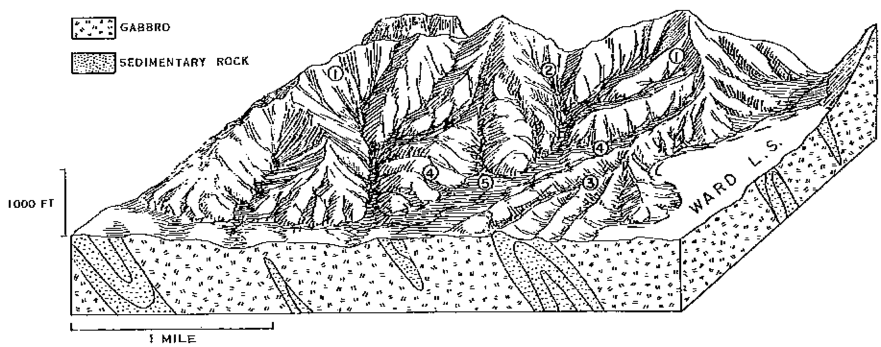
DUBUNA LAND SYSTEM (110 SQ MILES)

Mainly savannah-covered ridges, west of the Sogeri Plateau.

Geology.—Fine-grained gabbro and dolerite; remnants of the intruded sediments, including tuff, marl, and indurated metamorphosed limestone; steeply dipping, strike NW.; Palaeogene (Port Moresby group).

Geomorphology.—Irregular short ridges up to 900 ft high, with prominent spurs, and minor strike ridges up to 1400 ft high, with limestone escarpments; dense dendritic drainage with very close parallel primary gullies; only larger streams perennial; slumping fairly active.

Altitude.—0–1500 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: concave slopes, mainly 10–35° and up to ½ mile long, broken into parallel ridges and gullies and commonly slumped in upper parts; minor rocky escarpments; colluvial aprons in wetter parts; narrow ridge crests	Neutral brown lithosols (8*b*)—VII.e_7.st_6.so_4	Savannah (*Themeda australis–Eucalyptus, Themeda novoguineensis–Eucalyptus*) and patches of semi-deciduous thicket (*Eucalyptus–Acacia*); minor areas of slightly deciduous forest (*Garuga–Brachychiton, Albizia–Canarium*), mainly on higher ridges
2	Very small	Primary gullies in unit 1: narrow floors, gradients up to 30°, and steep walls, up to 40°		Slightly deciduous forest (*Albizia–Canarium*)
3	Small	Lower spurs and foot slopes: concave slopes, 5–15° and up to ¼ mile long, generally dissected into spurs up to 100 ft high	Brown clay soils: Bomana family (11*b*). In wetter parts acid red to brown clay soils: Diulu family (9*a*)—III.e_3.so_2	Savannah (*Ophiuros–Eucalyptus alba*) and slightly deciduous forest (*Albizia–Canarium*)
4	Very small	Minor valley flats: up to 50 yd wide, slopes 1–2°; traversed by meandering stream channels up to 10 ft wide and 6 ft deep	Dark cracking clay soils: Boroko family (7*a*)—III.d_3.w_2.so_2.a_3	Tall evergreen forest (*Casuarina–Dysoxylum*) and savannah (*Ophiuros–Eucalyptus papuana*)
5	Very small	Main flood-plains: up to 300 yd wide, slopes less than 0°30′; up to 5 ft microrelief in flood channels; main channels up to 100 ft wide and 20 ft deep	Moderately well-drained alluvial soils: neutral olive silty clays (6*b*)—III.d_3.f_3	Tall evergreen forest (*Octomeles–Artocarpus, Cerbera–Alstonia*)

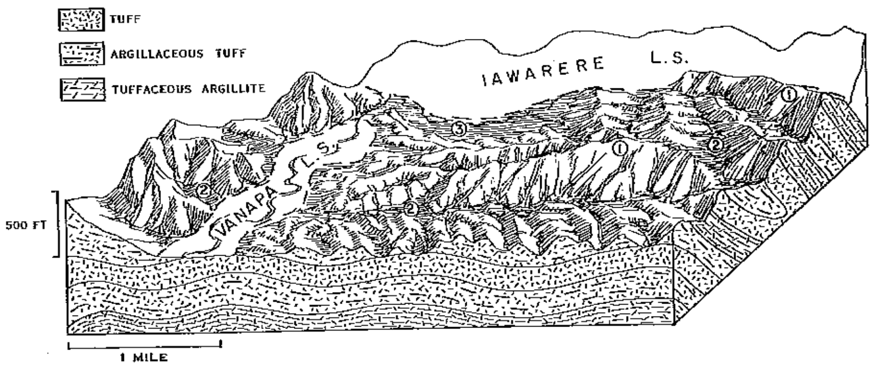
EDEBU LAND SYSTEM (45 SQ MILES)

Forested lower foothills near the Brown River.

Geology.—Slightly metamorphosed, grey sandy to argillaceous tuff and tuffaceous argillite and sandstone, striking NW. and dipping steeply; locally intruded by acid to intermediate, medium- to fine-grained igneous rocks; probably Cretaceous–Eocene (Port Moresby group).

Geomorphology.—Strike belt 2–4 miles wide, with close, branching ridges, mainly short and irregular but strike-aligned in south; relief mainly below 250 ft, attaining 500 ft in south; transverse main rivers, locally flanked by planed spurs, and branching perennial local streams with a dense, pinnate pattern of intermittent tributaries.

Altitude.—50–1000 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Ridges:** straight to concave slopes mainly up to 200 yd long, attaining 25° on spurs but exceeding 35° in valley heads and valley margins and on undercut slopes near Brown River; embayed by V-shaped gullies with amphitheatral heads; mainly narrowly rounded, undulating crests leading to pyramidal summits; lower spurs with steep marginal slopes near Brown River	Neutral brown lithosols (8*b*)—VII.e_7.st_6.so_4	Slightly deciduous forest (*Garuga–Brachychiton*, *Albizia–Canarium*); on some crests, semi-deciduous thicket (*Adenanthera–Colona*); minor savannah (*Imperata–Eucalyptus*)
2	Very small	**Tributary valley floors:** discontinuous and up to 100 yd wide; cross slopes and axial gradients 1–4°; upper sectors generally unchannelled, lower sectors with very small channels	Brown clay soils: Bomana family (11*b*)—II.e_2.so_3	Slightly deciduous forest (*Garuga–Brachychiton*)
3	Very small	**Flood-plains:** up to ¼ mile wide, gradients below 1 : 100; generally uneven, with small levees and flood banks; winding, locally anastomosing channels up to 30 ft wide and 5 ft deep	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.w_2.so_2.a_3	Slightly deciduous forest (*Planchonia–Adenanthera*)

IV. Upland Zone (650 sq miles) (Fig. 5)

Rainfall increases eastwards with increasing altitude, from 60 to 150 in.; rock weathering is intensified and streams are perennial. There are three sectors: a sheet of volcanic agglomerate and tuff, extending up to 1500 ft above sea level and dissected into ridges and smaller plateaux with up to 750 ft of relief, forms the north backing ranges; similar rocks, gently basined, form the Sogeri Plateau, mostly between 1600 and 2600 ft above sea level and with hills and ridges from 75 to 500 ft high;

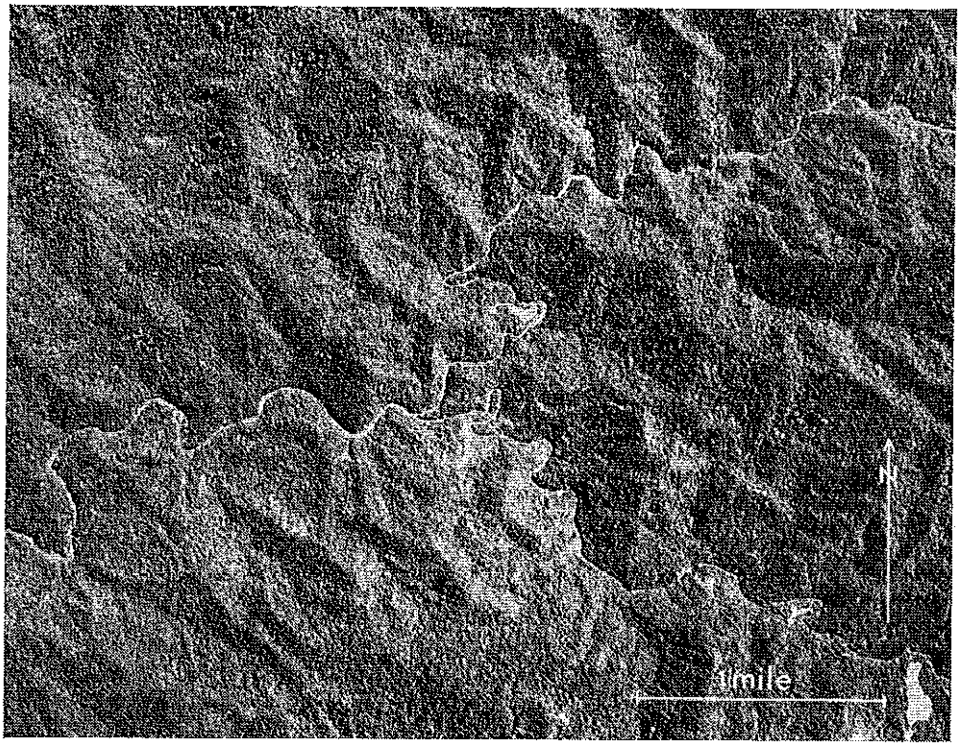


Fig. 5.—Forested massive ridges of the south backing ranges, up to 1000 ft high, traversed by the deep narrow valley of the Goldie River.

the south backing ranges attain 3600 ft above sea level and are mainly fairly massive ridges of phyllite up to 1200 ft high. Zonal soils are acid red to brown clay soils showing increasing acidity eastwards. The zone is largely covered with tall evergreen forest, including oak forest in the higher parts, with some slightly deciduous forest on crests and with minor savannah in the rain shadow of the Astrolabe Range.

In Table 5 and in the tabulated descriptions which follow, the land systems of the upland zone are arranged according to their occurrence in the three sectors: north backing ranges, Sogeri Plateau, and south backing ranges.

TABLE 5
DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE UPLAND ZONE

Land System	Lithology	Land Form	Relief	Predominant Soil	Predominant Vegetation
North backing ranges					
Mariboi	Agglomerate	Higher ridges and minor plateaux	Up to 750 ft	Acid red to brown clay soils	Tall evergreen forest
Rubberlands		Lower ridges	Up to 200 ft		As above, but extensively planted to rubber
Sogeri Plateau					
Sogeri	Weathered tuff and lava	Low ridges and undulating terrain	Up to 100 ft	Acid red to brown clay soils	Savannah
Subitana					Tall evergreen forest
Owers		Ridges	Up to 500 ft		
Vouku	Agglomerate		Up to 300 ft		Tall evergreen forest and savannah
South backing ranges					
Iawarere	Phyllite and minor limestone	Massive ridges	Up to 1200 ft	Acid red to brown clay soils	Tall evergreen forest
Uberi	Agglomerate over phyllite and sedimentary rocks				

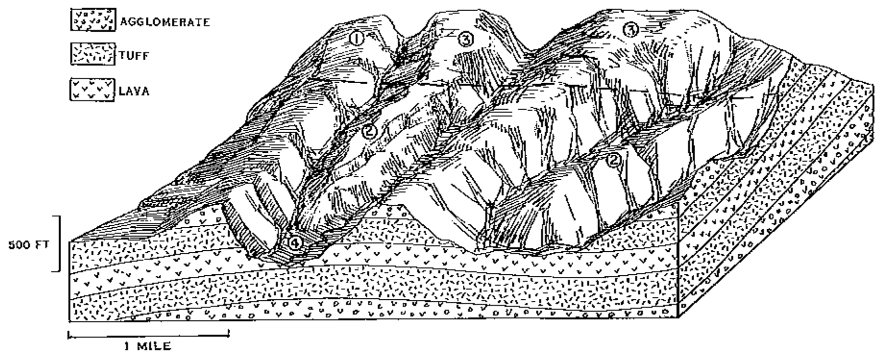
Mariboi Land System (260 sq miles)

Higher forested ranges on red-weathering volcanic rocks, in the north of the area.

Geology.—Andesitic agglomerate, tuff, and lava; gentle SW. dips; Pliocene. Deep, red, weathered profiles.

Geomorphology.—Ridges and uneven plateau strips descending mainly south and west, relief range 50–750 ft; moderately close, subparallel consequent rivers, mainly narrowly incised but with small valley floors near the lower margins, and dense pinnate or branching tributaries; larger streams perennial, smaller streams intermittent; small-scale slumping and minor rock falls on steep slopes.

Altitude.—50–1500 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Medium	Ridges at higher altitudes: 150–750 ft high, increasing in height north-eastwards; concavo-convex slopes mainly up to 30°, with minor rock faces and structural benches; locally smooth, but generally deeply embayed with V-shaped gullies, where marginal and head slopes may attain 38°; small slump scars on steepened sectors; flattish crests, slopes less than 5° and up to 100 yd long, commonly bouldery	Acid red to brown clay soils: Uberi family (9*c*), with Tiviki family (9*d*) in highest, wettest areas —VII.e_7.s_2. Locally, on agglomerate, acid brown lithosols (8*d*)—VIII.e_8.st_6	Tall evergreen forest (*Lithocarpus–Elaeocarpus*)
2	Very large	Ridges and escarpments at lower altitudes: as unit 1, with relief range 50–500 ft; crests become narrowly rounded as they decline south-westwards; on lower spurs and ridges (50–150 ft), slopes rarely exceed 10–20° except where undercut	Acid red to brown clay soils: Sogeri family (9*b*) —VII.e_7. Locally, on agglomerate, acid brown lithosols (8*d*)—VIII.e_8.st_6	On crests, slightly deciduous forest (*Albizia–Canarium*, *Intsia–Spondias*); on slopes, tall evergreen forest (*Pometia–Canarium*)
3	Medium	Plateau crests: 1–2 miles wide, exceptionally up to 4 miles, declining south-westwards; summit slopes less than 5°; summit relief 50–150 ft	Acid red to brown clay soils: Tiviki family (9*d*) —II.e_2.s_2	Slightly deciduous forest (*Intsia–Spondias*); on higher crests, tall evergreen forest (*Lithocarpus–Elaeocarpus*)
4	Very small	Valley floors: up to 200 yd wide in main valleys, discontinuous and up to 50 yd wide and commonly ill drained in tributaries; gradients 0°20′–5°, cross slopes 0°15′–5°; locally terraced up to 15 ft; winding channels up to 50 ft wide and 5 ft deep	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6. Locally, very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8. Minor acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2 on terraces and marginal slopes	Tall evergreen forests (*Pometia–Artocarpus*)

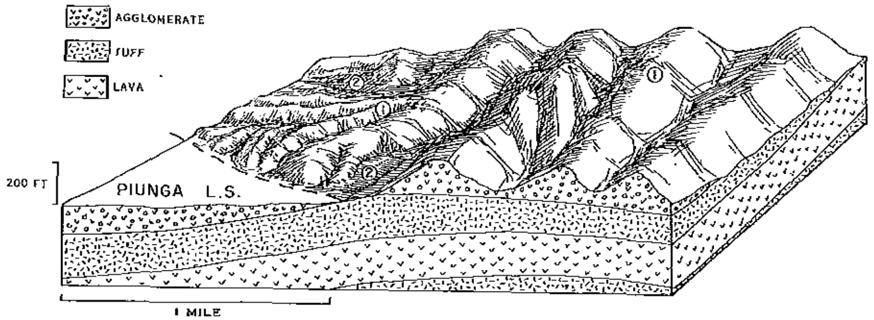
RUBBERLANDS LAND SYSTEM (60 SQ MILES)

Lower forested ranges on red-weathering volcanic rocks, in the north of the area.

Geology.—Andesitic agglomerate, tuff, and lava; gently dipping; Pliocene. Deep red weathered profiles.

Geomorphology.—Long narrow ridges with accordant crests decreasing in altitude to the SW.; relief up to 200 ft; fine-textured dendritic or parallel drainage pattern of permanent and intermittent streams; very shallow slumping common.

Altitude.—0–250 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: bouldery slopes up to 20°, rarely to 35°, and up to 300 yd long, with some steep rock faces up to 50 ft high; crests narrowly rounded or plateau-like (up to 200 yd wide) with slopes up to 6° and locally rocky; colluvial foot slopes 3–15° and up to 300 yd long; locally passing south-westwards into low branching ridges less than 50 ft high	Acid red to brown clay soils: Sogeri family (9*b*)—VII.e_7. Locally acid brown lithosols (8*d*)—VIII.e_8.st_6	On crests, slightly deciduous forest (*Albizia–Canarium, Intsia–Spondias*); on slopes, tall evergreen forest (*Pometia–Canarium*); very small areas with savannah (*Ophiuros–Eucalyptus alba*)
2	Very small	Flood-plains: up to ¼ mile wide, axial gradients up to 2°; locally with low levees above small stream channels; minor narrow terraces	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_5. Very locally on terraces, acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	Tall evergreen forest (*Alstonia–Kleinhovia*)

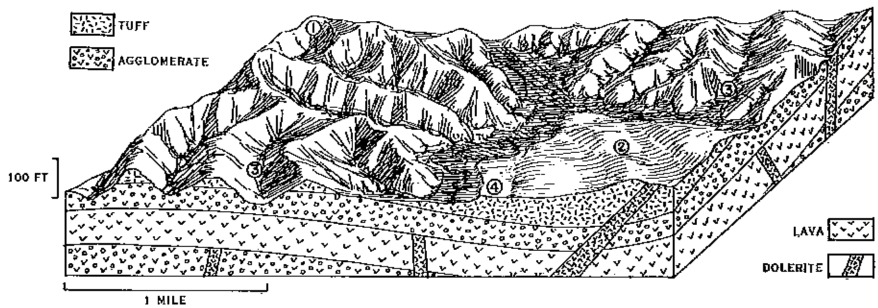
SOGERI LAND SYSTEM (25 SQ MILES)

Savannah-covered low hills with red volcanic soils, on the Sogeri Plateau.

Geology.—Deeply weathered andesitic tuff, lava, and dyke rocks and minor resistant flat-lying agglomerate; Pliocene.

Geomorphology.—Closely set, parallel or branching accordant ridges, mainly 50–100 ft high, with prominent short spurs; some broadly undulating terrain; terraced flood-plains of larger rivers; dense dendritic drainage with pinnate tributary pattern; much small-scale slumping and valley-silting; minor streams intermittent or ponded, larger streams perennial.

Altitude.—1600–2200 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Ridges and spurs**: straight, or concavo-convex slopes up to 150 yd long, mainly attaining 15–20° but steepening to 25° in valley heads and in undercut sectors; partly with shallow unchannelled re-entrants, partly deeply embayed by narrow, unchannelled valleys; concave foot slopes, 4–10° and mainly up to 50 yd long, locally attaining 300 yd	Acid red to brown clay soils: Sogeri family (9*b*)—VII.e_7	Savannah (*Ophiuros–Eucalyptus tereticornis*)
2	Medium	**Undulating terrain**: up to 50 ft of relief, with broad, mainly unchannelled valleys; flattish interfluve crests up to 300 yd wide, slopes less than 2°, and marginal slopes to 6° and up to 150 yd long	Acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	
3	Small	**Small valley floors**: up to 50 yd wide, axial gradients 0°30′–4°, cross slopes up to 4°; partly with small sluggish streams and commonly ill drained	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6. Minor very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Tall evergreen forest (*Casuarina–Dysoxylum*); *Pandanus* vegetation in wetter parts
4	Very small	**Alluvial terraces**: up to 300 yd wide, cross slopes up to 0°45′, longitudinal gradients <0°30′; generally, a more extensive terrace 8–15 ft above river level and a lower terrace subject to periodic flooding; meandering channels up to 50 ft wide and 10 ft deep	Acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	

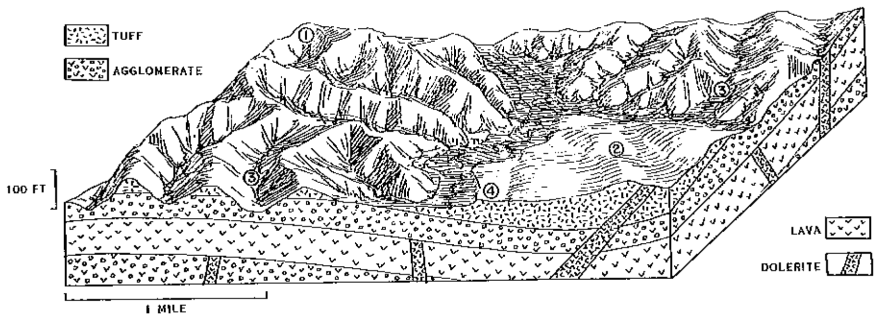
SUBITANA LAND SYSTEM (50 SQ MILES)

Forested low hills with red volcanic soils, on the Sogeri Plateau.

Geology.—Deeply weathered andesitic tuff, lava, and dyke rocks and minor resistant flat-lying agglomerate; Pliocene.

Geomorphology.—Closely set, parallel or branching accordant ridges, mainly 50–100 ft high, with prominent short spurs; some broadly undulating terrain; terraced flood-plain of Eworogo Creek; dense dendritic drainage with pinnate tributary pattern; much small-scale slumping and valley-silting; minor streams intermittent or ponded, larger streams perennial.

Altitude.—1600–2000 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Ridges and spurs:** concavo–convex slopes up to 150 yd long, mainly 15–20° but steepened to 30° in valley heads and margins, where slump alcoves are common; shallow re-entrants and rounded salients locally; undulating rounded crests up to 100 yd wide; concave foot slopes, 4–10° and mainly up to 50 yd long, locally attaining 300 yd	Acid red to brown clay soils: Uberi family (9*c*)—VII.e_7.s_2. Locally acid brown lithosols (8*d*)—VIII.e_8.st_6	Tall evergreen forest (*Castanopsis–Elaeocarpus*; minor mid-height grassland (*Ophiuros–Imperata*)
2	Small	**Undulating terrain:** up to 50 ft of relief, with flattish interfluve crests up to 300 yd wide, slopes less than 2°, and marginal slopes to 6° and up to 150 yd long	Acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	Tall evergreen forest (*Castanopsis–Elaeocarpus*; in lower parts, *Casuarina–Dysoxylum*)
3	Small	**Small valley floors:** up to 100 yd wide, gradients about 5°, concave cross slopes 2–5°; locally incised to 10 ft by small channels, but commonly poorly drained, with ill-defined runnels	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6	Tall evergreen forest (*Pometia–Artocarpus*)
4	Small	**Alluvial terraces:** up to 300 yd wide, cross slopes up to 0°45′, longitudinal gradients 0°15′ to 0°40′; generally, a more extensive terrace 8–15 ft above river level and a lower terrace subject to periodic flooding; meandering channels up to 50 ft wide and 10 ft deep	Acid red to brown clay soils as in unit 2. On lower terrace, areas of very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	

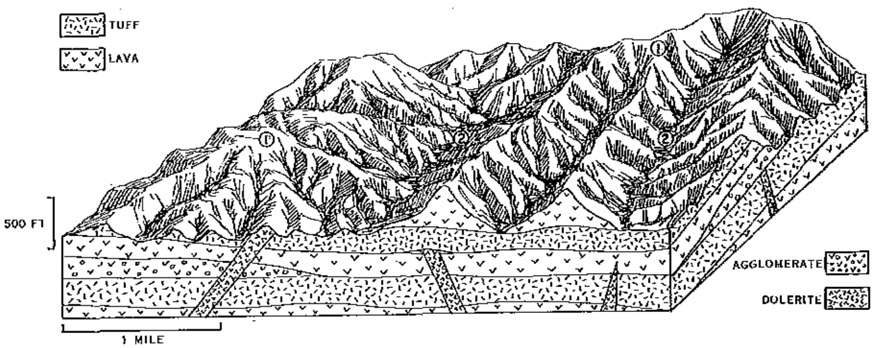
OWERS LAND SYSTEM (40 SQ MILES)

Forested high ridges with red volcanic soils, in the east of the Sogeri Plateau.

Geology.—Deeply weathered andesitic tuff, lava, and dyke rocks, and minor resistant flat-lying agglomerate; Pliocene.

Geomorphology.—Closely spaced, parallel straight ridges up to 500 ft high, locally branching, with areas of broken foothills with 50–150 ft of relief; very dense pinnate or dendritic drainage with many gullies; ephemeral or intermittent streams; slumping active on steepened slopes.

Altitude.—1800–2600 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Ridges**: concave slopes, mainly attaining 30° but steepening to 40° in amphitheatral valley heads and margins, where slump scars are common; closely spaced, parallel, shallow gully re-entrants; incised valleys, and prominent spurs, straight or stepped in chevron pattern, which locally continue as foothill ridges	Acid red to brown clay soils: Uberi family (*9c*)—$VII.e_7.s_2$. Locally, acid brown lithosols (*8d*)—$VIII.e_8.st_6$	Tall evergreen forest (*Castanopsis–Elaeocarpus*, minor *Lithocarpus–Elaeocarpus*); on some crests, slightly deciduous forest (*Albizia–Canarium*)
2	Very small	**Valley floors**: discontinuous, up to 50 yd wide, slopes up to 10°; small, but fairly deeply entrenched winding channels	Acid red to brown clay soils: Koitaki family (*9e*)—$II.e_2.s_2$	Tall evergreen forest (*Pometia–Artocarpus*)

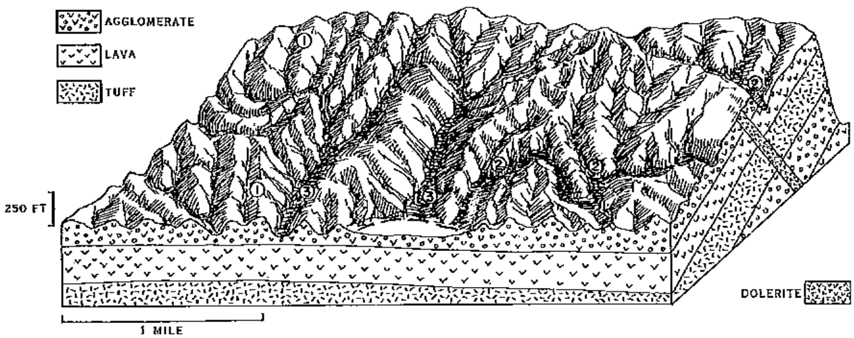
Vouku Land System (50 sq miles)

Mainly forested back slopes of the Astrolabe Range, and small plateau summits further east.

Geology.—Andesitic agglomerate and deeply weathered tuff, lava, and dyke rocks; flat-lying; Pliocene.

Geomorphology.—Dissected dip slopes consisting of closely spaced, branching ridges with accordant pyramidal summits; dendritic pattern of narrowly incised perennial streams; 50–300 ft of local relief.

Altitude.—1600–3600 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Ridges:** slopes 20–30°, locally to 40°, and 50–200 yd long; slump scars on steeper sectors; crests moderately to narrowly rounded	Acid red to brown clay soils: Sogeri family (9*h*)—VII.e_7. Locally, on steeper slopes, acid brown lithosols (8*d*)—VIII.e_8.st_6	Tall evergreen forest (*Castanopsis–Elaeocarpus*, *Lithocarpus–Elaeocarpus*; on steep lower slopes, *Casuarina–Dysoxylum*); on lower crests, savannah (*Ophiuros–Eucalyptus tereticornis*)
2	Very small	**Rock faces and benches:** up to 100 ft high, slopes 40° to sheer	Rock	Mainly bare; re-entrants with tall evergreen forest (*Casuarina–Dysoxylum*)
3	Small	**Valleys:** moderately steep lower hill slopes, and discontinuous gently sloping floors up to 50 yd wide; channels up to 20 ft wide	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6	Tall evergreen forest (*Casuarina–Dysoxylum*, *Pometia–Artocarpus*)

LAWARERE LAND SYSTEM (120 SQ MILES)

Forested ranges in the south-east of the area.

Geology.—Phyllite with minor sandstone and conglomerate and partly recrystallized laminated limestone; dips variable, strike NW.; Cretaceous–Eocene; locally, greywacke and breccia of possible Miocene age (Siro beds).

Geomorphology.—Subparallel, NW.-trending, massive ridges, 500–1200 ft high and 1 to 2 miles apart; trellis pattern of entrenched perennial streams, including large rivers, with closely spaced tributaries.

Altitude.—200–2300 ft.

Unit	Area	Land Form	Soil	Vegetation
1	Very large	Ridges: straight upper slopes 25–35°, rarely 45°, and up to $\frac{3}{4}$ mile long, with widely spaced major spurs and many shallow re-entrants; lower slopes closely dissected into steep-sided spurs; narrowly rounded crests; small dolines in upper valleys in limestone areas	Acid red to brown clay soils: Uberi family (9*c*)—VII.e_7.s_2, and acid brown lithosols (8*d*)—VIII.e_8.st_6	Tall evergreen forest (*Castanopsis–Elaeocarpus*)
2	Small	Lower spurs: slopes 25–35° and up to 200 yd long; crests range from narrowly rounded to gently sloping and up to 150 yd wide	Acid red to brown clay soils: Uberi family (9*c*)—VII.e_7.s_2	Tall evergreen forest (*Pometia–Artocarpus*)
3	Very small	Valley floors: terraced alluvial plains up to 200 yd wide, slopes less than 5°, narrowing and extending into tributary valleys; meandering channels up to 100 ft wide	On terraces, moderately well-drained alluvial soils: neutral olive silty clays (6*b*)—III.d_2.f_3. In tributary valleys, imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_8	Tall evergreen forest (*Pometia–Artocarpus*; also along streams, *Octomeles–Artocarpus*)

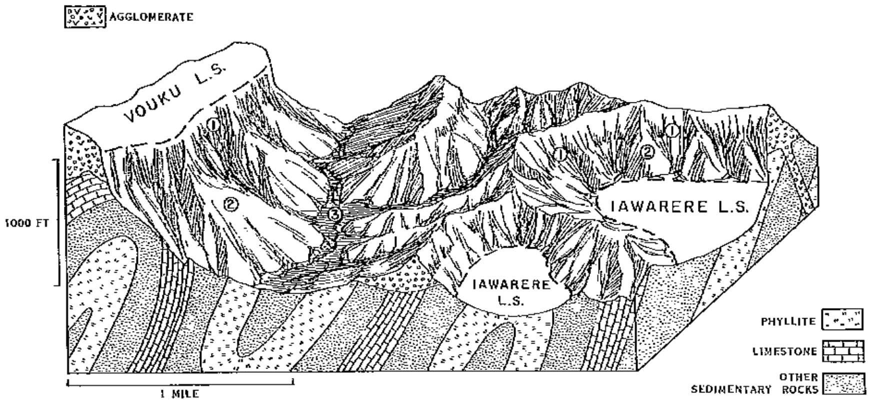
UBERI LAND SYSTEM (30 SQ MILES)

Forested massive ridges and gorges, east of the Sogeri Plateau.

Geology.—Andesitic agglomerate and tuff, lava, and dyke rocks, flat-lying and of Pliocene age; probably underlain by sedimentary and metasedimentary rocks of Cretaceous–Eocene age masked by volcanic debris.

Geomorphology.—Irregular, massive ridges 1–1½ miles apart, locally overlooking the gorges of the Musgrave River system, and including the walls of the Uberi gorge; up to 1200 ft of relief; branching pattern of narrowly incised perennial streams with closely spaced parallel gullies.

Altitude.—600–3000 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Rock faces:** continuous sheer walls up to 500 ft high locally, with joint-controlled buttresses and clefts	Rock	Bare
2	Very large	**Ridges:** fairly straight slopes up to ⅜ mile long, mainly up to 30°, but steeper in valley heads and margins; locally with stepped spurs in chevron pattern, elsewhere smooth; also straight slopes below unit 1, mainly 40–50°, mantled with agglomerate blocks	Acid red to brown clay soils: Uberi family (*9c*) — VII.e_7.s_2, and acid brown lithosols (*8d*)—VIII.e_8.st_6	Tall evergreen forest (*Castanopsis–Elaeocarpus, Lithocarpus–Elaeocarpus*); on some crests, slightly deciduous forest (*Albizia–Canarium*)
3	Very small	**Valley floors:** less than 50 yd wide, slopes up to 5°, with incised meandering channels	Imperfectly drained alluvial soils: acid brown clays (*5g*)—VI.d_3.f_6	Tall evergreen forest (*Pometia–Artocarpus, Octomeles–Artocarpus*)

V. Fluvial Plains Zone (550 sq miles) (Fig. 6)

These areas of deposition of Recent clay, silt, and sand by large perennial rivers extend up to 15 miles from the upland zone, with gradients from 1 : 250 to 1 : 1000. Altitudes range up to 100 ft above sea level, and rainfall is between 40 and 70 in. The soils are mainly moderately well-drained alluvial silty clay soils, with stratified soils near active and prior channels, minor ill-drained soils in back-plain depressions, and areas of acid red to brown clay soils on the inner margin of the

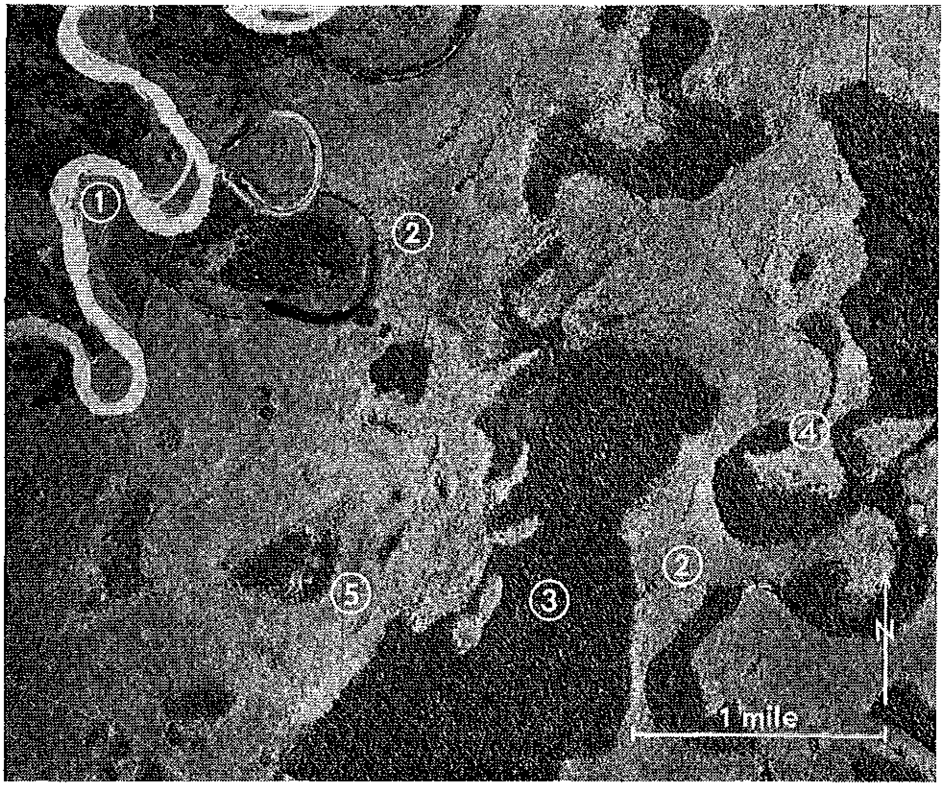


Fig. 6.—Northern plains, with the meandering Angabunga River in its unstable flood-plain (1), including oxbows and forested levees. Two prior meander tracts (2) are separated by a forested back-plain depression (3) and traversed by meandering prior channels which may be forested depressions (4) or raised sandy banks (5).

zone. The higher-lying former meander tracts with prior channels have mainly mid-height to tall grassland, whilst back plains and lower parts of the zone mainly have evergreen forest. The plains are traversed by shifting, meandering rivers in unstable flood-plains, with tall evergreen forest on active levees.

In Table 6 and in the tabulated descriptions which follow, the land systems of the fluvial plains zone have been listed under stable and unstable plains, with further arrangement of the stable plains under red clay plains and olive silty clay plains.

TABLE 6
DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE FLUVIAL PLAINS ZONE

Land System	Lithology	Land Form	Predominant Soil	Predominant Vegetation
Stable plains				
Red clay plains				
Inaukina	Alluvium derived from volcanic rocks	Fluvial plains with poor drainage	Acid brown clays	Tall evergreen forest
Olive silty clay plains				
Keviona	Fine-textured alluvium	Fluvial plains	Moderately well-drained, neutral olive silty clays	Mid-height grassland (*Ophiuros–Themeda australis*)
Pinu	Fine-textured alluvium and littoral clay and sand	Plains of combined fluvial and littoral origin	As above, but alkaline	Mid-height grassland (*Ophiuros–Imperata*)
Bebeo	Fine-textured alluvium	Prior meander plains	As above, but neutral	
Epo			As above, but alkaline	Tall grassland
Beipa		Back plains	Moderately well-drained to imperfectly drained alkaline silty clays	Tall evergreen forest
Babiko		Back plains with lowered water-table	Moderately well-drained neutral relic grey silty clays	Tall grassland
Vekabu		Plains subject to extensive seasonal flooding	Moderately well-drained neutral silty clays and alkaline/neutral stratified soils	Tall evergreen forest
Piunga			Imperfectly drained neutral olive grey silty clays	Mid-height and tall evergreen forest
Unstable plains				
Vanapa	Alluvium	Flood-plains of large rivers	Moderately well-drained to imperfectly drained stratified soils	Tall evergreen forest

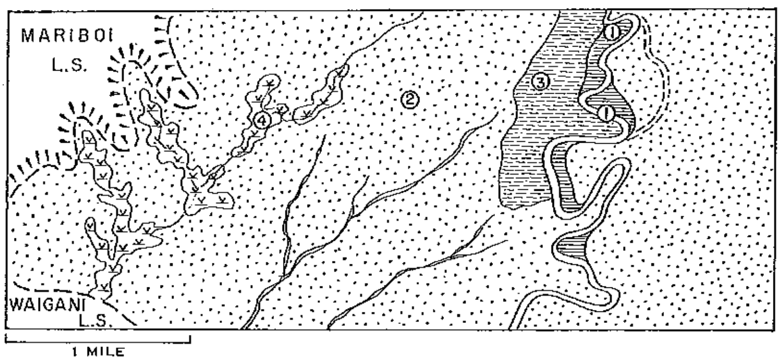
Inaukina Land System (45 sq miles)

Forested river plains with ill-drained red clay soils, at the foot of the ranges in the north of the area.

Geology.—Alluvium derived from volcanic rocks and weathered to reddish clay; Recent.

Geomorphology.—Stable alluvial plains extending up to 5 miles from north backing ranges; traversed by slightly incised river channels, and including back plains with swamps in blocked dendritic channels of local drainage; all larger channels are perennial.

Altitude.—10–100 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**River channels and levees**: channels 100–250 ft wide, with steep banks up to 15 ft high, and gravel beds; minor levees up to 300 yd wide, back slopes up to 2° with small overspill channels	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6	Tall evergreen forest (*Octomeles–Artocarpus*)
2	Very large	**Back plains**: up to 1 mile in extent, with local slopes up to 1°, and traversed by many small flood channels; locally short steep slopes where drainage is incised 5–10 ft		Tall evergreen forest (*Cerbera–Alstonia*, *Pometia–Celtis*)
3	Small	**Higher riparian plains**: zones up to ½ mile wide, generally 10–20 ft above main rivers and standing above flood levels	Acid red to brown clay soils: Koitaki family (9*e*)—II.e_2.s_2	
4	Small	**Blocked valley swamps**: up to ¾ mile in extent, in slightly entrenched, narrow branching valleys	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Mixed herbaceous vegetation (*Leersia–Hanguana*) with scattered groups and lines of palm vegetation (*Metroxylon–Macaranga*); *Pandanus* vegetation in pockets near valley heads

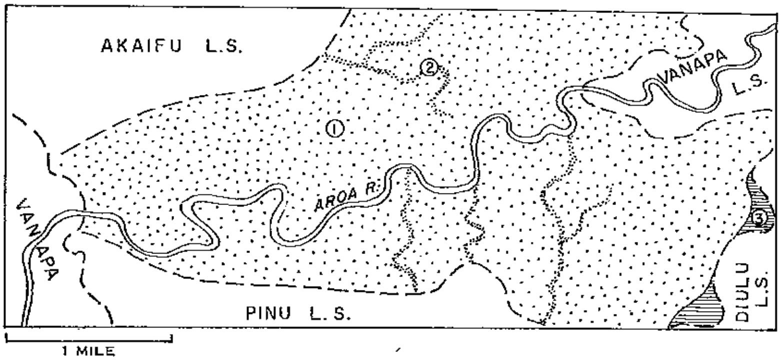
Keviona Land System (20 sq miles)

Plains with neutral soils and mid-height grassland astride the lower Aroa River.

Geology.—Alluvial clay, silt, sand, and minor gravel; Recent.

Geomorphology.—Stable alluvial plains up to 7 miles wide across the lower Aroa River, extending 10 miles down-river with average gradients of 1 : 1000; mainly dry, with numerous meandering prior channels, but with small depressions in tributary re-entrants subject to seasonal flooding.

Altitude.—10–50 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Plains:** flat or very gently undulating surfaces with up to 2 ft of local relief; short slopes up to 0°20′ near outer margins	Moderately well-drained alluvial soils: neutral olive silty clays (6*b*)—III.$d_2.f_3$	Mid-height grassland (*Ophiuros–Themeda australis*)
2	Very small	**Prior channels:** winding, locally discontinuous dry channels up to 120 ft wide and 8 ft deep, with bank slopes mainly up to 10°, locally to 15°; locally with small levee banks	Moderately well-drained alluvial soils, neutral olive stratified soils (6*d*)—III.$d_2.f_3$; locally, neutral olive sands (6*g*)—IV.$so_4.s_2.f_3$	As in unit 1, but with stands of *Saccharum spontaneum*
3	Very small	**Marginal depressions:** small tributary plains in unit 1; uneven surfaces with small flood channels	Moderately well-drained alluvial soils as in unit 1	Low evergreen forest (*Althoffia–Endospermum*)

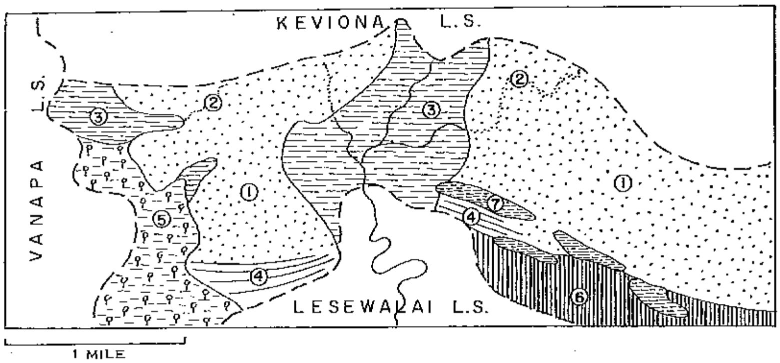
Pinu Land System (15 sq miles)

Plains with alkaline soils and mid-height grassland, south of the lower Aroa River.

Geology.—Alluvial and littoral clay, silt, and sand; Recent.

Geomorphology.—Stable plains of combined alluvial and littoral origin in a coastal tract 2–5 miles wide; higher parts have minor land-derived drainage with many prior channels; lower parts, which include back plains of Aroa River and plain margins against tidal flats, are subject to extensive seasonal or periodic flooding with minor saline tidal effects.

Altitude.—0–10 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Large	**Inner plain:** parallel with coast and lying between 3 and 5 miles inland; regional gradients about 1 : 2000, local slopes up to 0°30′	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*)—IV.$d_2.f_3.a_4$	Mid-height grassland (*Ophiuros–Imperata*)
2	Very small	**Prior channels:** winding, discontinuous, flat-floored depressions about 50 ft wide and 5 ft deep	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.$d_2.f_3.a_4$	As in unit 1, with stands of *Saccharum spontaneum*
3	Small	**Tributary drainage plains:** up to ½ mile wide and 2 ft below unit 1; small winding channels with sluggish flow	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.$d_2.f_3.a_4$	Strongly deciduous forest (*Bombax–Terminalia*)
4	Very small	**Stranded beach complex:** parallel broad ridges 6 in. to 1 ft 6 in. high, spaced 100–200 yd apart	Beach soils: brown fine sands (1*b*)—IV.$so_1.s_2.a_4$	In swales: low evergreen forest (*Avicennia–Ceriops* with *Sesuvium* ground cover) or low grassland (*Sporobolus–Eriochloa*). On ridges: evergreen thicket (*Hibiscus–Flagellaria*) or mid-height grassland (*Ophiuros–Themeda australis*)
5	Small	**Tidal back plains:** up to 2 miles wide and lying slightly above mean H.W.M.; uneven surfaces with many small runnels up to 2 ft deep leading to small tidal creeks	Imperfectly drained alluvial soils: alkaline olive grey silty clays (5*a*)—VI.$d_3.f_6.a_4$	Mid-height evergreen forest (*Excoecaria–Hibiscus*)
6	Small	**Seaward margin of plain:** zone up to ½ mile wide with very gentle slopes down to H.W.M.	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.$d_2.f_3.a_4$	Evergreen and semi-deciduous thicket (*Clerodendrum–Flagellaria, Gyrocarpus–Harpullia*)
7	Small	**Former lagunal flats:** up to 300 yd wide and ¾ mile long; subject to periodic shallow flooding with minor saline influence	Intertidal alluvial soils: brown sticky clays (3*b*)—VIII.$d_5.f_8.a_4$	Scrub (*Pluchea–Flagellaria*) or low grassland (*Sporobolus–Eriochloa*)

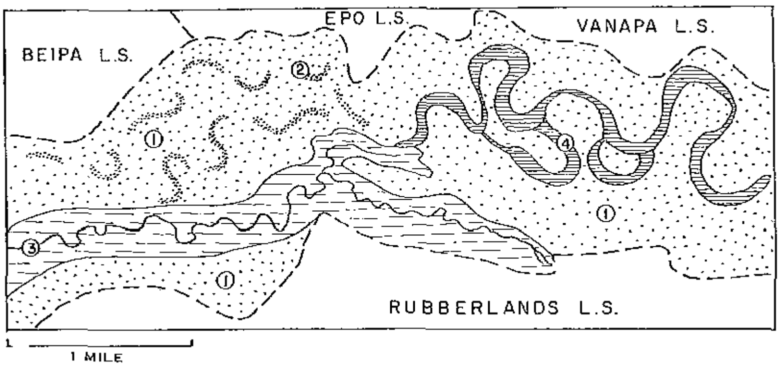
BEBEO LAND SYSTEM (25 SQ MILES)

Prior meander plains of the Angabunga River, with extensive mid-height grassland.

Geology.—Alluvial clay, silt, and sand; Recent.

Geomorphology.—Stable alluvial plains up to 2½ miles wide, sloping generally south for distances up to 8 miles, gradients about 1 : 500; comprising prior meander belts of the Angabunga River, with prior levee banks and meander depressions, partly ill-drained; subject to shallow periodic flooding, with many small channels.

Altitude.—50–100 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very large	**Prior meander plains:** up to 2 miles wide; very broadly undulating, with slopes less than 0°30′	Moderately well-drained alluvial soils: neutral olive silty clays (*6b*)—III.$d_2.f_3$	Mid-height grassland (*Ophiuros–Imperata*); savannah (*Ophiuros–Eucalyptus papuana*) in the south-east
2	Small	**Prior levee banks and channels:** banks up to 4 ft high, slopes up to 1° and up to 100 yd long; meandering channels up to 200 ft wide and 4 ft deep	Moderately well-drained alluvial soils: alkaline olive brown sands (*6f*)—IV.$so_1.s_2.f_3.a_1$	Tall evergreen forest (*Cananga–Pometia*); in the south-east, savannah as in unit 1
3	Medium	**Back-plain depressions:** up to ½ mile wide and 1–2 ft below the level of unit 1; uneven surfaces traversed by many small flood channels; drained by small channels up to 50 ft wide and 15 ft deep	Imperfectly drained alluvial soils, neutral olive grey silty clays (*5b*)—VI.$d_2.f_6$	Tall evergreen forest (*Cerbera–Alstonia*)
4	Small	**Prior meander depressions:** up to ¼ mile wide, with prior channels up to 200 ft wide and 8 ft deep	Imperfectly drained alluvial soils: alkaline olive grey stratified soils (*5c*)—VI.$d_2.f_6.a_1$	Mid-height evergreen forest (*Nauclea–Kleinhovia*)

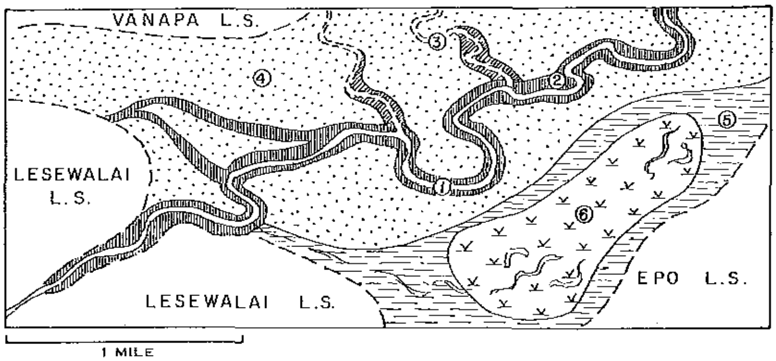
BABIKO LAND SYSTEM (30 SQ MILES)

Plains with lowered water-table and changing vegetation through abandonment of lower Angabunga course.

Geology.—Alluvial clay, silt, sand, and minor gravel; Recent.

Geomorphology.—Stable alluvial plain constituting prior flood-plain of the lower Angabunga River, which has undergone 10–15 ft lowering of water-table due to change of course, up to 6 miles wide and extending for 15 miles down-river with gradients below 1 : 1000; extensive back plains, meandering old Angabunga channel and shallow winding prior channels, and dried-out back swamps.

Altitude.—0–50 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	Abandoned Angabunga channel: up to 200 ft wide and 10 ft deep, generally with steep banks; uneven sandy floor with small amounts of gravel; tidally flooded in lower sector	Bed-load	Tall grass vegetation (*Saccharum robustum*) on former banks; dry bed invaded by *Saccharum spontaneum*; in tidal part, a line of young *Bruguiera* trees along banks
2	Small	Prior levees of abandoned channel: up to 100 yd wide and 3½ ft high, back slopes mainly 0°15′–0°40′, but locally attaining 2° near crest; branching in lowermost sector as distributary zones up to 400 yd wide	Moderately well-drained alluvial soils: alkaline relic olive grey stratified soils (6*i*)—IV.d_2.f_3.a_4	Tall evergreen forest (*Octomeles–Artocarpus*) under drought stress
3	Very small	Prior channels and levees in unit 4: winding tracts up to 100 yd wide, consisting of channels up to 50 ft wide and 10 ft deep, with moderately steep banks, and single or paired levees with slopes locally attaining 1°		In channels, tall grassland (*Phragmites–Saccharum robustum*); on levees, evergreen thicket (*Hibiscus–Flagellaria*)
4	Large	Back plains: very gently sloping, locally uneven plains up to 1½ miles wide	Moderately well-drained alluvial soils: neutral relic grey silty clays (6*h*)—III.d_2.f_3	Tall grassland (*Saccharum spontaneum–Imperata*), with tracts of mid-height evergreen forest (*Nauclea–Kleinhovia*)
5	Medium	Back-plain depressions and lower margins: zones up to ½ mile wide		Low evergreen forest (*Althoffia–Endospermum*)
6	Medium	Dried back swamps: elongate tracts up to 2 miles wide; hummocky surfaces traversed by frequent dry channels, including dry oxbows, up to 50 ft wide and 5 ft deep		Tall grassland (*Phragmites–Saccharum robustum*) under drought stress, invaded by twiners (*Passiflora foetida*) and regrowth shrubs (*Trema*)

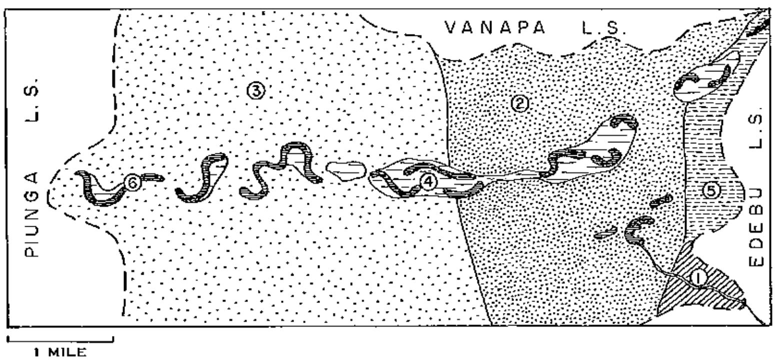
VEKABU LAND SYSTEM (80 SQ MILES)

Forested river plains between the Brown and Vanapa Rivers.

Geology.—Alluvial silt and clay overlying sand and gravel; Recent.

Geomorphology.—Stable alluvial plains up to 9 miles wide, average gradient 1 : 1500; disorganized prior drainage with many channel swamps, mainly in lower-lying tract up to 3 miles wide; ill drained near inner margin, and subject to extensive periodic flooding from adjacent large rivers and intermittent streams; local drainage consists mainly of intermittent flood channels.

Altitude.—15–50 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Tributary valley plains:** up to ½ mile wide, gradients about 1 : 100; small intermittent channels, e.g. 15 ft wide and 5 ft deep	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*)—IV.d_2.f_3.a_1	Slightly deciduous forest (*Spondias–Celtis*)
2	Medium	**Upper sectors of plains:** extending up to 4 miles from foothills, regional gradients about 1 : 500; local cross slopes, as on prior levees, up to 1 : 100; about 20 ft above normal river levels	Moderately well-drained alluvial soils: alkaline/neutral olive stratified soils (6*e*)—III.d_2.f_3	Tall evergreen forest (*Pometia–Celtis*)
3	Large	**Lower sectors of plains:** extending up to 4 miles downslope from unit 2, with regional gradients less than 1 : 500; local slopes as in unit 2	Moderately well-drained alluvial soils: neutral olive silty clays (6*b*)—III.d_2.f_3	Slightly deciduous forest (*Spondias–Celtis*); tract of mid-height grassland (*Ophiuros–Imperata*)
4	Small	**Drainage-affected zones:** tracts up to 200 yd wide and 5–15 ft below unit 2, generally with small intermittent flood channels; includes uneven flood-plain up to 100 yd wide along small perennial river	Moderately well-drained alluvial soils: neutral olive stratified soils (6*d*)—III.d_2.f_3	Mid-height evergreen forest (*Nauclea–Kleinhovia*) and slightly deciduous forest (*Spondias–Celtis*)
5	Small	**Inner plain margin with obstructed drainage:** in close association with unit 4, and traversed by ill-drained flood-plains up to 100 yd wide, with small sluggish channels	Dark cracking clay soils: Inapi family (7*c*)—III.d_3.w_2.so_2.a_3	Mid-height evergreen forest (*Nauclea–Kleinhovia*)
6	Very small	**Swamps:** mainly permanent swamps, including cut-offs up to 100 yd wide and up to several miles long, and blocked marginal swamps up to ½ sq mile in extent	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_5	Mixed herbaceous vegetation (*Leersia–Hanguana*)

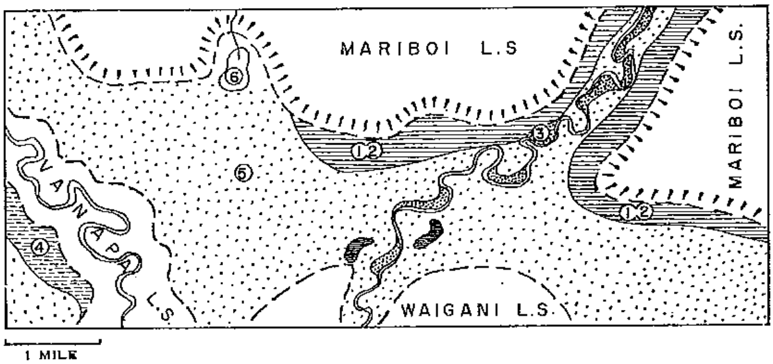
PIUNGA LAND SYSTEM (170 SQ MILES)

Poorly drained, forested river plains.

Geology.—Alluvial clay, silt, and sand; Recent.

Geomorphology.—Stable alluvial plains with poorly drained areas traversed by large meandering river channels; minor better-drained river terraces and higher margins; subject to extensive seasonal flooding.

Altitude.—25–200 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**Laloki plains:** up to ¾ mile wide and 10 ft above normal river level; even surfaces with slopes less than 1 : 250, locally traversed by secondary drainage channels; subject to infrequent flooding	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*)—IV.d_2.f_3.a_4, or neutral olive silty clays (6*b*)—III.d_2.f_3	Tall evergreen forest (*Cerbera–Alstonia*)
2	Small	**Terraces and inner plain margins:** Kubuna River terraces, mainly up to ½ mile wide, locally up to 1 mile, and 5–10 ft above normal river level, slopes up to 1 : 100; restricted plains extending up to ½ mile from foothills in volcanic rocks	Imperfectly drained alluvial soils: acid brown clays (5*g*)—VI.d_3.f_6	Mid-height and tall evergreen forest (*Nauclea–Kleinhovia, Pometia–Celtis*); slightly deciduous forest (*Spondias–Celtis*)
3	Very small	**River channels and levees:** main channels up to 100 ft wide and 20 ft deep; minor channels up to 20 ft wide and 5 ft deep; uneven, discontinuous flood-plains up to 100 yd wide and within 5 ft of normal river level; levee back slopes up to 0°30′ and up to 100 yd long	Moderately well-drained alluvial soils: neutral olive stratified soils (6*d*)—III.d_2.f_3	Tall evergreen forest (*Octomeles–Artocarpus*) on levees
4	Very small	**Prior levee tracts:** up to ¾ mile wide; uneven surfaces with small secondary drainage depressions up to 3 ft deep; local slopes up to 0°30′		Low and tall evergreen forest (*Althoffia–Endospermum, Pometia–Celtis*)
5	Very large	**Ill-drained plains:** low-lying plains and back plains of low gradient, commonly traversed by shallow or ill-defined drainage depressions	Imperfectly drained alluvial soils: neutral olive grey silty clays (5*b*)—VI.d_2.f_6	Mid-height and tall evergreen forest (*Melaleuca–Nauclea, Nauclea–Kleinhovia, Cananga–Pometia*)
6	Very small	**Swamps:** permanent swamps in blocked tributary valleys, cut-offs, and back-plain depressions; less than ¼ sq mile in extent	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Palm vegetation (*Metroxylon–Macaranga*) and tall grassland (*Phragmites–Saccharum robustum*)

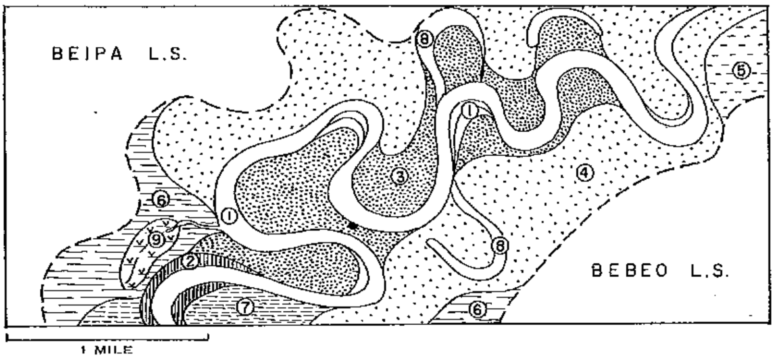
VANAPA LAND SYSTEM (60 SQ MILES)

Flood-plains along large rivers throughout the area.

Geology.—Alluvial clay, silt, sand, and gravel; Recent.

Geomorphology.—Unstable flood-plains of major rivers, up to 1½ miles wide, gradients from above 1 : 250 to below 1 : 1000; valley sectors with braiding channels, plains sectors mainly with migrating meanders with oxbows; pronounced levees in lower reaches; lower flood-plains subject to more frequent flooding and concurrent erosion and deposition; more stable higher flood-plains, up to 20 ft above normal river level; areas of active alluviation subject to seasonal or periodic flooding.

Altitude.—0–130 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**River channels and banks:** channels 100–400 ft wide and 3–12 ft deep; shelving accreting banks and point bars rising irregularly to 4 ft above normal river level, with crescentic swells and swales; low meander plugs	Very poorly drained alluvial soils: grey loams (4*b*)—VIII.d_8.f_8	Tall grass (*Saccharum robustum*)
2	Very small	**Low-lying levees:** discontinuous levees of the Biaru River, up to 50 yd wide and 4 ft high, irregular channelled slopes up to 5°; frequently flooded	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.d_2.f_6	Low and tall evergreen forest (*Artocarpus–Ficus, Octomeles–Artocarpus*); tall grass (*Saccharum robustum*) in swales
3	Medium	**Lower channelled flood-plains:** up to 1½ miles wide, ranging from normal river level to 10 ft above; 4 ft local relief of flood channels, levees, and crescentic swells and swales; frequently flooded	Imperfectly drained alluvial soils: alkaline olive grey stratified soils (5*c*)—VI.d_2.f_6.a_1, or neutral olive grey stratified soils (5*d*)—VI.d_2.f_6	
4	Large	**Higher channelled flood-plains:** as unit 3, but up to 20 ft above normal river level and less frequently flooded	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.d_2.f_3.a_4, or neutral olive stratified soils (6*d*)—III.d_2.f_3	Tall evergreen forest (*Octomeles–Artocarpus*)
5	Very small	**Prior flood-plain remnants:** up to ¼ mile wide and 1 mile long, with slopes up to 1° and subdued channel relief up to 2 ft; rarely flooded	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*)—IV.d_2.f_3.a_1, or neutral olive silty clays (6*b*)—III.d_2.f_3	Tall grassland (*Saccharum spontaneum–Imperata*) or slightly deciduous forest (*Spondias–Celtis*)
6	Small	**Back-plain depressions:** up to 300 yd wide; uneven surfaces, with up to 2 ft of relief and minor channels up to 5 ft deep; frequently inundated	Imperfectly drained alluvial soils: alkaline olive grey silty clays (5*a*)—VI.d_2.f_6.a_1	Mid-height and tall evergreen forest (*Melaleuca–Nauclea, Nauclea–Kleinhovia, Cerbera–Alstonia*)
7	Very small	**Flooded former back plain of Angabunga River:** tracts up to ¾ mile wide permanently inundated since recent change in course	Very poorly drained alluvial soils: relic olive silty clays (4*c*)—VIII.d_8	Tall grassland (*Saccharum spontaneum–Imperata*), evergreen thicket (*Hibiscus–Flagellaria*)
8	Small	**Oxbows:** up to 400 ft wide and 15 ft deep; steep outer and gently sloping inner banks; permanent standing water	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Mixed herbaceous vegetation (*Nymphaea–Azolla, Leersia–Hanguana*) or tall grass (*Saccharum robustum*)
9	Very small	**Back-plain swamps:** as unit 6, but permanently inundated		Tall grassland (*Phragmites–Saccharum robustum, Saccharum robustum*), locally scattered palm vegetation (*Metroxylon–Macaranga*)

VI. Swamp Zone (350 sq miles) (Fig. 7)

This zone comprises areas of permanent or seasonal standing water and periodically flooded plains, with Recent clay, silt, and peat. It extends up to 75 ft above sea level in the tectonic depression between the coastal hill zone and the upland and

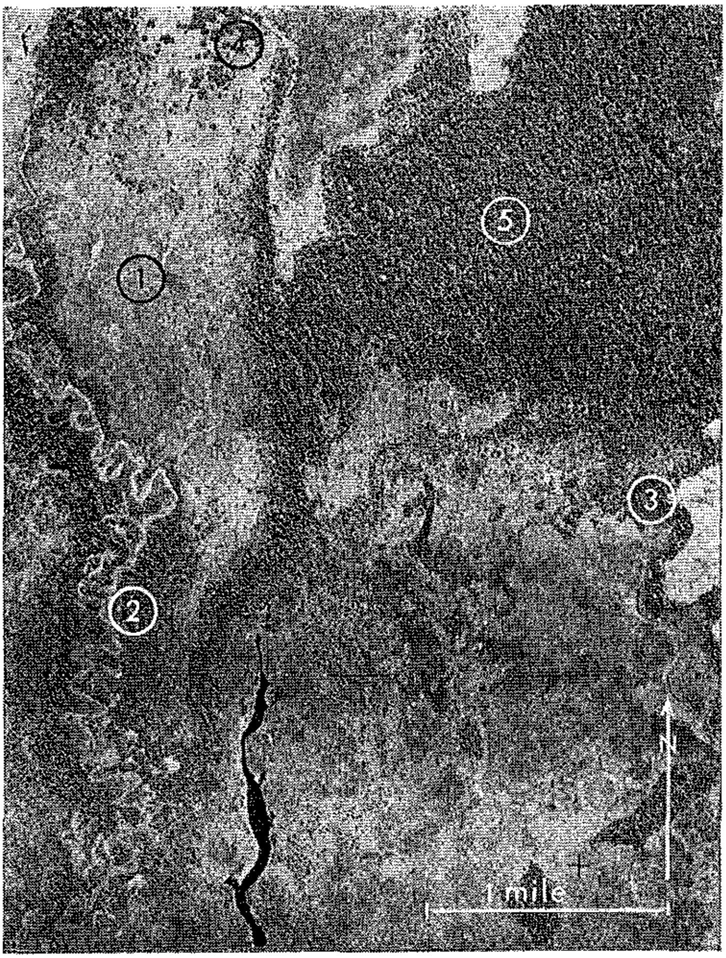


Fig. 7.—Akaifu land system, with permanent herbaceous and grassland swamp (1) and small areas of open water in back-plain situations, and seasonal swamps in higher-lying riparian tracts (2) and swamp margins (3). An area of sago palms is shown (4). Forested fluvial plains (5) limit the land system. There are many signs of prior channels through the swamp.

foothill zones. The permanent swamps, ranging from large basins to smaller back swamps, have grey sticky clays and floating herbaceous vegetation and tall grassland. The seasonal swamps and swamp margins, and riparian tracts of through-going rivers, have imperfectly drained alluvial silty clays or stratified soils and mid-height and tall evergreen forest and minor areas of sago palms. Higher-lying, periodically flooded plains have imperfectly drained alluvial soils and mainly evergreen thicket.

In Table 7 and in the tabulated descriptions which follow, the land systems of the swamp zone are arranged as mainly permanent swamps and mainly seasonal swamps. This arrangement, expressing decreasing inundation and increasing importance of through drainage, also expresses a transition from very poorly drained to imperfectly drained soils, and with it a range from tall grassland to evergreen forest or thicket.

TABLE 7

DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE SWAMP ZONE

Land System	Lithology	Land Form	Predominant Soil	Predominant Vegetation
Mainly permanent swamps				
Waigani	Fine-textured alluvium	Swamps with little through-going drainage	Very poorly drained alluvial soils	Tall grassland
Engepa		Complex swamp with moderate through-going drainage	Very poorly or imperfectly drained alluvial soils	Tall grassland and sago palm vegetation
Akaifu		Swamps with much through-going drainage		Tall grassland with minor evergreen forest
Mainly seasonal swamps				
Biaru	Fine-textured alluvium	Back swamps and partly brackish, seasonally flooded back plains	Imperfectly drained neutral or alkaline silty clays	Mid-height evergreen forest
Doura		Periodically or seasonally flooded back plains with meandering rivers	Imperfectly drained alkaline silty clays	Evergreen thicket

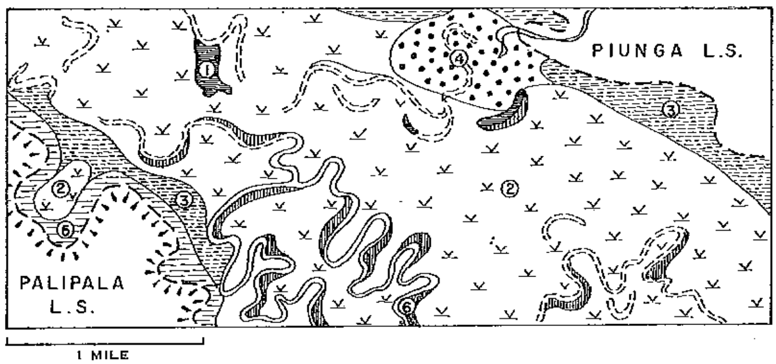
Waigani Land System (160 sq miles)

Extensive grassland swamps in the north and centre of the area.

Geology.—Alluvial silt and clay, peat; Recent.

Geomorphology.—Extensive, mainly permanent swamps with small lakes, traversed by levees of many prior and some active meandering river channels, and with marginal zones of seasonal or intermittent flooding; areas of alluviation and minor peat accumulation.

Altitude.—0–50 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	Lakes: irregular areas up to 1 sq mile in extent, with water more than 5 ft deep		Without vegetation or with mixed herbaceous vegetation (*Nymphaea–Azolla*)
2	Very large	**Permanent swamps**: extensive inner parts, with shallow standing water	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Mixed herbaceous vegetation (*Leersia–Hanguana*) or tall grassland (*Phragmites–Saccharum robustum*); locally with clumps or lines of palm vegetation (*Metroxylon–Macaranga*)
3	Small	**Partially seasonal swamps**: partially dry but with high water-table during dry season; more shallowly inundated than unit 2, and generally higher-lying and marginal		Tall grassland (*Phragmites–Saccharum robustum*), with tracts of mid-height evergreen forest (*Melaleuca–Nauclea*)
4	Small	**Drainage intake zones**: up to 1 mile in extent; permanently or seasonally with shallow water; higher parts traversed by many small distributary channels		Palm vegetation (*Metroxylon–Macaranga*)
5	Very small	**Swamp margins**: gently sloping zones up to 100 yd wide and rising to 2 ft above unit 4; seasonally inundated	Imperfectly drained alluvial soils: neutral grey sticky clays (5*f*)—VI.d_3.f_6	Mid-height evergreen forest (*Melaleuca–Nauclea*) or tall grassland (*Saccharum spontaneum–Imperata*)
6	Very small	**Levees**: discontinuous tracts up to $\frac{1}{4}$ mile wide and attaining 3 ft above permanent water level, associated with active through-going or abandoned river channels	Imperfectly drained alluvial soils: alkaline olive grey stratified soils (5*c*)—VI.d_2.f_6.a_1	Mid-height and tall evergreen forest (*Nauclea–Kleinhovia, Octomeles–Artocarpus*), with riparian fringe of scrub (*Hibiscus–Flagellaria*) and tall grass (*Saccharum robustum*)

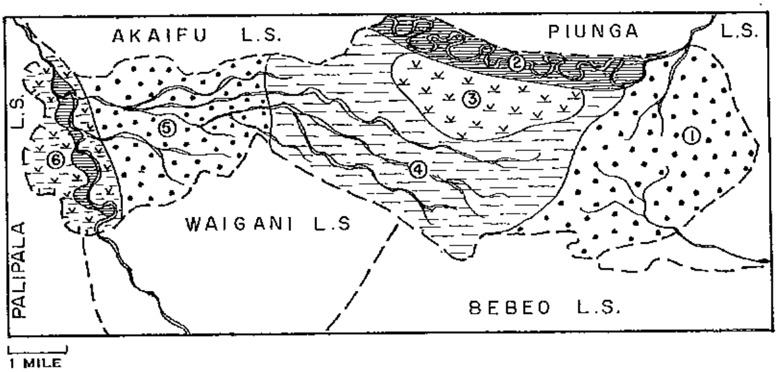
Engepa Land System (35 sq miles)

Permanent grassland swamps mixed with forested seasonal swamps and river tracts, in the north of the area.

Geology.—Alluvial silt and clay, peat; Recent.

Geomorphology.—A tract up to 4 miles wide, extending for 20 miles between the Biaru and Angabunga River plains; extensive permanent swamps, some back plains with seasonal marginal swamps, periodically flooded levee tracts and higher alluvial plain remnants; disorganized drainage from Inawafunga River, with anastomate and distributary patterns and multiple small flood channels; area of alluviation and peat accumulation.

Altitude.—20–75 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Medium	**Eastern intake swamp**: area with distributary feeder drainage with narrow, low-lying levee tracts, and many intervening small back-swamp basins	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8. On levees, imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.d_2.f_6	Mainly palm vegetation (*Metroxylon–Macaranga*)
2	Small	**Northern meander belt**: up to 1 mile wide with small meandering channel, fairly prominent levees and back slopes, and a small area of higher-lying alluvial plain eastwards from Engepa village	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.d_2.f_6	Mainly mid-height evergreen forest (*Nauclea–Kleinhovia*)
3	Small	**Central swamp**: elongate back-plain basin up to 1½ miles wide	Very poorly drained alluvial soils, as in unit 1	Mainly tall grassland (*Phragmites–Saccharum robustum*)
4	Medium	**Central swamp fringe**: zone up to 1½ miles wide traversed by very many anastomosing flood channels	Imperfectly drained alluvial soils, as in unit 2	Mainly mid-height evergreen forest (*Melaleuca–Nauclea*)
5	Medium	**Western swamp**: receiving drainage from units 2 and 4, and characterized by a few winding channels with paired narrow levees and back swamps about 1 mile wide	Very poorly drained and imperfectly drained alluvial soils, as in unit 1	Tall grassland (*Phragmites–Saccharum robustum*) with many stands of palm vegetation (*Metroxylon–Macaranga*)
6	Small	**Western margins**: up to 3 miles wide, with subparallel anastomosing channels, levees, and elongate narrow back swamps; small blocked-valley swamps on margin	Levees, probably imperfectly drained alluvial soils, as in unit 2. Back swamps, very poorly drained alluvial soils, as in unit 1	On levees, low evergreen forest (*Artocarpus–Ficus*); back swamps, tall grassland (*Phragmites–Saccharum robustum*)

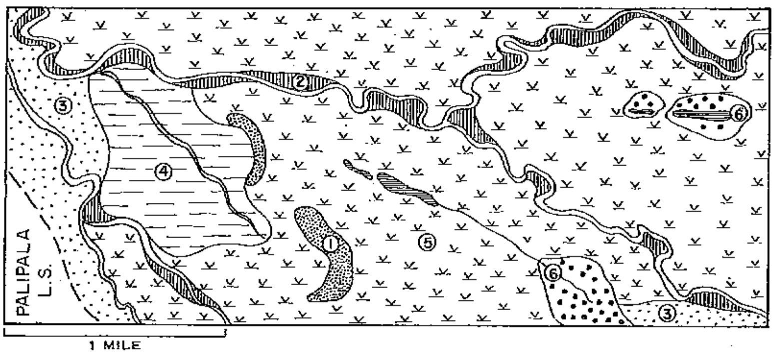
Akaifu Land System (90 sq miles)

Mainly grassland swamps in the centre and north of the area, with forests along through-going channels and on margins.

Geology.—Alluvial clay, silt, and sand, peat; Recent.

Geomorphology.—Mainly permanent swamps with significant through-drainage; including meandering channels, prior or active levee tracts up to 1 mile wide, back swamps up to 2 miles wide, and seasonally inundated swamp margins; areas of alluviation and peat accumulation.

Altitude.—10–25 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Higher levees:** mainly prior levees up to ½ mile wide and 3–7 ft above normal river levels; flat or very gently sloping surfaces, rarely flooded	Moderately well-drained alluvial soils: alkaline olive silty clays (6*a*) — IV.d_2.f_3.a_4, or neutral olive silty clays (6*b*)—III.d_2.f_3	Tall grassland (*Saccharum spontaneum–Imperata*) or mid-height evergreen forest (*Nauclea–Kleinhovia*)
2	Very small	**Low levees and river channels:** up to 50 yd wide along Biaru River and tributaries, with narrow crests up to 4 ft high, and irregular back slopes; tracts up to ¼ mile wide in lower Dilava swamps; meandering, fast-flowing channels up to 100 ft wide	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.d_3.f_6	Low evergreen forest (*Artocarpus–Ficus*) or tall grassland (*Saccharum spontaneum–Imperata*)
3	Small	**Swamp margins:** gently sloping zones up to ¼ mile wide, subject to intermittent flooding; locally as riparian tracts up to ½ mile wide	Imperfectly drained alluvial soils: neutral grey sticky clays (5*f*)—VI.d_3.f_6; or in riparian tracts, alkaline olive grey stratified soils (5*c*)—VI.d_2.f_6.a_4	Tall evergreen forest (e.g. *Cerbera–Alstonia*)
4	Small	**Mainly seasonal back swamps:** flat, or sloping very gently for distances up to 1 mile to secondary drainage channels, with small ponds in lowest parts; also as small levees in unit 5.	Imperfectly drained alluvial soils: alkaline olive grey silty clays (5*a*)—VI.d_2.f_6.a_4 or, on levees, as in unit 2	Mid-height evergreen forest (*Melaleuca–Nauclea*)
5	Very large	**Mainly permanent back swamps:** up to 2 miles wide, parallel with general drainage, with many small lakes	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Mixed herbaceous vegetation (*Nymphaea–Azolla, Leersia–Hanguana*), or tall grassland (*Phragmites–Saccharum robustum*) with scattered stands of palm vegetation (*Metroxylon–Macaranga*)
6	Very small	**Drainage intake areas or submerged levees** in unit 5; permanently or seasonally flooded to shallow depth		Palm vegetation (*Metroxylon–Macaranga*)

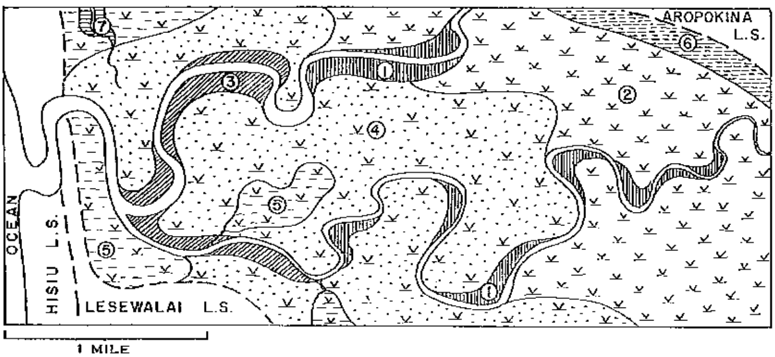
BIARU LAND SYSTEM (10 SQ MILES)

Partly brackish, wooded seasonal swamps in the north of the area.

Geology.—Alluvial silt, clay, and sand; Recent.

Geomorphology.—Mainly seasonal back-plain swamps up to 2 miles wide flanking tidal river reaches and large tidal creeks and ranging from fresh water to saline.

Altitude.—0–10 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Riparian tracts above H.W.M.**: low levees up to 50 yd wide, back slopes up to 2°, less than 4 ft above normal water level; river channels up to 300 ft wide and 15 ft deep	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.d_2.f_6	Palm vegetation (*Metroxylon–Artocarpus*)
2	Large	**Back plains and freshwater back swamps**: up to ½ mile wide, with slopes less than 0°30′; hummocky surfaces with up to 1 ft of relief; permanently waterlogged and seasonally inundated	Imperfectly drained alluvial soils: neutral olive grey silty clays (5*b*)—VI.d_2.f_6. Probably sticky clays in swamps	Mid-height evergreen forest (*Melaleuca–Nauclea*); shallow swampy tracts with mixed herbaceous vegetation (*Leersia–Hanguana*) and tall grassland (*Phragmites–Saccharum robustum*) with scattered stands of palm vegetation (*Metroxylon–Macaranga*)
3	Very small	**Riparian tracts below H.W.M.**: as unit 1	Mangrove soils: grey clayey peats (2*c*)—VIII.d_8.f_8.a_4	Palm vegetation (*Nypa*); on scrolls, low evergreen forest stands (*Sonneratia acida*)
4	Large	**Brackish back swamps and back plains**: tracts up to ¼ mile wide, slopes less than 0°30′; hummocky surfaces with up to 3 ft of relief; permanently waterlogged and frequently inundated	Imperfectly drained alluvial soils: alkaline olive grey silty clays (5*a*)—VI.d_2.f_6.a_4	Evergreen thicket (*Hibiscus–Flagellaria*), scrub (*Pluchea–Flagellaria*), or mid-height evergreen forest (*Excoecaria–Hibiscus*)
5	Small	**Salt-water back swamps**: up to ¼ mile wide; hummocky surfaces below extreme H.W.M.; minor salt pans	Mangrove soils: grey clayey peats (2*c*)—VIII.d_8.f_8.a_4	Low evergreen forest (*Avicennia–Excoecaria*); areas of bare ground
6	Very small	**Alluvial fringes**: up to 50 yd wide, with slopes less than 0°30′	Imperfectly drained alluvial soils: alkaline grey sticky clays (5*e*)—VI.d_3.f_6.a_5	Mid-height evergreen forest (*Nauclea–Kleinhovia*)
7	Very small	**Prior levees flanking tidal creek**: up to 4 ft above H.W.M.; 150 yd wide with back slopes up to 2°	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.d_2.f_3.a_4	Evergreen thicket (*Hibiscus–Flagellaria*)

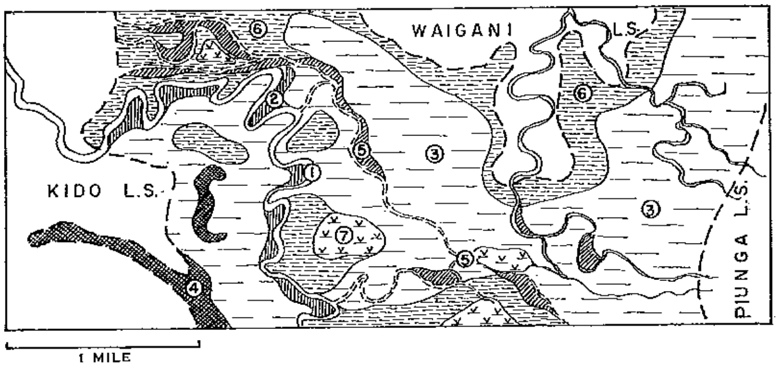
Doura Land System (35 sq miles)

Seasonally flooded, low-lying plains with evergreen thicket, south-east of Galley Reach.

Geology.—Alluvial sand, silt, clay; Recent.

Geomorphology.—Back plains and seasonal back-plain swamps, traversed by lowermost non-tidal reaches of large meandering rivers; back plains with winding swamp outlet channels and levees, and including cut-offs and small permanent swamps which are mainly remnants of disorganized drainage; minor higher-lying prior levees; subject to extensive periodic or seasonal flooding.

Altitude.—0–25 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Main channels and accreting banks:** meandering channels up to 150 ft wide; shelving meander point banks up to 30 yd wide and ¼ mile long, rising to 2 ft above river level, with gentle back slopes	On banks, very poorly drained alluvial soils: grey loams (4*b*)—VIII. $d_8.f_8$	On banks, tall grass (*Saccharum robustum*)
2	Very small	**Main levees:** discontinuous, up to ½ mile long and 30 yd wide; single or parallel crests 2–5 ft above normal river level; short back slopes up to 2°; frequently flooded, with many small overspill channels	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.$d_2.f_6$	Tall evergreen forest (*Octomeles–Artocarpus*)
3	Large	**Back plains:** extending up to 3 miles from channels, which they meet in 2–5 ft banks and from which they descend with overall slopes below 0°30′; locally uneven surfaces, with small, seasonally dry channels	Imperfectly drained alluvial soils: alkaline olive grey silty clays (5*a*)—VI.$d_2.f_6.a_4$	Evergreen thicket (*Hibiscus–Flagellaria*); scrub (*Pluchea–Flagellaria*)
4	Very small	**Prior levees:** tracts up to 500 yd wide, with smooth slopes, 0°15′ to 0°30′, and flattish crests 5–8 ft above normal river level	Moderately well-drained alluvial soils: alkaline olive stratified soils (6*c*)—IV.$d_2.f_3.a_4$	Tall grassland (*Saccharum spontaneum–Imperata*) or semi-deciduous thicket (*Gyrocarpus–Harpullia*)
5	Small	**Secondary channels and levees:** meandering channels up to 50 ft wide; fairly continuous levees up to 50 yd wide, attaining 2–4 ft above normal river level, back slopes 0°30′	Imperfectly drained alluvial soils: neutral olive grey stratified soils (5*d*)—VI.$d_2.f_6$	Mid-height evergreen forest (*Ficus–Myristica*, locally *Heritiera–Bruguiera* on lowest levees)
6	Medium	**Seasonal swamps:** up to 1 mile in extent; flat or very gently sloping surfaces with small pans and prior channels; seasonally flooded to 5 ft	Imperfectly drained alluvial soils: neutral olive grey silty clays (5*b*)—VI.$d_2.f_6$; minor alkaline olive grey silty clays (5*a*)—VI.$d_2.f_6.a_4$	Mid-height evergreen forest (*Melaleuca–Excoecaria*), evergreen thicket (*Hibiscus–Flagellaria*), minor tall grassland (*Saccharum spontaneum–Imperata*)
7	Very small	**Permanent swamps:** up to ½ mile in extent, commonly with some open water	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII. d_8	Tall grassland (*Phragmites–Saccharum robustum*) and mixed herbaceous vegetation (*Leersia–Hanguana*, *Nymphaea–Azolla*)

VII. Littoral Plains Zone (200 sq miles) (Fig. 8)

This zone is formed of Recent littoral, estuarine, and fluvial sediments ranging from sand near the shore to clay and silt inland. Rainfall is mainly between 40 and 50 in. The beaches, inner stranded beach ridges, and beach plains have sandy soils and are vegetated with scrub and evergreen or deciduous thicket which is commonly disturbed, giving way to mid-height grassland on inner beach plains. The tidal flats

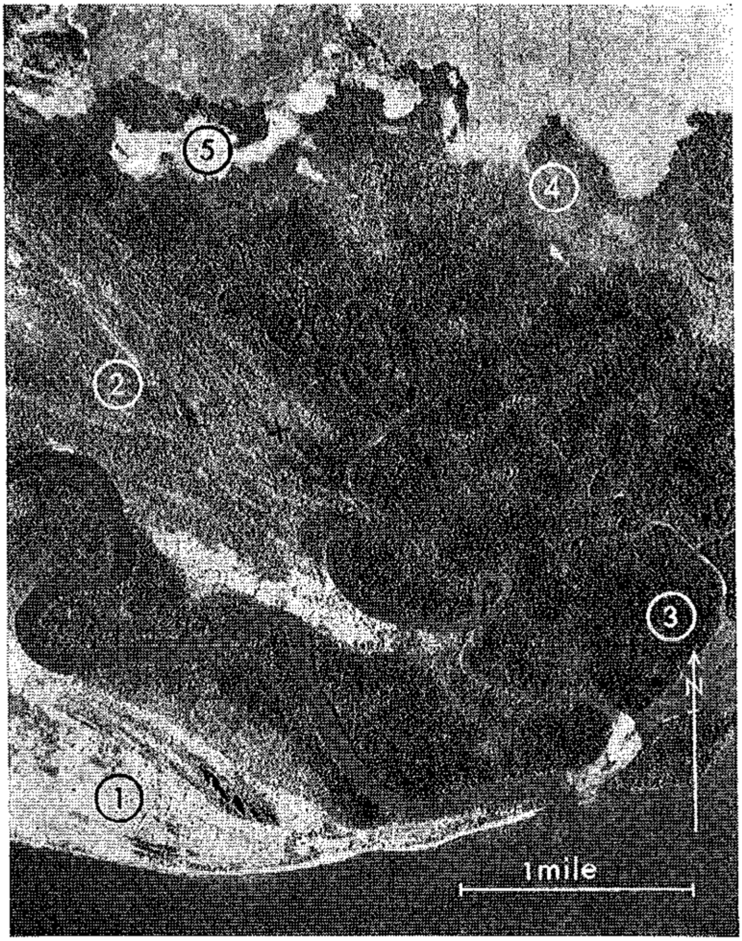


Fig. 8.—Littoral plains zone near Galley Reach, showing outer (1) and inner (2) beach ridges, and lower-lying (3) and higher-lying (4) mangrove forests drained by tidal creeks, with an inner fringe of salt flats (5).

have mangrove soils, with mangroves ranging from dense mid-height evergreen forest below high-water mark to open low evergreen forest near high-water mark and with grass-covered or bare salt flats reached only by the highest tides. The estuaries have grey-brown inter-tidal alluvial soils, mainly silty clays, and the vegetation consists of nypa palm vegetation in riparian tracts and mangroves in tidal back plains.

In Table 8 and in the tabulated descriptions which follow, the land systems of the littoral plains zone are arranged according to the three physiographic settings: beaches, tidal flats, and estuaries. The land systems of the tidal flats are listed in order of increasing height and decreasing frequency of tidal flooding. The complex Papa land system, consisting of beaches *and* flats, has been listed under tidal flats. Papa land system is also exceptional in that it occurs in small embayments, forming outliers of the littoral plains zone on the land system map.

TABLE 8

DIAGNOSTIC FEATURES OF LAND SYSTEMS OF THE LITTORAL PLAINS ZONE

Land System	Lithology	Land Form	Predominant Soil	Predominant Vegetation
Beaches				
Hisiu	Littoral sand	Beach ridges and sand plains	Brown fine sands	Semi-deciduous thicket and mid-height grassland
Tidal flats				
Galley Reach	Littoral clay	Tidal flats below mean high-water mark	Grey clayey peats	Tall mangrove forest (*Rhizophora–Bruguiera*)
Lesewalai		Tidal flats mainly above mean high-water mark	Grey clayey peats seaward; grey to brown silty clays inland	Low mangrove forest (*Avicennia–Ceriops*)
Kido			Grey loamy peats and clayey peats seaward; grey to brown silty clays inland	Low mangrove forest and salt flats
Papa	Littoral sand and clay	Small complexes of beaches and tidal flats	Complex of mangrove and beach soils	Complex of all above vegetation types
Estuaries				
Nipa	Alluvial and littoral silt and clay	Estuarine plains	Grey loamy peats and silty clays	Nypa palm vegetation and mid-height evergreen forest

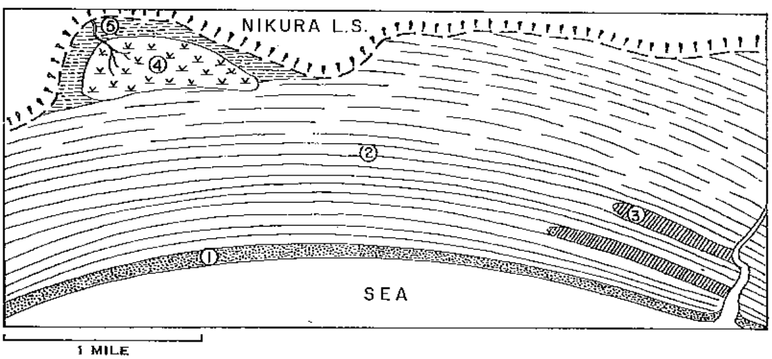
Hisiu Land System (40 sq miles)

Plains of sandy beach ridges along the northern part of the coast.

Geology.—Littoral sand, and alluvial silt and clay; Recent.

Geomorphology.—Prograded beach plains up to 3 miles wide, locally impounding small freshwater swamps on inland margin.

Altitude.—0–25 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Present beaches and foredunes:** lower beaches up to 50 yd wide, with gentle slopes steepening to 10° near H.W.M.; upper beaches with irregular single or double foredunes attaining 10 ft above H.W.M.	Beach soils: on beaches, grey sands (1*c*)—VIII. $d_8.f_8.a_4$; on foredunes, grey fine sands (1*a*)—IV.$so_4.s_2.a_4$	Above H.W.M.: mixed herbaceous vegetation (*Spinifex–Canavalia*)
2	Very large	**Beach ridge complexes and sand plains:** long, parallel sand ridges spaced 30–150 yd apart, up to 3 ft high and with local slopes to 10° near coast, becoming more subdued inland and commonly passing into level or gently sloping sand plain	Beach soils: brown fine sands (1*b*)—IV.$so_4.s_2.a_4$	On beach ridges: evergreen thicket (*Clerodendrum–Flagellaria*, *Hibiscus–Flagellaria*) and semi-deciduous thicket (*Gyrocarpus–Harpullia*), or mixed herbaceous vegetation (*Hyptis–Imperata*). On plains: mid-height grassland (*Ophiuros–Themeda australis*); lower-lying areas with tall grassland (*Saccharum spontaneum–Imperata*)
3	Very small	**Swales below H.W.M.:** up to 200 yd wide and 1 mile long	Mangrove soils: grey loamy peats (2*b*)—VIII.$d_8.f_8.a_4$	Low and mid-height evergreen forest (*Avicennia–Ceriops* without ground cover; *Excoecaria–Hibiscus*)
4	Small	**Swamps:** shallow elongate depressions up to ½ mile wide with local relief up to 1 ft	Very poorly drained alluvial soils: grey sticky clays (4*a*)—VIII.d_8	Open water with patches of mixed herbaceous vegetation (*Nymphaea–Azolla*, *Leersia–Hanguana*)
5	Very small	**Swamp margins:** seasonally flooded zones up to ¼ mile wide, with gentle slopes towards unit 4 and generally not more than 2 ft above it	Imperfectly drained alluvial soils: alkaline grey sticky clays (5*e*)—VI.$d_3.f_6.a_4$	Low grassland (*Sporobolus–Eriochloa*) with patches of mid-height evergreen forest (*Excoecaria–Hibiscus*); fringing mid-height evergreen forest (*Melaleuca–Nauclea*)

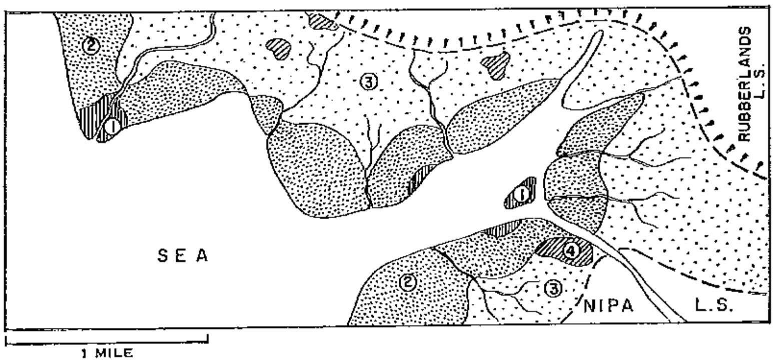
Galley Reach Land System (70 sq miles)

Broad tidal flats with dense mangrove, around large inlets in the north of the area.

Geology.—Littoral and estuarine clay and silt; Recent.

Geomorphology.—Lower tidal flats up to 3 miles wide developed about larger coastal inlets; drained by tidal creeks and estuaries; minor areas of prograding shore, and extensive accumulation of mud and peat.

Altitude.—Sea level.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	Prograding banks: flats up to 2 ft above L.W.M., comprising outermost prior delta of Angabunga River, and discontinuous tracts up to 100 yd wide, mainly in shallow embayments and commonly near tidal river outlets	Inter-tidal alluvial soils: grey silty clays (3*c*)—VIII.d_8.f_8.a_4	Colonizing low evergreen forest (*Avicennia–Sonneratia*)
2	Large	Lower tidal flats: mainly below M.S.L. and forming seaward fringe up to ½ mile wide, locally wider between tidal creeks; up to 1½ miles wide in prior delta of Angabunga River; locally with microrelief as in unit 3 but smaller; traversed by tidal creeks	Mangrove soils: grey loamy peats (2*b*)—VIII.d_8.f_8.a_4	Mid-height evergreen forest (*Rhizophora–Bruguiera* without ground cover)
3	Very large	Upper tidal flats: extending from M.S.L. to H.W.M., forming zones up to 3 miles wide inland from unit 2; extremely hummocky surfaces with mounds up to 4 ft high developing into platforms up to 5 yd across, with intervening passages up to 5 yd wide, generally with water; traversed by small tidal creeks	Mangrove soils: grey clayey peats (2*c*)—VIII.d_8.f_8.a_3	Mid-height evergreen forest (*Rhizophora–Bruguiera* with ground cover)
4	Very small	Uppermost tidal flats: up to ½ mile in extent between tidal creeks within upper part of unit 3, and as tidal back plains near river outlets and subject to freshwater flooding; surfaces as in unit 3		Low and mid-height evergreen forest (*Avicennia–Excoecaria*; *Heritiera–Bruguiera*)

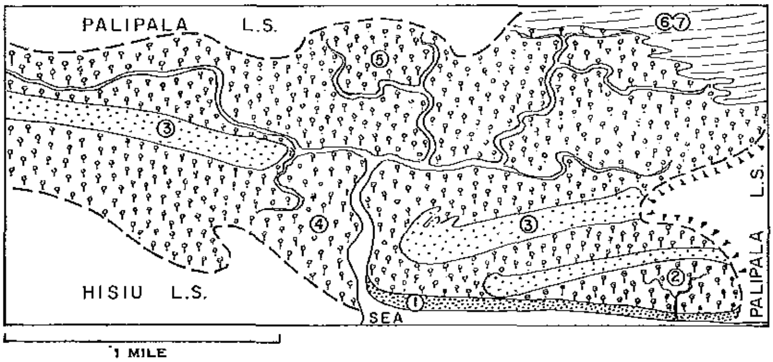
LESEWALAI LAND SYSTEM (20 SQ MILES)

High-lying tidal flats with open low mangrove forest, in the north of the area.

Geology.—Littoral sand and clay, with some alluvial silt; Recent.

Geomorphology.—Tidal flats slightly above mean H.W.M., locally on a retreating coast, elsewhere up to 6 miles inland and in association with old sand beach ridges; locally, an innermost complex of partially buried beach rises and swales; mainly subject to shallow tidal flooding and drained by small creeks, locally subject to fresh-water flooding.

Altitude.—0–5 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	*Present beaches:* lower beaches up to 50 yd wide, slopes 1°30′ to 10°; upper beaches and irregular foredunes up to 10 ft above H.W.M., slopes locally attaining 20°	Beach soils: on fore-dune, grey fine sands (1*a*)—IV.$so_4.s_2.a_1$; on beaches, grey sands (1*c*)—VIII.$d_8.f_8.a_1$	Above H.W.M.: mixed herbaceous vegetation (*Spinifex–Canavalia*)
2	Very small	**Tidal flats on open coast:** extending up to ¾ mile inland, and slightly below mean H.W.M.; hummocky, with up to 1 ft microrelief; small winding creeks	Mangrove soils: grey clayey peats (2*c*)—VIII.$d_8.f_8.a_1$	Mid-height evergreen forest (*Rhizophora–Bruguiera* with ground cover), backed by low evergreen forest (*Avicennia–Excoecaria*)
3	Small	**Inner beach ridges:** subdued sandy rises up to 100 yd wide, slopes up to 1°30′, attaining 3 ft above H.W.M.	Beach soils: brown fine sands (1*b*)—IV.$so_4.s_2.a_1$	Evergreen thicket (*Clerodendrum–Flagellaria, Hibiscus–Flagellaria*)
4	Large	**Inner tidal flats:** extending up to 2 miles inland, above mean H.W.M.; hummocky, with up to 2 ft microrelief; numerous minor creeks; minor salt pans and lagoons	Seaward situations, mangrove soils as in unit 2	Low evergreen forest (*Avicennia–Ceriops*, without ground cover in lowest situations, elsewhere with *Sesuvium* ground cover); salt flats bare or with mixed herbaceous vegetation (*Sesuvium–Tecticornia*); low evergreen forest (*Avicennia–Excoecaria*) marginal to units 3 and 6
5	Large		Landward situations, intertidal alluvial soils: grey to brown silty clays (3*a*)—VIII.$d_8.f_8.a_1$	
6	Small	**Innermost beach rises:** very subdued and up to 50 yd wide, near extreme H.W.M.	Intertidal alluvial soils as in unit 5, but with thinner silty overlay	Evergreen thicket (*Clerodendrum–Flagellaria, Hibiscus–Flagellaria, Acacia–Myoporum*); mid-height evergreen forest (*Excoecaria–Hibiscus*) marginal to unit 7
7	Very small	**Innermost beach swales:** up to 50 yd wide, and up to 2 ft below unit 6	Intertidal alluvial soils as in unit 5	Scrub (*Pluchea–Flagellaria*) and evergreen thicket (*Acacia–Myoporum*); mixed herbaceous vegetation (*Sesuvium–Tecticornia*) in lowest swales

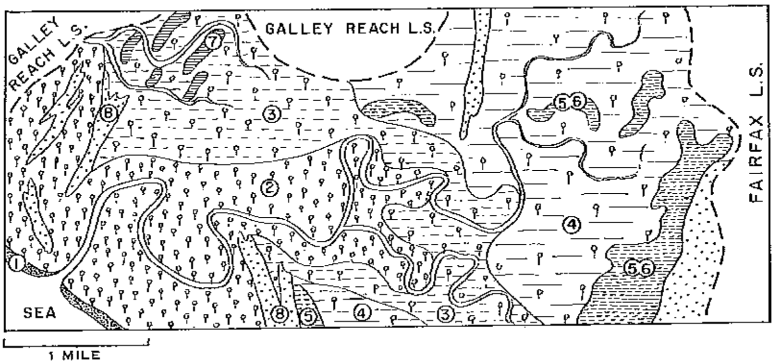
Kido Land System (50 sq miles)

Tidal flats near Redscar Head, with a complex pattern of mangroves, salt flats, and sandy beach ridges.

Geology.—Littoral sand and clay; Recent.

Geomorphology.—Tidal flats mainly above H.W.M., with branching creek systems separated and backed inland by salt flats and stranded sand beach ridges at various levels, and leading to tidal inlets between barrier beaches.

Altitude.—0–15 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Very small	**Outer beaches:** present sand beach with irregular single or multiple foredunes up to 15 ft above H.W.M.; locally backed by complexes up to ½ mile wide of broad low beach ridges and swales, slopes up to 3°, relief up to 5 ft	Beach soils: on beaches, grey sand (1*c*)—VIII. $d_8.f_8.a_4$; on foredunes, grey fine sands (1*a*)—IV.$so_4.s_2.a_4$	Foredunes on seaward side, mixed herbaceous vegetation (*Spinifex–Canavalia*); otherwise, evergreen thicket (*Clerodendrum–Flagellaria*)
2	Medium	**Lower mangrove zone:** up to ½ mile wide astride tidal creeks; below mean H.W.M.; mounds up to 3 ft high	Mangrove soils: grey loamy peats (2*b*)—VIII.$d_8.f_8.a_4$	Low and mid-height evergreen forest (*Avicennia–Sonneratia*; *Rhizophora–Bruguiera* without ground cover)
3	Medium	**Intermediate mangrove zone:** mainly up to 200 yd wide, parallel with creeks; near mean H.W.M.; mounds up to 1 ft high in lower parts	Mangrove soils: grey clayey peats (2*c*)—VIII.$d_8.f_8.a_4$	Low evergreen forest (*Ceriops*)
4	Medium	**Upper mangrove zone:** mainly up to ¼ mile wide, locally attaining 1 mile, and parallel with creeks; at or a little above mean H.W.M.	Intertidal alluvial soils: grey to brown silty clays (3*a*)—VIII.$d_8.f_8.a_4$	Low evergreen forest (*Avicennia–Ceriops* partly with *Sesuvium* ground cover, *Avicennia–Excoecaria*)
5	Very small	**Lower salt flats:** mainly narrow tracts 200–400 yd wide, locally attaining ½ mile in extent; lying 1–2 ft above mean H.W.M.		Mainly bare, with islands of mixed herbaceous vegetation (*Sesuvium–Tecticornia*); fringe of low evergreen forest (*Avicennia–Ceriops* scrub) marginal to units 3 and 4
6	Small	**Higher salt flats:** discontinuous margins against unit 8, mainly less than 400 yd wide; very rarely reached by tides	Intertidal alluvial soils: brown sticky clays (3*b*)—VIII.$d_8.f_8.a_4$	Low grassland (*Sporobolus–Eriochloa*)
7	Very small	**Lower inner beach ridges:** generally not exceeding 1 mile long or 200 yd wide and lying 1–3 ft above H.W.M.; also as swales in unit 8 and as multiple narrow ridges in complex with units 3 and 4	Beach soils: brown fine sands (1*b*)—IV.$so_4.s_2.a_4$	Scrub (*Lumnitzera*); locally on higher parts, evergreen thicket (*Acacia–Myoporum*)
8	Small	**Higher inner beach ridges:** up to 2 miles long, with flat or gently undulating crests up to 400 yd wide, 2–5 ft above H.W.M.		Mixed herbaceous vegetation (*Hyptis–Imperata*), remnants of semi-deciduous thicket (*Gyrocarpus–Harpullia*)

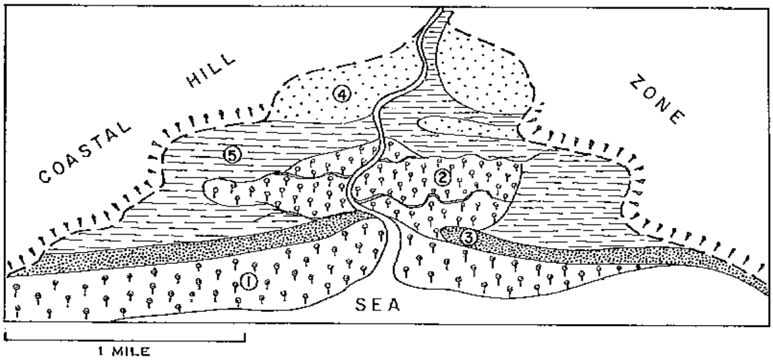
PAPA LAND SYSTEM (10 SQ MILES)

Small complexes of sandy beaches and mangrove flats, mainly in the south half of the area.

Geology.—Littoral sand and clay; Recent.

Geomorphology.—Discontinuous littoral plains mainly less than 1 mile wide behind fringing reefs; with outer tidal flats on accreting coasts, and inner tidal flats, slightly below and slightly above mean H.W.M., between present and inner beach ridges; drained by small creeks.

Altitude.—0–15 ft.



Unit	Area	Land Form	Soil	Vegetation
1	Medium	Outer tidal flats: zones up to 300 yd wide sloping gently to fringing coral reefs	Mangrove soils: grey sandy peats (2*a*)—VIII.d_8.f_8.a_4	Mid-height evergreen forest (*Rhizophora Bruguiera*, stunted form)
2	Medium	Lower inner tidal flats: close to mean H.W.M.; generally up to 200 yd wide, parallel with coast and drained by small creeks; locally extending up to 1 mile inland along larger creeks	Mangrove soils: grey clayey peats (2*c*)—VIII.d_8.f_8.a_4	Low evergreen forest (*Avicennia–Ceriops* without ground cover)
3	Small	Present beaches: gently sloping lower beach up to 50 yd wide; steeper upper beach and irregular low foredune backed by flattish beach-ridge crest up to 50 yd wide, 2–5 ft above H.W.M.	Beach soils: on beach, grey sands (1*c*)—VIII.d_8.f_8.a_4, on foredunes, grey fine sands (1*a*)—IV.so_4.s_2.a_4	Above H.W.M.: mixed herbaceous vegetation (*Spinifex–Canavalia*)
4	Medium	Inner beaches: up to ¼ mile wide, consisting of sand plain or of subdued parallel ridges up to 2 ft high, slopes to 2°	Beach soils: brown fine sands (1*b*)—IV.so_1.s_2.a_4	Mixed herbaceous vegetation (*Hyptis–Imperata*), mid-height grassland (*Imperata–Themeda australis*), scrub (*Premna–Scaevola*) or evergreen thicket (*Clerodendrum–Flagellaria*)
5	Medium	Higher inner tidal flats: elongate flats or swales up to ½ mile wide at or slightly above mean H.W.M., draining to unit 2	Intertidal alluvial soils: brown sticky clays (3*b*)—VIII.d_8.f_8.a_4	Lower parts bare or with mixed herbaceous vegetation (*Sesuvium–Tecticornia*); higher parts with low grassland (*Sporobolus–Eriochloa*)

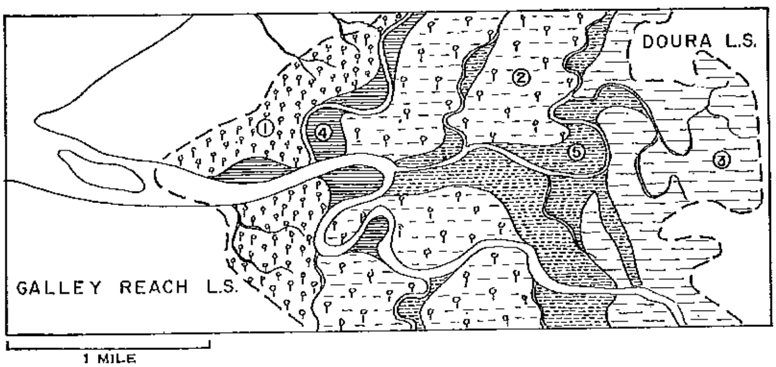
Nipa Land System (30 sq miles)

Inner mangrove flats with areas of nypa palms, near Redscar Bay and Lesi Inlet.

Geology.—Alluvial and littoral silt and clay; Recent.

Geomorphology.—Estuarine plains extending between 1 and 5 miles inland, and between M.S.L. and H.W.M., mainly draining to and extending inland along large tidal rivers, but also extensively drained to tidal inlets; riparian zones flanking tidal creeks and rivers; back plains flooded from rivers and large creeks, but sloping to minor outlet creeks; much tidal accretion aided by vegetation.

Altitude.—Near sea level.



Unit	Area	Land Form	Soil	Vegetation
1	Small	**Outermost tidal flats:** up to 1 mile wide, generally below M.S.L.; hummocky surfaces	Mangrove soils: grey loamy peats (2*b*)—VIII.d$_8$.f$_8$.a$_4$	Mid-height evergreen forest (*Rhizophora–Bruguiera* with ground cover)
2	Medium	**Outer tidal back plains:** up to 1 mile in extent between main tidal creeks, drained by smaller creeks; probably extending about 3 ft below H.W.M.; uneven surfaces with mounds up to 3 ft high and interconnecting depressions with standing water at low tide		Mid-height evergreen forest (*Heritiera–Bruguiera*)
3	Medium	**Inner tidal back plains:** as unit 2, but situated on its landward margins and also commonly fronting directly on channels and major creeks	Intertidal alluvial soils: grey silty clays (3*c*)—VIII.d$_8$.f$_8$	As unit 2; also palm vegetation (*Nypa*, successional stage to *Heritiera–Bruguiera* forest)
4	Small	**Nipa flats:** levee zones up to ½ mile wide astride tidal rivers and creeks, narrowing and becoming discontinuous inland; sloping gently from creeks towards units 2 and 3; uneven surfaces with mounds up to 2 ft high, extending to near H.W.M.; also, active and cut-off meander points commonly up to ½ mile in extent, with scrolls and accreting point bars	Seaward parts, mangrove soils: grey clayey peats (2c)—VIII.d$_8$.f$_8$.a$_4$	Palm vegetation (*Nypa*); on accreting banks and scrolls, low evergreen forest stands (*Sonneratia acida*)
5	Medium		Landward parts, more liable to freshwater flooding, intertidal alluvial soils: grey silty clays (3*c*)—VIII.d$_8$.f$_8$	

PART IV. CLIMATE OF THE PORT MORESBY–KAIRUKU AREA

By E. A. FITZPATRICK*

I. INTRODUCTION

(a) *Principal Climatic Features*

The general character of the climate within the area may be described according to either the Köppen (1931) or Thornthwaite (1931) classifications as grading from a tropical savannah or subhumid tropical type in the driest areas to a tropical rain forest or wet tropical type in areas of highest rainfall (*Aw* to *Af* or *CA'r* to *AA'r* types respectively).

A prominent feature of the climate is the very limited range of temperature, both seasonal and diurnal. At coastal localities the annual range of mean temperature is about 5°F and the mean diurnal range for any month does not exceed 15°F. Frost does not occur within the area. Rainfall ranges from about 40 in. in the most sheltered locations along the coast to about 150 in. in exposed slope situations at higher altitudes. In all parts of the area rainfall is highest between December and April. Between June and October drier conditions prevail, although nowhere within the area does this drier season assume the almost rainless character of large parts of northern Australia.

(b) *Climatic Controls*

Climate in the area strongly reflects the seasonal alternation in wind systems and the influence of the major physiographic features as related to those systems. As elsewhere in Papua–New Guinea, two wind systems can be recognized as major controls, and these largely explain the broad features of the climate. Winds predominantly from the north-west (monsoons) occur between December and mid April, and with these the heaviest and most frequent rainfalls are clearly associated. South-easterlies (trades) prevail between June and mid October, and drier conditions occur during this period throughout the area. However, where prominent topographic barriers occur across the path of moist air masses, substantial rainfall does occur even during this season. Very brief transitional or "doldrum" periods of light and variable winds occur during late October and November and again during late April and May. The marked seasonal contrasts in wind conditions are clearly shown by the series of wind roses given in Figure 9. These are based upon data obtained from 3-hourly observations at Jackson's Airport over the period 1952 to 1957, as presented originally in table form by Glendinning (1959). This regime of winds can be regarded as generally representative for the area, although immediate terrain effects and differences in the intensity to which land and sea breezes are developed do cause minor local modifications. It is particularly noteworthy that the mean wind velocity is greatest and winds are directionally most persistent during the

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south-east season; by contrast, winds during the north-west season are very variable. The south-easterlies reach their peak in September. For a description of wind and other synoptic controls in relation to the observed character of weather and climate in this and other parts of Papua–New Guinea, readers are referred to Glendinning (1959), Hounam (1951), and Hogan (1940).

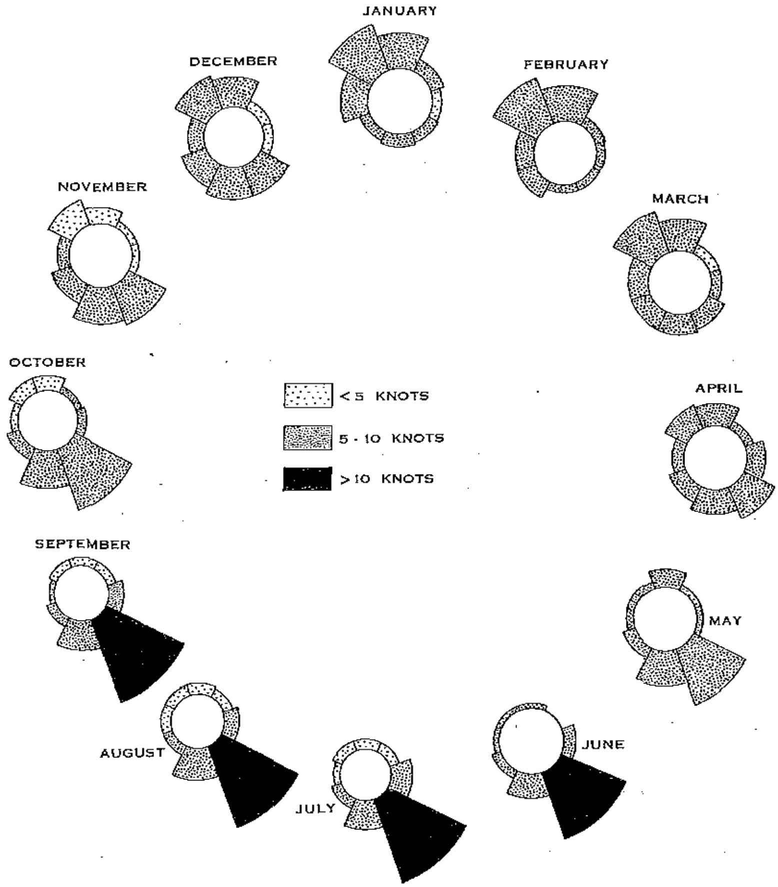

Fig. 9.—Monthly wind roses from Jackson's Airport, showing percentage frequencies of wind from eight compass point intervals with their associated mean velocities and the frequency of calm conditions. The total area of each of the wind roses is the same and represents a percentage frequency of 100. Areas of central circles (representing the percentage frequency of calm conditions) and of each of the eight surrounding sectors (representing the percentage frequency of winds from that sector) are proportional. *Tonal symbols show differences in* mean wind velocity for each sector as indicated in the legend.

A feature having an important bearing upon the climate of the area is the generally parallel alignment of the coast and ranges with prevalent winds. Except in restricted localities where significant coastward extensions of the main ranges occur, or where open valleys can effectively cause the funnelling and uplift of moist air masses in the upland zone, conditions are generally less favourable for rainfall than they are either south-east or north-west of the area, where the coast and ranges have an oblique trend with respect to the prevailing winds. This feature largely accounts for the abnormally low rainfall along this part of the Papuan coast.

Temperature and humidity, as well as rainfall, are broadly controlled by alternations in the major wind systems. During the north-west season warm and humid conditions prevail, and cooler and drier weather is associated with the south-easterlies, particularly when pressure patterns to the south promote a long passage of air over cold southerly oceans. Since the climate is dominated by maritime controls, very high temperatures with low humidities are not a characteristic feature before the onset of the wet season, as they are in much of northern Australia.

Local winds are a prominent feature of daily weather. These include land and sea breezes which operate throughout the year but which are particularly conspicuous during the transitional months. Strong nocturnal katabatic (mountain) winds from higher areas reinforce land breezes, and daytime upslope (valley) winds often act in conjunction with the normal onshore sea breezes. Although the area is outside the zone of tropical cyclones, localized winds of up to 50 knots do occur at times. These squally conditions are generally associated with the north-west season and often occur with rain. A particularly violent squall wind known as the guba is a distinctive feature in the vicinity of Fairfax Harbour near Port Moresby.

II. General Climatic Characteristics

(*a*) *Rainfall*

Rainfall stations within the area are very unevenly distributed, and most stations have records for less than 10 years. Only in the Port Moresby–Sogeri area is the network of stations sufficiently close to establish the distribution of rainfall with some clarity. In most cases the available data are so limited that the pattern can be estimated only by extrapolating relationships between rainfall and environmental features observed in other parts of the area. Because rainfall records are generally short, valid comparisons between stations are difficult. To facilitate regional comparison reference here is based primarily upon rainfall records over the 7-year period 1954–60. Although this interval is shorter than is generally considered necessary to establish stable "normals", this procedure has been adopted to achieve some degree of homogeneity in the data. In a few instances mean rainfalls could be obtained from data over considerably longer periods, but the differences between these values and the means obtained from the adopted 7-year period are small.

Table 9 gives mean monthly and annual rainfall data for all stations within or close to the area which have records over at least 5 years, and Figure 10 shows the estimated pattern of mean annual rainfall within the area. Figure 10 is based primarily upon the 7-year means, but supplementary reference was made to means obtained from shorter records where stations are sparse, and the isohyets are placed with consideration given to altitude, aspect, vegetation, and soils.

Mean annual rainfall generally increases inland from the coast, the isohyets being approximately parallel to the coast except where orographic effects are prominent. The lowest of the 7-year means (approx. 39 in.) is at Government House,

TABLE 9

RAINFALL CHARACTERISTICS FOR 15 STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Bisianumu (5 yr of records)													
Mean rainfall (in.)	9·5	10·8	10·5	14·4	6·8	4·9	7·2	4·2	7·0	9·6	5·0	12·8	102·8
Mean number of rain days*	17	16	15	19	16	13	8	5	12	11	9	18	159
Bereina (7 yr of records†)													
Mean rainfall (in.)	7·3	8·9	7·6	7·9	1·3	0·9	0·8	0·6	1·9	1·7	2·0	9·2	50·2
Mean number of rain days	18	17	14	15	7	7	6	4	7	8	5	13	121
Boroko (5 yr of records)													
Mean rainfall (in.)	8·7	7·1	6·7	6·2	3·0	1·3	0·4	0·8	3·8	0·4	0·5	4·8	43·7
Mean number of rain days	16	14	12	15	8	7	4	4	7	4	4	11	106
Bomana Pumping Station (5 yr of records)													
Mean rainfall (in.)	6·1	7·7	5·0	5·1	3·0	0·9	0·7	0·8	3·3	1·2	2·0	4·7	40·3
Mean number of rain days	17	20	15	16	11	8	6	4	10	7	6	13	133
Eilogo (7 yr of records†)													
Mean rainfall (in.)	8·7	10·3	9·2	15·5	10·3	4·0	2·2	3·4	7·2	8·6	7·7	12·4	99·6
Mean number of rain days	15	16	16	17	14	9	7	6	12	13	11	15	151
Ilolo (7 yr of records†)													
Mean rainfall (in.)	9·6	11·6	9·2	11·9	8·8	4·0	2·2	3·5	6·8	9·1	7·5	11·6	95·7
Mean number of rain days	19	21	19	20	18	12	10	8	15	17	14	20	193
Itikinumu (7 yr of records†)													
Mean rainfall (in.)	10·5	11·2	18·7	15·5	13·8	5·2	3·1	3·4	8·7	11·5	11·3	13·8	126·6
Mean number of rain days	18	21	19	21	19	11	9	8	15	18	16	17	192
Jackson's Airport (7 yr of records†)													
Mean rainfall (in.)	5·8	8·7	5·7	8·8	1·5	0·6	0·4	0·9	2·6	0·9	3·2	6·3	45·2
Mean number of rain days	16	18	17	16	7	6	4	4	7	7	7	14	123

Iawarere (7 yr of records†)													
Mean rainfall (in.)	10·7	11·5	13·1	16·3	14·0	8·4	5·1	5·9	8·8	9·6	10·6	19·5	133·5
Mean number of rain days	16	18	20	18	20	18	15	13	15	15	12	16	196
Kairuku (7 yr of records†)													
Mean rainfall (in.)	7·1	10·5	8·0	6·4	1·1	1·0	0·5	0·4	2·0	1·2	1·4	8·7	48·4
Mean number of rain days	12	15	13	11	5	4	4	3	5	6	4	10	92
Koitaki (7 yr of records†)													
Mean rainfall (in.)	9·8	12·6	9·5	11·2	11·9	5·3	3·3	4·8	8·5	10·3	9·0	11·3	107·2
Mean number of rain days	15	18	16	14	15	8	8	7	10	13	11	12	147
Mageri (6 yr of records)													
Mean rainfall (in.)	8·0	10·8	9·6	11·4	8·6	3·4	2·4	4·4	7·7	6·9	5·9	8·3	87·4
Mean number of rain days	17	22	19	22	17	12	10	10	13	15	11	16	184
Port Moresby—Government House (7 yr of records†)													
Mean rainfall (in.)	5·2	8·4	4·7	5·7	1·3	0·7	0·5	1·2	3·1	0·4	1·8	5·6	38·8
Mean number of rain days	12	14	12	13	6	4	3	3	6	5	5	10	93
Rouna Hotel (7 yr of records†)													
Mean rainfall (in.)	7·8	12·2	10·5	10·3	7·1	2·9	2·2	2·4	4·8	4·0	6·7	8·1	79·0
Mean number of rain days	13	15	13	13	10	7	6	5	7	8	8	12	117
Subitana (5 yr of records)													
Mean rainfall (in.)	9·4	11·2	14·4	16·4	16·5	7·1	3·5	5·5	10·8	14·7	13·4	19·4	142·2
Mean number of rain days	14	15	16	18	16	12	8	9	11	15	12	18	164
Ukua (5 yr of records)													
Mean rainfall (in.)	6·9	11·0	8·1	9·3	9·2	4·4	5·6	3·0	8·0	10·2	8·2	17·1	101·0
Mean number of rain days	16	18	17	18	15	9	10	10	16	16	11	18	174

* Rain day is considered here as a day with recorded rainfall, i.e. $\geqslant 0 \cdot 01$ in.

† The period referred to is 1954–60 inclusive.

Port Moresby, and the highest (approx. 127 in.) occurs at Itikinumu estate on the Sogeri Plateau. It should be noted, however, that a mean value of approximately 142 in. over a 5-year period at Subitana estate appears valid, and field evidence suggests that even higher rainfall occurs on exposed slopes in the vicinity of this station.

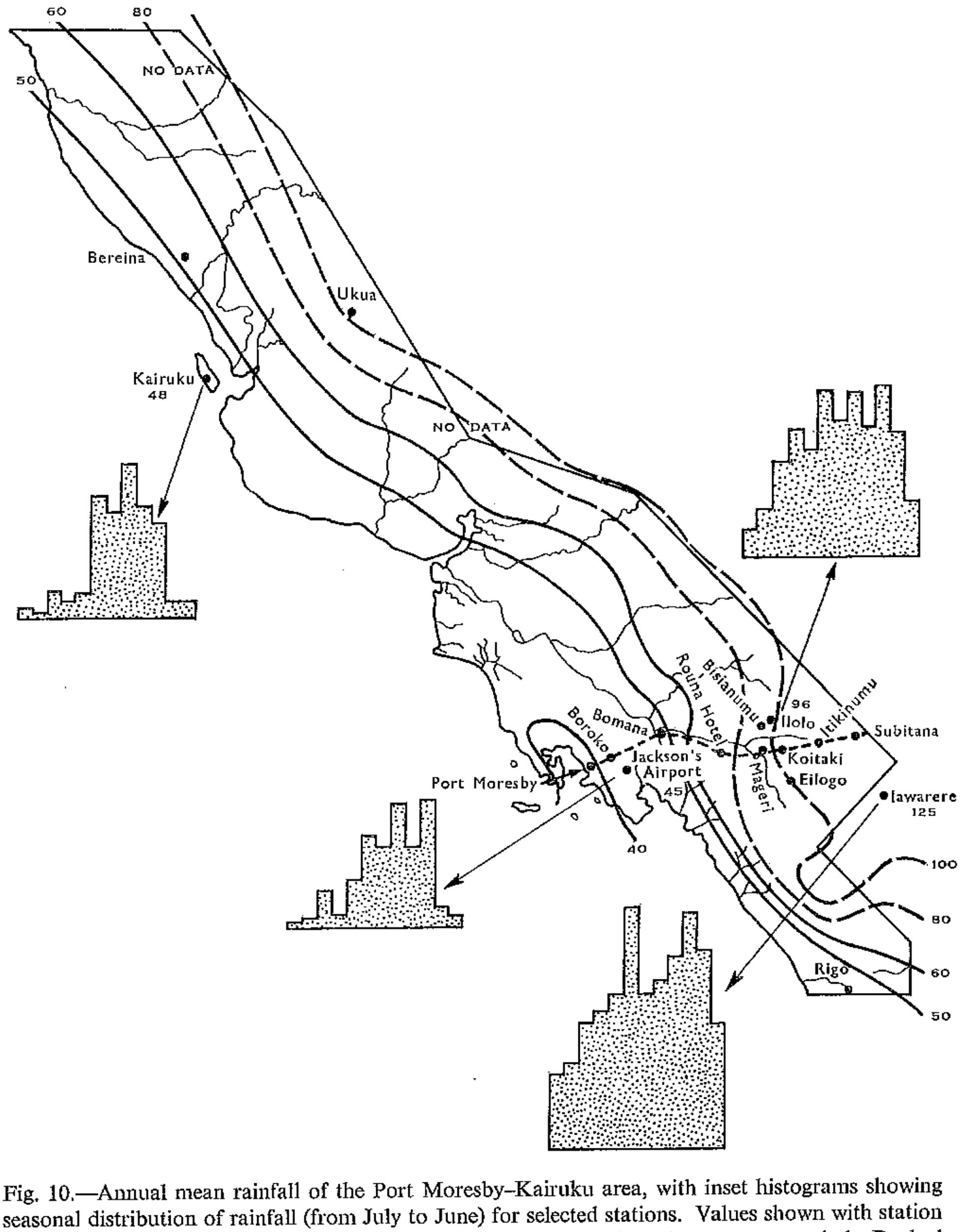

Fig. 10.—Annual mean rainfall of the Port Moresby–Kairuku area, with inset histograms showing seasonal distribution of rainfall (from July to June) for selected stations. Values shown with station names are the mean annual rainfall for the station over the adopted seven-year period. Dashed line from Port Moresby to Subitana is that along which the profiles in Figure 11 are taken.

Throughout the north backing ranges the isohyetal pattern in Figure 10 is at best tentative, since this is an area of complex relief, and the only stations other than Ukua for which records are available are situated either close to the coast or much further inland. The mean annual rainfall over the 5 years at Ukua is approximately 100 in. Some stations further inland (in the headwaters of the Angabunga River and well outside the area) have lower mean annual rainfalls, suggesting a complex distribution with considerable rain-shadow effects.

Although the amount and character of rainfall are strongly affected by differences in aspect of slopes relative to the major wind systems, there is an obvious general increase in rainfall with elevation throughout the area. This is clearly seen from the section in Figure 11 depicting general conditions from Port Moresby to the Sogeri Plateau. These relationships can be regarded as generally representative of the progressive increase in rainfall from the coast to the upland zone, but higher falls do occur at lower elevations on strongly exposed slopes, and rain-shadow effects are evident on the leeward sides of prominent relief features within sheltered valleys at higher altitudes.

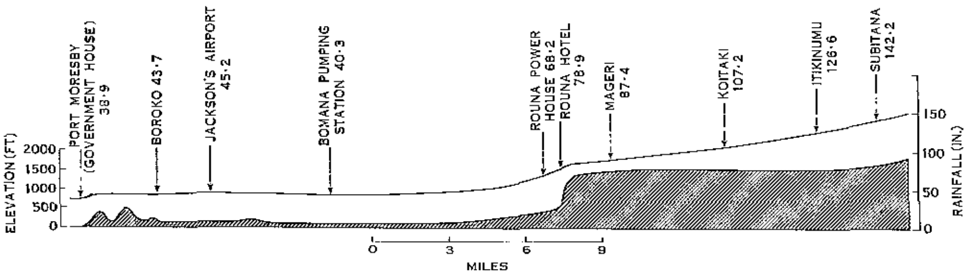

Fig. 11.—Relationship between mean annual rainfall and altitude along a profile from Port Moresby to Bomana pumping station on the Laloki River, and thereafter upstream along the general courses of the Laloki River and Eworogo Creek.

The strong seasonal contrasts in rainfall throughout the area are evident from mean monthly values given in Table 9 and from the histograms included in Figure 10. It is notable that only in the coastal lowland are the mean monthly rainfalls during the driest parts of the south-east season below 1 in. At higher elevations the lowest mean monthly values are generally between 2 and 4 in. At Iawarere, to the east of the Sogeri Plateau, mean rainfall of the driest month is about 5 in. During the wet north-west season, mean monthly rainfalls over the low coastal lowland are between 5 and 8 in. whereas at higher altitudes they are generally over 10 in. The mean number of rain days follows closely the same seasonal and spatial relationships as does mean rainfall.

Both annual and monthly rainfalls vary considerably from year to year. The coefficients of variation of annual rainfall at Port Moresby and Itikinumu are approximately 20 and 18% respectively. This degree of annual rainfall variability is about equal to that occurring in areas of similar mean rainfall in northern Australia, but is higher than that noted by Arnold (unpublished data) for the Wewak–Lower Sepik area. The wide range of monthly rainfall which occurs at both coastal and elevated inland stations is evident from the percentage frequencies given in Table 10.

The persistency of rainfall differs considerably throughout the area. Within the dry coastal lowland, runs of consecutive rain days are not often longer than 10 days during the north-west season or 5 days during the driest part of the south-east season. On the other hand, within the wettest portion of the Sogeri Plateau and adjacent mountainous areas, runs of rain days of these durations are the rule rather than the exception.

TABLE 10

PERCENTAGE OF MONTHLY RAINFALLS EXCEEDING SPECIFIED AMOUNTS AT PORT MORESBY AND ITIKINUMU

Amount (in.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Port Moresby						
0·5	100	100	98	95	68	63	49	49	58	53	77	95
2·0	98	95	91	77	44	18	19	16	18	23	40	77
4·0	74	82	74	49	18	5	4	4	4	9	16	56
8·0	30	37	28	19	4	2	—	—	—	4	4	18
16·0	2	7	2	4	2	—	—	—	—	—	—	2
						Itikinumu						
0·5	100	100	100	100	100	93	98	96	97	98	100	100
2·0	97	96	100	100	97	85	76	85	92	98	99	100
4·0	92	93	100	100	86	74	41	74	89	95	96	100
8·0	71	72	90	89	60	35	19	29	47	73	82	68
16·0	29	16	37	42	21	5	—	3	14	11	27	22

Rainless spells of from 5 to 10 days are common during the wet season within the dry coastal lowland, and occasionally periods of more than two weeks without rainfall may elapse during this season; during the drier part of the year, the passing of whole months without rainfall or with amounts less than 0·5 in. is not uncommon in this coastal area, as seen from the percentage frequencies for Port Moresby in Table 10. In the higher-rainfall areas of the Sogeri Plateau, rainless spells longer than one week during the north-east season or longer than a fortnight during the south-east season are uncommon.

The percentages of rain days with total falls within specified ranges are shown for three stations in Table 11. In general, these indicate that the high monthly totals are mainly the result of moderate but frequent falls. At all the stations included in Table 11, roughly 80% of the daily totals during January and February are less than 1 in. From the values for Eilogo and Iawarere, it appears that the high monthly totals during the north-west season in the Sogeri–Upper Kemp Welch area are largely the result of many daily falls within the range of 1 to 4 in., but daily totals higher than 4 in. are not often experienced even in these high-rainfall areas. At Jackson's Airport, between 80 and 90% of the daily falls between June and August are of less than 0·25 in.

(b) *Temperature*

Extended temperature records are available only in the vicinity of Port Moresby. Some records have been kept for Kairuku and Bereina, but these are not given here since the temperature characteristics of Port Moresby can be considered generally representative of the coastal lowland. A few years of 9 a.m. and 3 p.m. temperature data are available for Rouna power station (elevation 520 ft), but these do not differ greatly from comparable data collected at Jackson's Airport. Small amounts of data are also available from non-standard installations maintained privately.

General temperature characteristics at Jackson's Airport are shown in Table 12.

Mean maximum temperature ranges from 82°F in August to nearly 90°F in December. As seen from the percentage frequencies, the highest maxima occur mostly between October and December, but it is notable that even at this time,

TABLE 11

PERCENTAGE OF RAIN DAYS* WITH TOTAL FALLS WITHIN SPECIFIED RANGES FOR THREE STATIONS

Amount (in.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Eilogo						
0·01–0·24	42	20	45	26	37	61	70	63	42	36	38	44
0·25–0·99	44	61	32	47	41	26	20	16	40	46	42	26
1·00–1·99	6	8	14	16	14	7	9	9	12	11	17	21
2·00–3·99	7	11	10	10	8	6	2	12	5	6	3	7
⩾4·00	—	—	—	2	—	—	—	—	1	1	—	1
						Jackson's Airport						
0·01–0·24	66	50	67	63	77	83	87	89	76	87	54	67
0·25–0·99	23	36	23	16	14	17	8	11	16	13	38	19
1·00–1·99	6	11	5	16	5	—	5	—	2	—	7	9
2·00–3·99	5	2	4	4	4	—	—	—	4	—	—	4
⩾4·00	—	2	—	1	—	—	—	—	2	—	—	—
						Iawarere						
0·01–0·24	42	42	47	29	48	52	70	57	42	37	39	25
0·25–0·99	34	36	31	31	26	31	21	29	31	37	28	42
1·00–1·99	17	12	14	26	17	14	8	8	22	21	25	17
2·00–3·99	7	9	8	13	9	3	2	5	5	5	7	12
⩾4·00	—	—	—	2	1	—	—	1	—	—	1	4

* Rainfall ⩾0·01 in. considered as a rain day. Percentages obtained from 7 yr of record.

temperatures above 95°F are rare. This condition can be attributed to strong day-time advection of cooler air from the sea. Although maximum temperatures are likely to be somewhat higher further inland within the low coastal zone, sea-breeze effects are strong enough to cause some suppression of the daily temperature rise throughout the area generally. During the cooler months, June to August, about 80 to 85% of the daily maxima exceed 85°F, but only about 7% are above 90°F at this time.

Annual variation of the mean minimum temperature has an even smaller range than that of the mean maximum. At Jackson's Airport the mean minimum ranges from 72·9°F in August to 76·3°F in December. Even in the coolest months, only a small percentage of the daily minima is below 65°F. Dew-point temperatures in this area are normally between 70 and 75°F, and the minimum temperatures usually fall below this. Heavy dew formation is thus characteristic throughout the year.

TABLE 12
TEMPERATURE CHARACTERISTICS AT JACKSON'S AIRPORT, PORT MORESBY*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean maximum temperature (°F)	89·4	88·6	88·4	87·4	85·8	84·2	82·5	82·0	83·7	85·9	88·0	89·7	86·3
Mean temperature (°F)	82·8	82·3	82·2	81·4	80·4	79·0	77·6	77·5	78·7	80·3	81·9	83·0	80·6
Mean minimum temperature (°F)	76·1	76·0	75·9	75·3	75·0	73·9	73·0	72·9	73·8	74·7	75·7	76·3	74·9
Percentage of daily maxima above 85°F	97	93	95	80	90	85	78	86	88	100	95	97	
90°F	59	32	41	14	19	7	7	10	16	46	64	62	
95°F	1	—	—	—	—	—	—	—	—	1	1	1	
Percentage of daily minima below 75°F	89	90	94	90	81	93	97	98	85	78	73	84	
70°F	1	2	4	8	16	26	25	25	10	13	8	2	
65°F	—	—	—	—	3	4	2	3	1	1	—	—	

* Temperature means obtained from published data of Bureau of Meteorology (1956); other data from daily temperature records, 1950–62 inclusive.

Minimum temperatures can be expected to be generally lower with greater distance inland and with increased altitude; however, temperatures throughout the area are never low enough to pose a risk of frost. Limited data from non-standard installations in the Sogeri Plateau area suggest that minimum temperatures there are not greatly dissimilar from those given in Table 12.

(*c*) *Humidity*

Average humidity conditions throughout the year at Jackson's Airport are shown in Table 13 under the headings relative humidity and 9 a.m. vapour pressure. Mean relative humidity is high throughout the year, the monthly average index of mean relative humidity ranging narrowly between 74 and 82%. The higher levels during the period May to October are the result of lower temperatures. Mean 3 p.m. relative humidity shows a similar annual course, but is generally about 10% lower than the average index. It is notable that even in this relatively dry part of the area the mean daytime humidity does not fall below 65%. It may be reasonably expected that mean relative humidities much higher than this occur in the wetter parts of the area, particularly within microenvironments having denser vegetational cover and persistently moist soil conditions. The mean monthly 9 a.m. vapour pressures may be interpreted as measures of the absolute atmospheric moisture conditions. These show only small variation through the year, but are evidently higher in the wet north-west season than in the dry south-east season.

(*d*) *Cloud, Sunshine, and Total Incoming Radiation*

Mean cloudiness and duration of sunshine for Jackson's Airport are included in Table 13; with these are given total incoming radiation estimates obtained from the mean sunshine data by the method of Black, Bonython, and Prescott (1954).

Although cloudiness is distinctly highest during the north-west season, the seasonal contrasts are not as pronounced as might be expected from consideration of seasonal differences in rainfall alone. With few exceptions, mean cloudiness in the afternoon is higher than in the morning.

Mean daily duration of sunshine ranges generally between 6·0 and 7·5 hr. However, November is a distinctly sunnier month with a mean of 8·4 hr of sunshine per day.

The estimated total incoming radiation ranges between 350 cal/cm^2/day in July, when reduced day length and sun angle are important, to 525 cal/cm^2/day in November when longer days, higher sun angles, and comparatively low cloudiness combine to form optimal conditions for large total energy receipts. The estimated levels during the north-west season are roughly comparable to those observed during the wet season at Darwin (Bureau of Meteorology 1963), but during the south-east season these estimates are lower, agreeing with the cloudier conditions normally occurring at this time in the area.

Although no other data relating to radiation are available from the area, it is well known that much cloudier conditions prevail along the slopes of the higher ranges. Doubtless total radiation in these areas is considerably lower than the estimates given in Table 13.

TABLE 13

MEAN MONTHLY DATA FOR ELEMENTS OTHER THAN RAINFALL AND TEMPERATURE AT JACKSON'S AIRPORT

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average index of relative humidity*	74	75	77	79	81	80	81	80	82	80	79	76	78
3 p.m. relative humidity (%)	66	68	68	71	72	72	69	71	67	66	65	65	68
9 a.m. vapour pressure† (inHg)	0·837	0·834	0·854	0·854	0·847	0·799	0·772	0·758	0·811	0·834	0·867	0·865	
9 a.m. cloudiness‡ (tenths)	6·4	6·6	6·0	5·5	5·2	5·3	5·5	5·8	5·7	5·5	5·0	5·5	5·7
3 p.m. cloudiness (tenths)	6·8	7·0	7·1	5·8	5·2	5·5	5·3	5·8	5·8	6·1	5·8	6·4	6·1
Duration of sunshine§ (hr/day)	6·6	6·0	6·7	6·4	7·5	7·1	6·5	6·6	6·7	7·6	8·4	7·4	7·0
Total (global) radiation‖ (cal/cm²/day)	436	456	439	403	379	364	350	376	439	470	525	462	5099
Evaporation¶ (in./month)	6·36	4·99	5·53	4·70	5·27	4·56	5·58	6·50	6·45	7·91	7·52	7·09	72·46

* Average index of relative humidity is an approximation of the mean daily relative humidity and is calculated from the ratio of the 9 a.m. vapour pressure to the saturation vapour pressure at the mean air temperature. Source of data: Bureau of Meteorology (1956).

† Derived from average index of relative humidity (Bureau of Meteorology 1956) and mean air temperature (Table 12).

‡ Data published by Bureau of Meteorology (1940).

§ From daily records from Campbell-Stokes recorder, 1957–62 inclusive.

‖ Estimated by method of Black, Bonython, and Prescott (1954).

¶ From daily records of evaporation from standard Australian tank, 1957–62 inclusive.

(e) *Evaporation*

Evaporation data are available from Jackson's Airport since 1957, and means obtained from these are included in Table 13. Some very short and broken records are also available from evaporation tanks installed in the Sogeri Plateau area. The data for Jackson's Airport may be considered representative of the dry coastal zone. Monthly values range from about 4·5 in. to 8·0 in. The highest evaporation rates occur during the October to December period when the highest maximum temperatures are observed (Table 12) and when total radiation is high. The mean annual evaporation at Jackson's Airport is about 70 in.

Estimates of evaporation in the cloudier and more humid environments found at higher altitudes within the area are difficult to obtain in the absence of data other than rainfall. However, the limited tank evaporation data from the Sogeri Plateau suggest that *in general* evaporation is only about 60% of that observed at Jackson's Airport.

III. Climate, Plant Growth, and Land Use

The climate of the area is generally favourable for plant growth, with temperatures normally within an optimal range and with moisture adequate either over the entire year or over a considerable part of it. Nonetheless, marked contrasts in vegetational characteristics do occur within the area and these suggest a considerable degree of adaptation to local differences in the length and severity of the drier season.

To assess the extent to which variations in rainfall are likely to be restrictive in agriculture, all weekly rainfall data available for Jackson's Airport and Koitaki over the period 1939 to 1961 have been analysed using water-balance evaluation techniques of Slatyer (1960). These may be considered generally appropriate for crops established in the early part of the wet season and thereafter dependent solely upon rainfall for their water requirements. Similar methods used by Fitzpatrick (1965) which have been found to give good agreement with native pasture growth characteristics in northern Australia have also been applied. In recognition of likely differences in available stored soil moisture, depending upon variable soil properties and rooting depth, these evaluations have been made with two levels of assumed maximum storage, viz. 2 in. and 4 in. For details of the methods employed, these references may be consulted.

On the basis of Slatyer's water-usage models for crops assumed to have been sown in late December, the water-balance evaluations suggest that rainfall has never been so low or so poorly distributed at either station as would result in an early termination of crop development. These conditions apparently apply for both of the assumed storage levels, even for crops with a growth period as long as 20 wk. This is in marked contrast to conditions found over much of northern Australia, where, even in areas of more favourable rainfall, inadequacies (either in amount or in its incidence within the required period) prevent the completion of normal crop development on some occasions. It should be noted, however, that even though a long crop-growing season seems assured, the estimates do suggest that some degree of intra-seasonal water stress can be expected. During the 12-wk interval following the assumed sowing date, there are on the average at Jackson's Airport 1·8 wk with accumulated deficits (amount by which estimated weekly evapotranspiration exceeds the available water) greater than 1 in. This value is only slightly less than that obtained for Katherine, N.T. (Fitzpatrick 1965).

The estimated total duration of useful pasture growth and related characteristics for Jackson's Airport and Koitaki are given in Table 14. For comparison, values for Katherine obtained with an assumed maximum available storage of 4 in. are also given. The values given for the total duration of estimated useful pasture growth

TABLE 14

CHARACTERISTICS OF THE PERIOD OF USEFUL PASTURE GROWTH AT KOITAKI, JACKSON'S AIRPORT (PORT MORESBY), AND KATHERINE, NORTHERN TERRITORY

	2 In. Max. Available Storage		4 In. Max. Available Storage		
	Koitaki	Jackson's Airport	Koitaki	Jackson's Airport	Katherine, N.T.
Commencement of estimated dominant pasture growth period					
Mean	—	Dec. 7	—	Dec. 7	Nov. 30
Standard deviation (wk)	—	3·3	—	3·3	2·7
Total duration (wk) of estimated useful pasture growth					
Mean	50·5	28·7	51·6	41·6	22·4
Standard deviation	—	4·2	—	3·0	2·8
Total duration (wk) of estimated pasture growth with available water $>60\%$ of assumed maximum available storage					
Mean	46·4	23·6	47·7	22·0	14·5
Standard deviation	3·8	3·8	4·3	3·9	3·0

may be interpreted as the time over which some green feed is likely to be available from rainfall alone. The more restricted duration with available water exceeding 60% of the assumed maximum available storage gives a better indication of the time during which the most active growth conditions prevail. According to both criteria, it is evident that much more favourable conditions for sustained growth occur at Koitaki than at Jackson's Airport. For the same assumed maximum available storage (4 in.), the total duration of estimated useful pasture growth at Jackson's Airport is considerably larger than at Katherine. It is notable, however, that with the lesser assumed maximum available storage (2·0 in.), the estimated total duration at Jackson's Airport is much lower, and the contrast with Katherine is much less striking. This emphasizes the necessity for giving careful consideration to specific soil conditions when assessing climate–growth relationships in greater detail. Insufficient measurements of physical soil properties are available from the area to allow such interpretations to be made at this stage.

From the point of view of prevailing temperature and moisture conditions, the area would appear to have a greater potential for agriculture and for pasture utilization than is generally realized, although special agronomic problems related to other aspects of climate may present themselves. The coastal lowland has a more definite dry season than most parts of Papua–New Guinea. This would appear an advantage for some crops, but the prevailing high humidities may cause some difficulty in proper maturation and in harvesting operations. Low radiation receipts and the lack of marked seasonal differences in day length may also present special agronomic problems. With frequent and moderately heavy rainfalls causing continued leaching, maintenance of soil fertility would appear to be a major difficulty within the whole of the area.

IV. Acknowledgments

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PART V. GEOLOGY OF THE PORT MORESBY–KAIRUKU AREA

By J. G. Speight*

I. Introduction

The following geological summary is mainly a synthesis from previous reconnaissance geological surveys, none of which covers the area completely. Gaps in the coverage have been eliminated and certain correlations and interpretations have been added as a result of observations at query points in the field. Boundaries on the accompanying geological map have been inferred from photo interpretation.

The geology of the area between Port Moresby and the Sogeri Plateau escarpment has been covered in some detail by Glaessner (1952) and earlier by Montgomery (1930), who also discussed areas at Dareeba hill, Redscar Head, Oroi, Yule Island, and Popo (Palipala hills). The strip between Hall Sound and Galley Reach is discussed in the report on the Kaufana Bore (Power 1960), and the whole area north of Galley Reach is considered in general terms by Australasian Petroleum Company Proprietary (1961). Unpublished work includes miscellaneous records of the Bureau of Mineral Resources, Geology and Geophysics as well as reconnaissance survey reports of the Australasian Petroleum Company for the Galley Reach area, for a traverse inland from Kapa Kapa, and for some other areas adjacent to the survey area. Early work in the area was reported by Stanley (1911, 1919, 1923). Although there are no regional accounts, broader relationships may be drawn from publications dealing with New Guinea as a whole (Glaessner 1950; Montgomery, Glaessner, and Osborne 1950).

Tectonic activity associated with the formation of the fold mountains of the central ranges of Papua has dominated the evolution of the major landscape features of the survey area. Folding and associated faulting on north-westerly lines have produced a coastal anticlinal belt with strike ridges on pre-Pliocene rocks, succeeded inland by a synclinal belt with alluvial plains and swamps. Broad transverse warping divides the coastal anticline into three parts, the Palipala hills, central hills, and southern hills, between which the plains and swamps extend to the sea.

The sediments of the coastal anticlinal belt increase in age south-eastwards, from Pliocene in the Palipala hills to Miocene in the central hills and Palaeogene in the southern hills. Metamorphosed rocks of Palaeogene or Mesozoic age are exposed in the south backing ranges, but the major part of the upland zone on the inland side of the area is mantled by sheets of dominantly agglomeratic Pliocene volcanic rocks.

II. Regional Geology

The rocks of the area fall into five age groups, each with characteristic structure and lithology: Cretaceous–Palaeogene, Miocene, Pliocene, Pleistocene, and Recent. The distribution of land systems among these groups is set out in Table 15.

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TABLE 15
RELATIONSHIP BETWEEN GEOLOGY AND LAND SYSTEMS

Age	Structure	Lithology	Land System
Recent	Undisturbed	Fluvial gravel, sand, and mud	Vanapa
		Fluvial alluvium, fine-textured	Inaukina, Boroko, Keviona, Bebeo, Epo, Beipa, Babiko, Vekabu, Piunga
		Fluvial alluvium and littoral clay	Pinu
		Swamp alluvium	Waigani, Engepa, Akaifu, Biaru, Doura
		Swamp alluvium, and littoral sand, silt, and clay	Nipa
		Littoral clay	Galley Reach, Kido, Lesewalai
		Littoral sand and clay	Papa
		Littoral sand	Hisiu
Pleistocene	Very gently warped	Coral limestone	Tsiria
Pliocene	Warped	Andesitic agglomerate	Mariboi, Rubberlands, Uberi (upper part), Vouku
		Weathered tuff and lava	Owers, Sogeri, Subitana
		Sandy tuff and volcanic conglomerate	Aropokina, Diulu, Kanosia
		Sandy tuff	Nikura (central hills north of Tubu)
	Gently folded	Coarse, ill-sorted sandstone	Palipala (inland part)
		Sandy limestone	Ouou
Miocene	Moderately folded	Limestone	Pokama, Hanuabada (west of Boera), Palipala (coastal part)
		Conglomerate and limestone	Fairfax
		Mudstone	Ward (west of Fairfax Harbour)
		Sandstone, mudstone, limestone	Diumana
		Sandy tuff	Nikura (central hills south of Tubu)
		Volcanic rocks	Kopu (extreme SE. part), Rouna (extreme SE. part)
Cretaceous–Palaeogene	Isoclinally folded	Cherty limestone	Tovobada, Hanuabada (not west of Boera)
		Cherty mudstone	Kabuka
		Mudstone and muddy tuff	Kopu (not extreme SE. part)
		Muddy tuff	Edebu, Bomana Creek, Nikura (near Port Moresby), Ward (east of Fairfax Harbour)
		Phyllite with minor limestone	Iawarere, Uberi (lower part)
	Concordantly intruded	Gabbro with included limestone	Dubuna, Nikura (near Mt. Lawes)
		Gabbro capped by agglomerate	Rouna (not SE. part)

(a) *Cretaceous–Palaeogene*

Metamorphosed and unmetamorphosed sediments including limestone, sandstone, mudstone, chert, and tuff, with moderate to high dips and intruded by gabbro, dolerite, and serpentine, occur throughout the south backing ranges, southern foothills, and southern hills, except for an area north-west of Port Moresby.

(i) *Stratigraphy*.—A sequence of dominantly phyllitic rocks including a foliated limestone member is exposed near Iawarere, inland from the Sogeri Plateau, and all the high ridge country of the southern backing ranges appears to be formed on rocks of this type. No fossils have been found, but a lithological correlation may be made with strata at Mafulu, 50 miles inland from Kairuku, which have yielded Cretaceous and Eocene fossils (Australasian Petroleum Company, unpublished report).

The Bogoro limestone and Barune sandstone (Glaessner 1952) are respectively a pink sheared limestone and a bedded calcareous quartz sandstone, both with Upper Senonian foraminifera. They occur only as small lenses associated with the Port Moresby group.

The Port Moresby group (Glaessner 1952) gives rise to the ridges of the southern hills, and includes two classes of rocks. The first consists of nummulitic limestone with silicified lenses, limestone metamorphosed up to garnet–pyroxene grade, and beds of green and red mudstone and calcareous sandstone. The second class includes hard chert, either massive and concretionary or thin-bedded, which lenses into cherty mudstone; these cherty rocks are interbedded with soft mudstone and marl, and are characterized by intraformational slumping and the formation of chert balls and rolls. The rocks of the group show a consistent north-west strike and high angles of dip generally to the north-east, the stratigraphic thickness being of the order of 5000 ft. Massive limestone dominates the lower part of the sequence near the main road bridge over the Laloki River but is less important in other areas, where calcareous rocks are represented by bedded cherty limestone and marl. A tuffaceous component is present in the north-east and is dominant in the north. Microfossils include abundant radiolaria and large foraminifera indicating an Upper Eocene age.

The Port Moresby group is concordantly intruded by gabbro and by smaller amounts of dolerite and serpentine. The serpentine occurs as small lenses parallel to the strike near Port Moresby, the dolerite forms dykes in a belt extending south-south-east from the Laloki bridge, and the gabbro dominates the southern foothills from the Brown River along the lower parts of the Astrolabe escarpment and some 15 miles further to the south-east. The gabbro has an average crystal size of about 1 to 2 mm and weathers to a sandy material resembling weathered coarse tuff.

Many strike vales in the southern hills, as at Boroko, near Port Moresby, are eroded on the Dokuna tuff and agglomerate (Glaessner 1952), which consists mainly of some 2000 ft of tuffaceous, soft, green or dark-coloured mudstone and tuffaceous limestone apparently occupying synclines in the structures of the Port Moresby group. The agglomerate, which is not abundant and occurs only at the base of the sequence, includes blocks of vesicular basalt and derived Eocene sediments. Foraminifera in calcareous strata are Middle Oligocene in age.

(ii) *Structure.*—Glaessner (1952) has drawn a schematic cross section of the Port Moresby area indicating isoclinal folding and strike faulting and showing the generally concordant position of the intrusions. He considers that the Bogoro and Barune rocks underlie the Port Moresby group unconformably. He has also attempted a reconstruction of the geosynclinal environment of the time, showing a north-east to south-west sequence of volcanic rock, chert over limestone, and reef limestone. As shown by the A.P.C. isopach maps (Australasian Petroleum Company Proprietary 1961), the tectonic axes were northerly to north-westerly throughout this period and the axis of a major geosyncline lay somewhere to the east of the present coast. However, deposition was not continuous; the Lower and Middle Eocene near Port Moresby are represented by an unconformity, and both the Lower and Upper Oligocene are missing. The Upper Oligocene is thought to have been a period of general emergence.

(*b*) *Miocene*

Miocene rocks cover large areas in the central hills and a part of the southern hills. They include important beds of coral limestone as well as a considerable thickness of other marine sediments (largely silty) and occasional conglomerate. Thick basic volcanic deposits occur in the extreme south-east of the survey area.

(i) *Stratigraphy.*—The Boira tuff and limestone (Glaessner 1952) is a coarse-bedded sequence with tuffaceous grit, gravelly limestone grit, limestone blocks, and massive limestone, striking north-north-west and dipping at moderate to high angles to the east. The formation is limited to an area near Boera village, 10 miles north-west of Port Moresby. It is richly fossiliferous, containing abundant foraminifera indicating an Aquitanian (lowermost Miocene) age.

The Siro beds (Glaessner 1952) consist of pebbly sandstones and coarse boulder conglomerates appearing immediately west of Fairfax Harbour and also under Hombron Bluff (not mapped). Pebbles and fragments include quartz, igneous rocks, schist, chert, and feldspar grains, but there is no evidence of contemporaneous volcanicity. A Lower Miocene (but post-Boira) age has been suggested by Glaessner on tenuous stratigraphic evidence. By photo interpretation these beds have been extended to the north towards the Galley Reach area.

The Gidobada series (E. R. Stanley 1919, cf. G. A. V. Stanley, A.P.C. unpublished report) is a poorly defined group of volcanic rocks in the extreme south of the area, including a pink coralline limestone bed 50 ft thick which dips moderately to the north-west and contains Middle or Lower Miocene algae.

In the central hills four Miocene formations have been defined by Power (1960). They are the Kaieu greywacke (Lower or Middle Miocene), Bokama limestone and Diumana greywacke (Middle Miocene), and Vanuamai siltstone (Upper Miocene), each several hundred feet thick. The sequence is conformable and well bedded and contains abundant reef deposits and coral debris. Correlated beds extend as far north as Yule Island. Other Miocene rocks without formation names are Lower Miocene coralline and foraminiferal limestone and calcareous tuff at Dareeba hill and Redscar Head, and Upper Miocene strata at Oiapu, where 1200 ft of limestone overlies 600 ft of mudstone. This limestone is largely coralline with some hard calcareous sandstone and shelly foraminiferal grit and conglomerate.

(ii) *Structure*.—The contact of the Boira tuff and limestone against the Port Moresby group is a thrust fault, but that between the Siro beds and the Port Moresby group has not been observed. All Miocene beds have been folded into moderate to steep anticlines on north-west axes, but faulting is not important. A geosyncline shown on the A.P.C. isopach map probably continued south-eastwards about 40 miles off the present coast, which was then a hinge-line zone of littoral and reef deposition. Areas to the east of Boera and north-west of Kapa Kapa may have been land throughout the epoch. Volcanism was important in the south and in some areas adjacent to the survey area, but did not much affect the sediment composition in other places.

(*c*) *Pliocene*

Volcanic plateaux in the upland zone comprise thick deposits of andesitic agglomerate and lava which grade westwards to tuffaceous sandstone and conglomerate and finally to thin-bedded tuffaceous limestone in the Palipala hills. Palaeontological control is generally lacking, and the position of the Plio–Pleistocene boundary is completely unknown.

(i) *Stratigraphy*.—The Sogeri Plateau is formed of a sheet of thick-bedded agglomerate, conglomerate, and lava of basaltic to andesitic composition with interbedded basic tuff in a sequence up to 1500 ft thick with dips less than 10°. Erosional peaks of the Uberi land system which stand above the plateau north and south of Subitana appear to be a product of related but more localized volcanic activity. Rocks similar to those of the Sogeri Plateau form an apron along the entire north backing range from the Vanapa River to beyond the Akaifu River. Dips are low towards the south-west and are thought to be mainly depositional. Thickness attains 10,000 ft in places. The age of these rocks can only be estimated as between Upper Miocene and Lower Pleistocene inclusive.

The Palipala hills are composed largely of a Pliocene sequence 5000 ft thick dominated by thin-bedded gritty sandstone with fine conglomerate, sandy shale, and calcareous silt. These are mainly volcanic-derived continental deposits but there is some reef coral near the base. The volcanic component increases towards the east until in Vanuamai area the strata consist of tuffaceous calcareous sandstone interbedded with basic lapillitic tuff, laharic conglomerate, and rare basaltic lava. These in turn grade into agglomeratic rock.

(ii) *Structure*.—Except near anticlinal axes in the Palipala hills, there is a considerable decrease in the degree of deformation of Pliocene strata as compared with those of the Miocene. Even so, the warping and faulting which have occurred on north-westerly or northerly axes have given rise to considerable tectonic relief. The undulating terrain and accordant crests of low hills of the Sogeri Plateau probably represent a depositional surface without significant depositional dip, providing a reference plane from which to gauge subsequent tectonic movements. This surface has been warped into a D-shaped basin, with the straight side rising at 3° to 7° through 1500 ft to the Astrolabe Range in the south-west, and the other sides rising at 1° to 6° towards outlying plateau remnants, some of which are more than 2500 ft above the centre of the basin. In the remainder of the survey area much of the warping responsible for the presence of the major depositional basins and the three areas of coastal hills must also have occurred at this time.

Contacts between Pliocene and older rocks are almost or quite conformable in the north-west, but are strongly unconformable in the south-east, where there is a considerable stratigraphic gap. Most of the area covered by Pliocene deposits previously had emerged above sea level, and the coastline lay close to its present position.

(*d*) *Pleistocene*

Raised coral reefs of Pleistocene age, consisting of a thin veneer of coral covering benches from 10 to 50 ft above present sea level, are prominent on the west coast of Yule Island and on the coast west of Hisiu, and also occur near Port Moresby.

(*e*) *Recent*

Deposits that post-date the last major sea-level change (the Flandrian transgression) cover 40% of the area. Detrital material derived mainly from the mountainous hinterland, and ranging from boulders to clay, is being laid down and reworked by fluvial and littoral agents at a rapid rate. As a result, peaty deposits are significant only in the broadest swamps. Fringing and barrier coral reefs extend from Hall Sound southwards.

III. Tectonic Summary

From the Cretaceous period to the Pliocene the area was a scene of geosynclinal activity, with apparent pauses in deposition in the Lower and Middle Eocene and Lower and Upper Oligocene. The axis of marine deposition moved towards the west about the beginning of the Miocene, leaving the coastline not far inland from its present position. Large-scale basic intrusion occurred after deposition of the Eocene rocks, and basic volcanism was present throughout, with shifting centres of activity, concluding with prominent, largely terrestrial, outpouring in the Pliocene. Folding on north-west to north-north-west axes is present in all formations, the intensity increasing with age, and post-Pliocene transverse warping is evident.

IV. Geology and Land Systems

The distribution and characteristics of the land systems have been strongly influenced by two geological factors: lithology, which determines the resistance of the rocks to exogenic geomorphic agents as well as influencing soil formation and vegetative growth, and degree of structural deformation, here closely related to the age of the rocks, which determines the degree of destruction of initial geomorphic forms. Relationships between geology and land systems are set out in Table 15.

The depositional zones of the area comprise 22 land systems occurring on undeformed Recent deposits, grouped mainly by depositional environment in Table 15. These are discussed fully in Part VI. Tsiria land system represents the most extensive area of Pleistocene coral reef.

In the erosional zones lithology and structure are basic to zonal contrasts. Land systems in the coastal hill zone show a pattern of strike ridges and vales related to steeply dipping, alternate resistant and non-resistant beds, except in the north, where relief follows primary anticlinal structures. Land systems of the foothill and upland zones are formed either on young little-disturbed volcanic rocks or on older rocks without marked expression of structure. The relief contrast between the foothill zone and the upland zone is due to the greater post-Pliocene uplift towards the main range of New Guinea.

Pliocene volcanics (Plate 10, Fig. 1) underlie 10 land systems characterized by warped or undisturbed constructional surfaces with consequent drainage, elevated areas having greater internal relief and steeper slopes. Uberi land system stands apart from the rest, being an area of erosional mountains (Plate 11, Fig. 2). Anticlinally warped and folded Pliocene sedimentary deposits underlie Ouou and most of Palipala land systems. The northern part of Nikura land system is transitional between volcanic and sedimentary phases.

Pokama land system, part of Hanuabada land system near Redscar Head, and the higher coastal part of Palipala land system comprise long strike ridges formed on Miocene limestone, which also makes up the ridge element in Diumana land system. Undulating structural lowlands on Miocene sandstone and mudstone predominate in this land system as they do in Fairfax, a large part of Nikura, and the western part of Ward land systems (Plate 4, Fig. 2). In the extreme south-east of the area parts of Kopu and Rouna land systems include closely dissected hills of Miocene volcanic rock without marked expression of structure.

Similar dissected hills are formed on some tuffaceous sediments of Cretaceous–Palaeogene age in Kopu and Edebu land systems, but elsewhere, as in Ward, Bomana Creek, and part of Nikura land systems, these sediments underlie erosional plains and foot slopes in strike vales. Prominent long strike ridges of cherty rocks of similar age dominate Hanuabada, Tovobada, and Kabuka land systems. The largest ridges and hills of the area, apart from those on volcanic plateaux, are on phyllites (Plate 9, Fig. 2) in Iawarere land system and gabbro with sedimentary remnants (Plate 9, Fig. 1) in Rouna, Dubuna, and part of Nikura land systems. The north-westerly structural trends of these rocks is discernible only in the major landscape features.

V. Economic Geology

No minerals are at present of economic importance in the area, but several have shown promise in the past and may yet prove valuable. Information used in this section was assembled by Mr. L. Hamilton of the Bureau of Mineral Resources, Geology and Geophysics.

(*a*) *Copper*

A proclaimed field of 1000 sq miles mainly in Rouna and Dubuna land systems of the gabbroic southern foothills contains lodes of pyrite–chalcopyrite ore associated with lenses of sediment of the Port Moresby group. Other minerals present include marcasite, sphalerite, and galena. When production ceased in 1942, 81,000 tons of ore had been extracted, averaging 4·5% copper and 2·6 dwt/ton of gold with some silver. Reserves have been estimated as far exceeding 250,000 tons, and further prospecting is planned.

(*b*) *Manganese*

The cherty sediments of the Port Moresby group, which occur in Hanuabada and Kopu land systems and, to a lesser extent, in Kabuka and Bomana Creek land systems, contain high-grade pyrolusite, assaying as much as 86% manganese dioxide. The deposits take the form of beds, laminae, pockets, and disseminations associated with cherts and "chocolate mudstones". Production, mainly from the Pandora mine, near Kapa Kapa, ceased in 1961 after nearly 2000 tons of ore of battery grade had been won.

(*c*) *Gold*

As well as that associated with copper ore, gold has been obtained from time to time at Iawarere, east of the Sogeri Plateau. It appears to come from veins in the folded phyllitic rocks of the area.

(*d*) *Construction Materials*

The use of rock and sand in construction is limited by high transport costs, and a further difficulty is that the widespread cherty rocks react chemically with cement and are therefore useless as concrete aggregate. Limestone is commonly used for this purpose, and limestone, gabbro, and chert are used for road surfacing.

(*e*) *Water*

The scarcity of water in the dry season over the coastal hill zone has limited settlement there but only locally has there been serious effort either to store rain-water or stream-flow or to tap ground water, which may be expected at shallow depth in many areas.

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PART VI. GEOMORPHOLOGY OF THE PORT MORESBY–KAIRUKU AREA

By J. A. Mabbutt*

I. Introduction

This Part aims to provide an understanding of the geomorphology of the land systems. It names the main environmental zones and their constituent sectors, so establishing a regional framework for discussion of the land systems. This is followed by a brief geomorphic history and by a statement of the geomorphic principles upon which the land systems have been grouped. Finally, the land systems are described in erosional and depositional classes, with further grouping by environmental zones and on the basis of land forms.

No detailed geomorphic account of the area has been published previously, although there is mention of land forms in many of the geological reports referred to in Part V.

II. Regional Geomorphic Description

(a) *General*

The survey area embraces the coastal lowland along most of the eastern shore of the Gulf of Papua and extends for short distances into the outer parts of the main range of New Guinea. The coastal lowland is about 20 miles wide in the north of the area, but in the southern third it narrows to less than 10 miles where the Sogeri Plateau forms an upland salient. The survey area here reaches furthest into the uplands and attains 3600 ft above sea level in the east.

The environmental zones described in Parts II and III are essentially geomorphic zones, with characteristic land forms and geomorphic processes. The zones are mainly not continuous and fall into sectors by virtue of discontinuities of relief or depositional patterns, so giving rise to the break-down set out in Table 16 and shown in the geomorphology map.

(b) *Erosional Surfaces*

(i) *Coastal Hill Zone.*—This is a strike belt of parallel ridges and lowlands, mainly less than 10 miles wide, and it occurs in three sectors: the Palipala hills in the north, the central hills between Hall Sound and Redscar Bay, and the southern hills extending southwards from Redscar Head. These are separated by swamps and depositional plains. Ridges are more developed in the seaward half of the zone, which corresponds to an anticlinal belt, and erosional lowlands mark a corresponding tectonic depression on the inland side. The lowlands are generally less than 150 ft above sea level and the ridges are mainly less than 500 ft high, but relief locally attains 900 ft. In detail, the position of the coastline in these sectors is deter-

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mined by strike ridges of resistant rock, principally of cherty limestone, and the shores are generally rocky and steep, with south-facing embayments where the coast transgresses local fold axes, as it does near Port Moresby.

Steep offshore gradients, broken only by the barrier reef platform, suggest a faulted coast, whilst the north-west to south-east trend of the coastline is controlled by Cainozoic fold axes. Coastal submergence, accentuated by post-glacial recovery of sea level, is indicated by the embayed coastline near Port Moresby and by the way in which the steep slopes of the island-like coastal ridges in the north of the area plunge beneath the Recent deposits of the littoral plains. Signs of prior emergence are strongest in the south, in the wave-cut benches at more than 100 ft above

TABLE 16

GEOMORPHIC ZONES AND SECTORS OF THE PORT MORESBY–KAIRUKU AREA

Zone	Sector	Zone	Sector
Erosional surfaces		Depositional surfaces	
Coastal hill	Palipala hills	Fluvial plains	Northern plains
	Central hills		Upper Dilava plains
	Southern hills		Aroa plains
Foothill	Central foothills		Southern plains
	Southern foothills	Swamp	Northern swamps
Upland	North backing ranges		Lower Dilava swamps
	Sogeri Plateau		Southern swamps
	South backing ranges	Littoral plains	Lesi Inlet
			Hall Sound
			Redscar Bay

sea level on headlands near Port Moresby, and in an extensive uplifted marine plain on Fairfax station. A raised reef and marine platform also flank the coast further north, between Hall Sound and Redscar Bay, although here not more than 50 ft above sea level. The coast is reef-fringed south of Hall Sound, with a barrier reef up to 10 miles wide south of Boera and up to 15 miles wide and apparently sunken further north.

(ii) *Foothill Zone.*—In two areas the coastal hill zone connects inland with ridges and hills which form a foothill zone, transitional to the uplands in relief, climate, and drainage characteristics. The most important sector of this zone is the southern foothills, which extend southwards from the Veimauri River and form a selvage to the Sogeri Plateau. Further north, the central foothills form an interrupted line between Hall Sound and Galley Reach. This zone lies mainly between 200 and 1500 ft, but attains 3200 ft in the Astrolabe Range escarpment, and there is a wide range of relief, mainly up to 1000 ft.

(iii) *Upland Zone.*—The coastal lowland is backed by uplands into which the survey area extends generally less than 10 miles and which are here termed the backing ranges. The north backing ranges, north of the Vanapa River, consist of ridges or plateau strips rising inland. The south backing ranges are prominent mountain ridges, formed largely in metamorphic rocks, drained by the Goldie and Musgrave Rivers. The third sector of the upland zone is the Sogeri Plateau with its prominent west-facing escarpment culminating in the Astrolabe Range. Much of this zone lies above the 1000-ft contour, and most of the Sogeri Plateau is between 1500 and 2500 ft; relief attains 1500 ft locally.

(c) *Depositional Surfaces*

There are two main areas of depositional plains in the coastal lowland, one extending north and south from Galley Reach and a second northwards from Hall Sound. Together, these account for half the extent of the coastal lowland, the remainder being the coastal hill zone. Three main zones can be recognized, namely fluvial plains, swamps, and littoral plains.

(i) *Fluvial Plains Zone*.—The inner margin of the depositional plains is generally less than 100 ft above sea level, and the major streams, on emerging from their upland valleys, have formed lobate plains in four main sectors. The most extensive are the northern plains, which comprise two lobes formed by the Akaifu and Angabunga Rivers. In sequence southwards are the upper Dilava plains, the Aroa plains, and the extensive southern plains formed by the Veimauri, Vanapa, Brown, and Laloki Rivers. These relatively stable alluvial surfaces are traversed by meandering rivers in unstable flood-plains.

(ii) *Swamp Zone*.—Beyond the lower margins of the fluvial plains, and to some extent ponded by them, are extensive swamps. The largest are the northern swamps lying inland from the Palipala hills and extending between the lobes of the northern plains, with an outlier on the south flanks of the northern plains. Further south, the swamps are smaller and comprise the lower Dilava swamps, draining to the Aroa River, and the southern swamps, which receive drainage from the southern plains.

(iii) *Littoral Plains Zone*.—The depositional lowlands reach the coast in a littoral plains zone comprising beaches, tidal flats, and estuaries. The largest sector of these littoral plains forms the shores of Redscar Bay and is centred on Galley Reach, a large tidal inlet which transects the coastal lowland. A second sector, in Hall Sound, consists mainly of a former delta of the Angabunga River. The third sector is around Lesi Inlet in the extreme north.

III. Geomorphic History

Although old land surfaces have little significance for the land systems, this brief history is included to link the geologic and geomorphic records and to show the significance of tectonic events in the relief of the area.

Any consideration of the evolution of land forms in the Port Moresby–Kairuku area must first treat the nature of the surface underlying the terrestrial Pliocene volcanic deposits and their original extent. In the south of the area, the agglomerates rest on a fairly even unconformity which is 700 ft above sea level near Rouna Falls, but north of the Vanapa River the base of the Pliocene falls sharply beneath the level of the plains. The south-westward fall of ridge and plateau crests in the north backing ranges represents the constructional volcanic surface, and there can have been little subsequent deformation there save for the marginal down-warp which formed the northern swamps and caused the incision of consequent streams on the former volcanic plain. In contrast, there has been important uplift and basin-warping of the Sogeri Plateau, where the deformed constructional surface is still expressed as a crest accordance, between 1600 and 2600 ft above sea level.

In the north of the survey area, the western limit of terrestrial volcanic deposition is set by the contemporary deposits of the Palipala hills which are marine in part. In the south, some indication of that limit is given by the contrasting land forms within the gabbroic belt which borders the volcanic plateau, for similar rocks form both the southern foothills and part of the lowlands further west. The higher ground of the southern foothills is probably the result of a former protective cover of agglomerate and of participation in the uplift of the Sogeri Plateau, whilst the adjacent coastal hill zone may well have escaped burial during the volcanic episode. An argument in support of this is that many foothill ridges rise to the level of the base of the adjacent agglomerate, as if attaining a stripped former surface of unconformity.

West of the volcanic cover, the onset of subaerial erosion as indicated by the youngest marine rocks may have been Upper Oligocene in the southern hills, uppermost Miocene in the central hills, and Pliocene in the Palipala hills, i.e. progressively later north-westwards.

In general, available relief within the coastal hill zone is tectonically determined, with an important watershed in a coastal anticlinal belt and with descent inland towards a synclinal axis marked by swamps and fluvial plains (see insets on accompanying map). However, primary tectonic land forms *sensu stricto* are limited to the more youthfully emergent Palipala hills, where anticlines form distinct ridges; in the southern and central hills there is closer adjustment of land forms to lithology, with paired uniclinal ridges formed by resistant limestones in breached anticlines. This is consistent with longer subaerial denudation in the south, but there is little land-form evidence, such as summit planes, of early stages in this history. Minor evidence is the transverse drainage through lower ridges in the southern hills, which is consequent on the flanks of the coastal anticline and which may have been inherited from an up-arched plain.

An important advanced stage of planation is represented in the erosional lowlands of the southern and central hills, and this is discussed more fully below. This planation surface has been tilted up towards the south, for it is generally more than 100 ft above sea level in the southern hills and descends to within 50 ft of sea level in the central hills sector, an unequal uplift also reflected in the altitudes of marine benches and raised coral reefs on its margins.

Dissection of these plains has resulted from the combined effects of uplift and of eustatic regression, but has been succeeded by deposition resulting from the ensuing Flandrian transgression. The distribution of Recent deposits, both marine and terrestrial, reflects the older tectonic disposition of relief in that the inner syncline has been extensively drowned and is now an area of alluviation, but superimposed on this pattern are the effects of cross-warping, with down-warps about Galley Reach and northwards from Hall Sound. The latest depositional episode has also been one of coastal progradation, and land forms marking the maximum post-glacial transgression, such as cliffed slopes and inner beaches, may now be some miles inland.

These innermost beaches reveal no evidence of tectonic deformation. Successive beach ridges and intervening tidal flats point to an intermittent progradation, probably related to the eustatic fluctuations of sea level known elsewhere to have occurred in later post-glacial time.

IV. Geomorphic Principles of Land System Grouping

In a geomorphologically young area such as this, with a range of dynamic environments, the major geomorphic contrasts and affinities between land systems can be adequately expressed in terms of formative processes and resultant land forms, and chronologic interpretations have lesser value. On these bases, the chief division must be that between the land systems of the erosional and depositional zones.

Among the erosional land systems, the most important characteristics are relief and landscape stability, which in turn express structure, climate, and relief energy as controlled by tectonic movements. Division into the three zones—coastal hill zone, foothill zone, and upland zone—brings out the most important contrasts. Further grouping of the erosional land systems is necessary because of geomorphic differences within these zones. Each sector of the upland and foothill zones contains a geomorphically distinct group of related land systems, but the sectors of the coastal hill zone are more heterogeneous and the land systems of this zone are grouped as ridges, lowlands, and minor alluvial plains, irrespective of the sectors in which they occur.

Among the depositional land systems, each zone shows a range of geomorphic conditions which have provided a basis for land system mapping and grouping and which largely cut across the sector pattern. For instance, land systems in the littoral zone are grouped under three settings, namely beaches, tidal flats, and estuaries, and sectors serve merely as locality references.

Table 17 gives the geomorphic grouping of land systems followed in this Part.

V. Erosional Surfaces

(a) *Coastal Hill Zone*

Despite a variety of land forms, the geologic and climatic unity of this zone gives it geomorphic character. Moderately to steeply dipping sedimentary rocks of differing hardness, although nowhere massively resistant, form ridges and aligned hill complexes of modest dimensions separated by broad strike lowlands. The ridge-builders are cherts and some hard limestones, whilst the lowlands have been eroded mainly on a variety of mudstones. A fairly low seasonal rainfall results in a morphogenetic regime of savannah type with ephemeral streams, akin to that of northern Australia. Parts of the landscape show a stability unusual in New Guinea, with land forms, surface deposits, and weathered profiles inherited from an earlier landscape cycle.

The land systems which make up the coastal hill zone are here treated under three headings: ridges, lowlands, and minor alluvial plains.

(i) *Ridges*.—The relief-building rocks are generally not sufficiently massive or resistant to impose simple structural forms, and each ridge tends to be the expression of a number of harder and softer beds. Free rock faces, apart from coastal cliffs, are small or lacking, structural benches are also insignificant, and hard rock outcrop is mainly limited to bouldery chert bands on ridge crests and upper slopes. The softer interbedded rocks, which consist largely of fine-grained rocks such as mudstone and marl, break down uniformly to fine-textured regoliths; hence ridge profiles tend to be smooth and crests to be rounded. Relief is mainly less than 500 ft but exceeds 800 ft exceptionally.

Nevertheless, structure is definitely expressed in relief, and the characteristic form is the strike ridge with a somewhat rectilinear dip slope and a concave escarpment steepening to about 27° and becoming rectilinear in its upper part. The escarpments are typically shallowly embayed by parallel primary valleys with open alcove-shaped heads lacking channels and more narrowly incised lower sectors which tend to open out on foot slopes. A short basal concavity connects the lower hill slope to the foot slope, which is characteristically less than 5°.

These stated maximum slopes may be exceeded by 5° in areas of strong relief, but slopes exceeding 32° are mainly restricted to upper valley heads, where small slump scars and terracettes result from restricted mass movement on argillaceous rocks during the wet season. The valley below normally has a thin stony fill derived from slope wash, into which a small channel is incised.

Most of these sedimentary rocks are chemically stable under the prevailing climate; furthermore, being fine-textured, they are impermeable. Run-off is increased and weathering penetration reduced, so that the effects of seasonal aridity are heightened. Loosened but little-altered rock lies near the surface on most hill slopes. The thin regoliths are generally dry, and mass movement is subordinate to slope wash as shown by the paucity of true colluvium at the base of hill slopes, by the general adjustment of slope angles to structure, and by rough stratification of foot-slope mantles unrestricted to streamlines. In general, hill slopes exhibit an abrupt basal concavity, even in interstream sectors, and give place to smooth, concave foot slopes which are commonly mantled with wash deposits in their lower parts.

Tovobada land system (Plate 3, Fig. 2), consisting of prominent rounded ridges and hills up to 1000 ft high, has the strongest relief in this group of land systems. The crest-building cherty limestone is here underlain by thick, relatively weak mudstone which is subject to extensive terracette slumping, with larger-scale slumping in steep valley heads.

Hanuabada land system (Plate 3, Fig. 1) comprises the coastal ridges, largely of cherty limestone, which extend throughout the southern hills. On coastal salients, wave attack at present and former higher sea levels have directly or indirectly formed cliffs or extremely steep scree-strewn slopes. Between these headlands are narrow, sloping alluvial plains.

Resistant folded limestone in Pokama land system (Plate 4, Fig. 2) gives rise to paired ridges with fairly pronounced structural control and with local development of steep free faces on upper escarpments.

TABLE 17

GEOMORPHIC GROUPING OF LAND SYSTEMS OF THE PORT MORESBY–KAIRUKU AREA

Zone	Land System	Land Forms	Main Occurrence where not Regionally Classified
EROSIONAL SURFACES			
Coastal hill zone			
Ridges	Tovobada	Prominent rounded ridges and hills	Southern hills
	Hanuabada	Coastal ridges of cherty limestone	Southern hills
	Kopu	Hills and ridges, mainly of tuffs	Southern hills
	Palipala	Sandstone hills and limestone ridges	Palipala hills
	Pokama	Limestone ridges	Central hills
	Kabuka	Subdued parallel ridges of cherty mudstone	Southern hills
Lowlands	Fairfax	Dissected uplifted marine plain	Southern hills
	Diumana	Dissected undulating terrain	Central hills
	Bomana Creek	Undulating terrain with short cherty ridges	Southern hills
	Nikura	Broadly undulating plains	Central hills
	Ward	Foot slopes in strike vales	Southern hills
	Ouou	Uplifted marine platform	Central hills
	Tsiria	Uplifted coral reef	Central hills
Minor alluvial plains	Boroko	Partly ill-drained dark clay plains	Southern hills
Foothill zone			
Central foothills	Aropokina	Higher cuestas of volcanic rock	
	Diulu	Undulating terrain with minor ridges, of volcanic rock	
	Kanosia	Plains and low rounded hills of soft tuffs	
Southern foothills	Rouna	Higher ridges and spurs of gabbro with agglomerate cliffs	
	Dubuna	Ridges and hills of gabbro	
	Edebu	Closely dissected hill belt of metamorphosed tuffs	
Upland zone			
North backing ranges	Mariboi	Higher ridges and plateaux of volcanic rock	
	Rubberlands	Lower ridges of volcanic rock	
Sogeri Plateau	Sogeri	Rounded low hills and minor undulating terrain on volcanic rock	
	Subitana	Rounded low hills of volcanic rock	
	Owers	Higher ridges of volcanic rock	
	Vouku	Dissected back slopes of Astrolabe Range; small plateaux	
South backing ranges	Iawarere	Massive ridges of phyllite	
	Uberi	Massive ridges with cliffs of agglomerate	

DEPOSITIONAL SURFACES			
Fluvial plains zone			
Stable plains			
Red clay plains	Inaukina	Ill-drained plains of red alluvial clays	Northern plains
Olive silty clay plains	Keviona	Alluvial plain	Aroa plains
	Pinu	Alluvial plain with marginal beach ridges, pans, and tidal back plain	Aroa plains
	Bebeo	Prior meander tracts	Northern plains
	Epo	Prior meander tracts	Northern plains
	Beipa	Prior back plain, partly poorly drained	Northern plains
	Babiko	Area of lowered water-table due to 1956–57 shift of Angabunga River	Northern plains
	Vekabu	Plains subject to extensive seasonal flooding	Southern and northern plains
	Piunga	Ill-drained plains subject to severe flooding	Throughout zone
Unstable plains	Vanapa	Unstable flood-plains of all large rivers	Throughout zone
Swamp zone			
Mainly permanent swamps	Waigani	Permanent swamps with very little through drainage	Throughout zone
	Engepa	Complex swamps with minor through drainage	Northern swamps
	Akaifu	Swamps with important through drainage and moderately extensive levee tracts	Northern swamps and lower Dilava plains
Mainly seasonal swamps	Biaru	Back-plain swamps ranging from freshwater through brackish to saline downstream	Northern swamps
	Doura	Periodically flooded plains and seasonal swamps with large through-going rivers	Southern swamps
Littoral plains zone			
Beaches	Hisiu	Beach plains, spits, barrier beaches	Throughout zone
Tidal flats	Galley Reach	Tidal flats below H.W.M.O.T.	Throughout zone
	Lesewalai	Tidal flats above H.W.M.O.T. and including stranded beach ridges	Throughout zone
	Kido	High-lying tidal flats with salt pans and stranded beach ridges	Redscar Bay
	Papa	Complex of beaches, mangrove flats, and salt pans	Narrow littoral plains along southern hills sector
Estuaries	Nipa	Mainly below H.W.M., with saline back swamps	Lesi Inlet and Redscar Bay

Kabuka land system consists of close-set parallel low rounded ridges built of mudstone with cherty bands, broken in many places by transverse drainage from adjacent higher ground. There is an unusually thick residual mantle of cherty brash on its moderate slopes, which has been extensively stripped for road-making near Port Moresby, and which is tentatively regarded as a truncated weathered profile inherited from an earlier period of higher rainfall.

Two land systems in this group stand apart in that they exhibit less structural alignment of major relief, being largely formed of uniform soft-weathering rock, and consist mainly of branching ridges and subconical hills rather than of simple strike ridges. Palipala land system, in the Palipala hills, has a coastal belt of resistant limestone which forms high strike ridges with chevron spurs separated by straight, steep-sided valleys which may partly result from spring sapping. The ridges give place inland to lower hill country eroded in fairly soft sandstone, with minor limestone benches. Kopu land system, in the southern hills, is formed mainly on tuffaceous mudstone, locally deeply weathered and subject to terracette slumping on steep slopes. Both land systems are characterized by dense dendritic drainage with deeper primary valley re-entrants than elsewhere in the coastal hill zone, and with some development of alluvial plains in larger valleys.

(ii) *Lowlands*.—These land systems range from moderately or gently undulating open plains to dissected and undissected foot slopes, and they are formed on a variety of weak, mainly fine-grained, sedimentary rocks. Some include minor ridges which resemble units in land systems of the preceding group. Most of them record a landscape history of prior planation, subsequent dissection of amounts generally less than 50 ft, and present-day slow alluviation. The former plains were mainly subaerial, but uplifted marine planation surfaces and coral reefs are included.

Erosional surfaces of slight relief rising with smooth, gentle concavity to steep-sided inselbergs have elsewhere been postulated as typical of margins of savannah plains, where they are fashioned by slope wash and characterized by the movement of fine-textured alluvium (Büdel 1957). Prior to their dissection the lowlands of the coastal hill zone provided extensive examples of such piedmont land forms; however, there is no trace of smoothed wash plains of deeply weathered rock claimed by Büdel to be typical of extensive lower parts of savannah plains. Relics of a ferruginous duricrust are widespread on older surfaces in the lowlands of the central hills sector, and stable foot-slope mantles in the southern hills have undergone limited lateritic weathering, but fresh rock generally lies close to the surface. The original plains were thinly but extensively masked with detritus, like the savannah plains of western Sudan (Dresch 1953), but here of much coarser grade; in particular, the foot-slope mantles of the southern hills have the calibre, rough sorting, and lack of stream alignment typical of sheet-flow deposits. Erosional and depositional features alike leave little doubt that pediplanation has operated in the past in this zone. Tricart and Cailleux (1955) have postulated that savannah landscapes in general are polygenetic in the sense that they all bear the marks of pediplanation during semi-arid episodes in the Quaternary. The extensive foot-slope deposits in the southern hills, which are no longer being added to, have probably resulted from the mobilization of hill-slope mantles, which has been attributed to slope instability resulting from change to a drier climate and with it the thinning of a formerly stabilizing vegetative cover (Butler 1959). The older, i.e. pre-dissection, lowlands of the coastal hill zone are accordingly regarded as the result of planation under a subhumid climate, with drier phases indicated by pediplanation, slope wash, and related deposits, and wetter phases associated with moderate chemical weathering.

Shallow but extensive dissection of the former savannah plains has resulted from uplift which was most marked in the southern hills and slight in the central hills. Uplift of the order of 100 ft is indicated by the dissection of strike vales near Port Moresby and by the altitude of the marine abrasion plain on Fairfax station. The raised coral reef and marine abrasion platform which flank the central hills nowhere exceed 50 ft above sea level, and dissection in the plains further inland is generally less than this.

Regressive erosion is locally active, as at the south end of Jackson's Airport, Port Moresby, but in general the main phase of dissection has ended and has been replaced by deposition of fine-textured alluvium in the slightly entrenched valleys. The nature of this alluvium points to an existing regime of slow erosion of hill slopes cut in fine-textured sedimentary rocks. However, the alluvial clays are commonly underlain by coarser-textured deposits, such as are now being formed in higher valley reaches, indicating an upstream encroachment of fine-textured alluviation and a general decline in erosion. In accord with this evidence, many of the underloaded streams have incised their channels to bed-rock, and high steep banks are the rule. An alluvial fill between 10 and 15 ft thick is generally revealed.

This history is reflected in the build of the lowland land systems, which include extensive flattish interfluves or gentle foot slopes, steepened interfluve margins, and shallowly entrenched, small drainage plains.

In much of the lowlands the prior plains and foot slopes were broadly and gently undulating rather than flat, as shown by gentle slopes on interfluves, and partial modification of such surfaces has accompanied later valley incision. For these reasons the interfluve crests now differ in stability, with stable surfaces generally sloping at less than 3°, and modified surfaces, ranging from 3° to 6°, subject to slight sheet erosion. Duricrust cappings on low flat rises indicate an interfluvial lowering of up to 10 ft in some areas. In the land system descriptions these stripped crests are grouped with the interfluve margins, which mainly range from 6° to 10°, although steeper locally owing to structure or stream undercutting. Severe sheet erosion and gullying were observed on many such slopes, particularly along tracks.

In all these lowlands the streams are ephemeral and mainly small, originating on the strike ridges of the preceding group of land systems. Drainage patterns are dendritic on the open plains and subparallel on foot slopes, and drainage density is moderately close although the larger streams receive few lateral tributaries. This is indicative of high run-off, much of it as sheet-flow from fairly long gentle slopes on relatively impermeable rock.

Fairfax land system consists of a dissected uplifted marine plain which rises inland to 100 ft above sea level on Fairfax station. The higher inner part is divided by narrow entrenched valleys into low plateaux, the lower part is moderately undulating, with shallow, open, unchannelled valleys and with remnants of a coral reef on its broad interfluves.

Diumana land system has been formed by very close dissection of foot slopes and plains, partly on calcareous rocks; its interfluves are rounded rather than flattish, and its side slopes are steeper than usual. It contains limestone ridges similar to but smaller than those of Pokama land system.

Bomana Creek land system typically consists of short cherty ridges and extensive foot slopes and undulating plains.

Nikura land system (Plate 4, Fig. 2) consists mainly of the extensive slightly dissected plains in the central hills sector, but it also includes dissected foot slopes in the southern hills.

Ward land system comprises relatively stable foot slopes below ridges of siliceous rock in the southern hills. The lower parts of the concave slopes retain an inherited mantle of slope-wash deposits as described above, whilst the upper parts may be erosional and may locally pass into low spurs. Drainage is very shallowly incised across these slopes and may fan out and become ill-defined in the lowest parts. The land system is continued up-valley as low gravel terraces of the Laloki River.

Ouou land system is the narrow coastal plain, formed mainly on soft calcareous rocks, which extends southwards from Delena in the central hills. It is an uplifted marine platform, now slightly dissected and with a low marginal bluff.

Tsiria land system is an uplifted coral reef with a featureless surface save for a few shallowly entrenched valleys.

(iii) *Minor Alluvial Plains*.—The alluvial black clay plains of the southern hills have been mapped as Boroko land system (Plate 5, Fig. 1). It occurs in strike vales inland from Port Moresby, as small valley plains further south, and as a narrow coastal terrace, probably of marine origin, south of Papa. The fine-textured alluvium which predominates is derived locally from small ephemeral streams, many of them ill-defined, but the land system also includes larger perennial streams from the southern foothills, with small flood-plains of silty alluvium. The plain margins may be sloping and are generally well drained, but the main parts of the land system are poorly drained and may be flooded seasonally.

(*b*) *Foothill Zone*

This is a transitional zone between lowlands and uplands. The lower boundary is lithologic—the western limit of a pronounced agglomeratic facies in the central foothills and the limit of gabbro outcrop in much of the southern foothills. Altitude and relief generally increase eastwards within the foothill zone, and the inner boundary has been placed where consequent increase in rainfall is significantly expressed in soils and in vegetation. The foothill zone is absent in the north of the area, where the uplands fall abruptly to the coastal plain.

Certain zonal characteristics can be recognized. With lesser lithologic contrasts, strike orientation of relief is less marked here, and broad cuestas or hill complexes replace the aligned narrow ridges of the coastal hill zone. Increased rainfall and chemically less stable rocks result in deeper weathering in the higher parts. With increasing relief comes a tendency towards steeper hill slopes, with maxima generally above 35° and commonly exceeding 40° in valley heads, and slopes generally exhibit more uniform steepness in this zone. The thicker weathering mantles, which are wet for longer periods, are more mobile. Slumping occurs on a larger scale on valley heads and sides, and a colluvial apron is commonly found on lower hill slopes, particularly in wetter environments.

Increased rainfall and relief lead to finer-textured drainage, with an associated multiplication of secondary spurs and ridges separated by narrow V-shaped valleys. The slopes are traversed by numerous parallel gullies, but although the slope re-entrants are deeper than in the coastal zone they tend to be partly choked with colluvium, and primary channels are poorly developed. Valley flats are small or very small, and are confined to the largest valleys; some are ill drained as a result of blockage through over-abundant colluvial supply. Streams above second order are generally perennial in this zone.

(i) *Land Systems of the Central Foothills.*—The rocks here consist of gently folded agglomerate, conglomerate, lava, and tuff, with resistant volcanic agglomerate more developed eastwards. In the west, these rocks give rise to broadly undulating terrain with minor escarpments, and further east to higher ridges, trending northwestwards with the regional strike, and with prominent, fretted, west-facing escarpments. The basic volcanic rocks are mainly red-weathering, with stone-free clay mantles on the tuffaceous rocks and with shallower bouldery mantles on agglomerate. The latter top the escarpments and are prominent on ridge crests, whilst stone-free surfaces characterize lower dip slopes.

Aropokina land system forms the highest foothills, with prominent ridges and many rock faces and small, structurally controlled, gently sloping ridge crests. It contains only very small strike valley plains, some of them ill-drained.

Diulu land system comprises the broadly undulating terrain with minor escarpments forming the lower part of these foothills.

Kanosia land system, where the central foothills meet the head of Galley Reach, is formed mainly on soft tuff. It contains relatively extensive plains which probably represent a former marine erosion surface; these pass inland into low rounded hills.

(ii) *Land Systems of the Southern Foothills.*—These land systems are formed mainly of gabbro, which weathers uniformly into a dark sandy clay passing downwards into loosened rock. They consist of branching ridges and hills between 500 and 1500 ft high, with narrow rounded crests, long straight upper slopes commonly attaining 40°, and short, concave lower slopes locally dissected into spurs. Closely spaced, parallel gullies, quite deeply recessed, are particularly characteristic of these slopes. Slump scars are very common on over-steepened sectors, but slopes up to 45° may be quite stable. The ridges and hills become more massive and higher eastwards, and the minor valley plains die out.

Rouna land system (Plate 9, Fig. 1) consists in part of the escarpment spurs below the Sogeri Plateau, and includes the agglomerate cliffs above (Plate 10, Fig. 1). These sheer rock faces, broken by vertical joint clefts, have yielded enormous rock falls to the slopes below, which otherwise resemble Dubuna land system. Rouna land system also comprises massive gabbroic ridges of the higher parts of the foothills north and south of the escarpment zone.

Dubuna land system comprises the western, lower foothills, with minor prominent ridges and cliffs formed by hard crystalline limestone.

Edebu land system, consisting of closely branching lower ridges and hills formed on softer metamorphosed tuff, forms a narrow north-western extension of the southern foothills.

(*c*) *Upland Zone*

Changes in land forms and morphogenesis which appear with increasing altitude and rainfall in the foothill zone here find fuller expression. Weathering and stream flow are intensified, and the landscape regime is one more typical of New Guinea as a whole.

Much of this zone is underlain by gently dipping volcanic rocks, including more resistant agglomerate which may appear little weathered in steep rock faces and benches (Plate 10, Fig. 1), and tuff and lava which weather more readily into deep red clay. The agglomerate may occur in a massive horizon, as in the Astrolabe Range, or may be thinly intercalated with more weatherable rock.

Heavy rainfall, impermeable regoliths, and generally steep slopes result in high run-off expressed in dense drainage nets which are commonly pinnate, with very closely spaced, parallel primary valley re-entrants on hill slopes. All but first-order streams are perennial.

The characteristic land forms are branching ridges, generally massive and fairly high, but the zone includes low hilly terrain in the centre of the Sogeri Plateau. Slumping is common on slopes exceeding 30°, on a small scale in valley-head alcoves on low ridges and more extensive in areas of high relief, where it is combined with falls from rock faces. The effectiveness of mass movement is shown by colluvial fills in primary gully re-entrants and by increasing development of colluvial aprons; in cleared areas it is reinforced by slope wash and may lead to blockage and poor drainage in minor valleys.

Massive agglomerates form prominent cliffs in areas of strong erosion and locally build small plateaux, whilst constructional volcanic surfaces are common in the north backing ranges. The valleys are mainly narrow, with negligible plains.

(i) *Land Systems of the North Backing Ranges.*—These consist mainly of parallel ridges which rise and increase in massiveness north-eastwards, where they may unite into plateau strips. The main ridge-builders are agglomerate beds, which form low rock faces on upper slopes. Accordant ridge crests, plateau remnants, and simple drainage patterns of parallel valleys reflect the original form of a volcanic sheet in this area.

Mariboi land system comprises the more massive higher ridges and plateaux, whilst Rubberlands land system consists of branching lower ridges with minor floodplain extensions from adjoining lowlands.

(ii) *Land Systems of the Sogeri Plateau.*—The basin structure of the plateau is reflected in its major relief, with an inner lowland drained by the upper Laloki River and Eworogo Creek, and with peripheral higher ground culminating in the Astrolabe Range to the west. The lowland continues as a narrow tongue eastwards along the Eworogo valley past Subitana.

The inner lowland lies mainly between 1600 and 2000 ft and consists of close-set, accordant, rounded ridges up to 150 ft high and a dense pinnate pattern of ill-drained valleys. In the south it passes into broadly undulating terrain east of the Laloki River. There is a discontinuous flood-plain with low alluvial terraces along Eworogo Creek, where incision is prevented by resistant agglomerate down-stream, but the Laloki River is more narrowly incised. The lowland coincides with a north-west-trending strike belt of deep-weathering volcanic rocks preserved within the structural basin upstream from the protective nick-point of Rouna Falls and the rapids above.

Sogeri land system forms the western part of the lowlands, and Subitana land system is the somewhat higher and wetter eastern part.

The high ground west of the lowlands, forming the back slopes of the Astrolabe Range, constitutes most of Vouku land system. There is a fall of between 300 and 600 ft per mile from the crest of the range at 3200 ft to the Laloki River, and it is essentially a dip slope with consequent valleys incised fairly consistently between 100 and 150 ft into weathered volcanic rock, exposing the underlying agglomerate in cliffs on lower valley sides. Between the incised valleys the eastward-descending spurs are broader and stepped in the higher parts, narrowing to ridges in the dissected lower slopes. The resistant rocks end in benches and cliffs overlooking the left bank of the upper Laloki River, which generally follows their eastern limit as though shifting down-dip. Locally, however, the river meanders in gorges through the resistant agglomerate, having been superimposed from the softer rock cover.

Vouku land system also includes small tabular summits formed by outliers of the agglomerate in the south backing ranges east of the Sogeri Plateau, as at Gerebu Hill.

The higher plateau rim east and north-east of the inner lowland forms Owers land system. In part, the greater altitude and dissection may reflect the greater peripheral uplift of the structural basin, but the resistant agglomerate is also more in evidence, and large blocks of it cap many ridges.

(iii) *Land Systems of the South Backing Ranges*.—A belt of phyllites extending from the Veimauri River southwards behind the Sogeri Plateau to the limit of the survey area forms the south backing ranges. These are mainly mapped as Iawarere land system, and consist of fairly short massive ridges, roughly orientated north-west to south-east and meeting in pyramidal summits (Plate 9, Fig. 2). Lower areas of very close dissection occur along strike belts of softer rock, and the upper Musgrave River and its flood-plain terraces at Iawarere occupy such a belt. Generally, even the main rivers such as the Goldie occupy narrowly incised, winding valleys. These inaccessible ranges were visited only near Iawarere, where the steep rectilinear slopes were seen to be mantled with clays, with only minor outcrop of little-weathered rock on ridge crests.

Uberi land system occurs along the upper Goldie River where a gorge has been cut in remnants of an agglomerate cover. It comprises cliffs of agglomerate and the steep slopes to the river below, mantled with agglomerate blocks; the small plateau summits above are included in Vouku land system. It also forms the ranges east of the Sogeri Plateau, namely the Iarivoro and Moatinumu Ranges. These contain massive narrow-crested branching ridges with high cliffs of agglomerate.

VI. Depositional Surfaces

(a) *Fluvial Plains Zone*

This zone, which contains the chief areas of deposition by the large perennial rivers draining from the uplands, occurs as lobate plains about the main valley exits, extending up to 15 miles from the upland border, with gradients mainly between 1 : 500 and 1 : 1000. All the alluvia are geologically young, as shown by the clear traces of the prior rivers which deposited them and by the immaturity of the soils formed from them.

In the upper sectors, that is, within 5 miles of the upland margin, the alluvium is commonly less than 20 ft thick and bed-rock may appear in bank sections; maximum thicknesses in lower sectors are unknown.

The chief distinction is that between the stable plains, subject to partial flooding but not liable to fluvial reworking, and the unstable flood-plains, which are directly affected by the frequent shifts of meandering channels and by concurrent deposition and erosion.

(i) *Land Systems of the Stable Plains*

(1) *Red Clay Plains.*—Alluvium derived locally from the volcanic rocks of the north backing ranges typically weathers to a red clay, which may be stony. Inaukina land system is defined as red clay plains resulting in part at least from alluviation by minor streams, and it generally survives in piedmont tracts between main river outlets. Stream channels tend to be fairly deeply incised into the plains, suggesting that they are relatively old, formed with a base level higher than the present one. Drainage of the plains is poor, partly by virtue of their irregular and impermeable surfaces, subject to flooding from main rivers as well as from ephemeral local streams, partly because local streams have commonly been blocked as a result of alluviation by the larger rivers. Narrow dendritic swamps in blocked valleys are typical of Inaukina land system.

(2) *Olive Silty Clay Plains.*—The other land systems in this group are mainly formed of a cover of uniform olive-coloured alluvium of silty clay grade, with sandy layers restricted to prior channel tracts as identified by microrelief and by air-photo patterns. This alluvium originates in schist and igneous and quartzose rocks in the ranges beyond the survey area. It is formed mainly by over-bank deposition behind levees, and clays or humic clays of prior back-plain swamps are rare. The chief differences between these land systems arise from liability to flooding, water-table levels, and the degree of preservation of former flood-plain features such as prior channels and back-plain depressions.

Relatively the highest, driest, and presumably most stable sector is the Aroa plains, which attain about 15 ft above the normal level of the Aroa River. They have even surfaces of low gradient, broken only by the shallow winding depressions of prior channels. The largest of these connect the Aroa near Keviona with the forested depression south-west of Madabaira village and hence with the tidal outlet at Manu Manu, and probably mark a former course of the Aroa River. Despite their height, however, the riparian tracts are flooded annually for short periods, and extensive inundation of the plains occurs at longer intervals, for the soils are everywhere mottled, although without water-tables.

Keviona land system comprises the higher inland plains flanking the Aroa River, whilst the seaward margin falls into Pinu land system. The latter is complex, being partly of littoral origin. East–west bandings on the air photographs are identifiable on the ground only in the lowest parts, where low sand-beach rises flank the depression south-west of Madabaira mentioned above as a possible former estuary. Seasonal flooding occurs extensively along the lower margin, where a line of clay pans near the mangrove edge marks a possible branch of the prior estuary. The fluvial plains have clearly extended into the littoral zone here, largely burying a former beach plain; the lowest parts are still reached by extreme high tides, whilst the land system includes the tidal back-plain of the lowermost Aroa River.

A somewhat less stable phase of the fluvial plains is represented by a group of land systems flanking the Angabunga River in the northern plains. Former channel tracts and prior flood-plain features such as levees, back slopes, back plains, and swamps are well preserved and give variety to the land systems. The abandonment of its lower course by the Angabunga River in 1956–57 was the latest of many changes, and air-photos show that the river has ranged over a fan-shaped tract up to 9 miles wide, with its apex at the head of the plains near Inawauni. As shown by comparison with the shallower prior channels, the river has cut down slightly in the central part of the inner plains, which are generally between 10 and 15 ft above normal river level and which are no longer subject to significant flooding from the main stream; in contrast, the south-western parts of the plains are mainly not more than 5 ft above normal river level and are potentially less stable. In consequence, the zone of river change is at present downstream. Major changes of course, as distinct from meander shifts, result from breaching of levees and can be regarded as adjustments towards increased gradient. For instance, progradation of the river mouth in Hall Sound had resulted in decreased river gradient prior to the 1956–57 change, and the new course offered a more direct and steeper outlet.

The innermost and presumably the oldest and most stable parts of the northern plains are represented by Bebeo land system, which occurs mainly near the apex of the plains. Epo land system is a downstream continuation, although at a higher level relative to the water-table. Characteristically, these land systems consist of meander tracts with prior channels of two types. The first are well preserved and continuous, locally with distinct low levees, and with some permanent or seasonal standing water, and they may still function periodically as flood channels. They form tracts of stratified clay, silt, and sand. The second are less distinct and are usually marked by broad low banks of loose sand. The banks generally lie on the north side of east–west-trending channels (i.e. on the lee side relative to the dominant southerly winds) and apparently result from wind-piling of former channel and levee sands—a process hardly reconcilable with present-day climate and vegetation cover. Both types exhibit meanders comparable in amplitude and frequency with those of the present Angabunga channel. The better-preserved prior channels occur in lower-lying situations with shallow water-tables, mainly near the outer parts of the plains, and are hence more subject to flooding from tributary or back-plain drainage. They are more typical of Bebeo land system, whilst the sandy type is better represented in Epo land system.

The lower-lying plains between Bebeo and Epo land systems are represented by Beipa land system. This consists mainly of back plains subject to extensive seasonal flooding and locally swampy.

Babiko land system is mapped along the recently abandoned channel of the Angabunga and is defined as the area affected by lowering of the water-table by amounts up to 15 ft following the change of course in 1956–57. It includes extensive back plains and dried-out back swamps, for this was the relatively low-lying, younger part of the plains. Prominent paired levees have confined tidal encroachment to the old river channel.

Vekabu land system, which occupies most of the southern plains, remains extensively forested and details of flood-plain morphology do not appear on air-photos. It appears to represent a less stable phase of the stable plains in that it is extensively flooded during the wet season, not only from main rivers, like the Brown and Vanapa, but also from many intermittent streams from the southern foothills. Only islands of higher ground then remain dry. The upper part of the plain is less mature than the plains further north, as is shown by thinner alluvium (between 5 and 15 ft in the bank sections of the Brown and Vanapa Rivers) and by the general occurrence of sand and gravel at little depth.

Flooding is particularly severe near the foothills, where lateral swamps have formed through blockage of minor valleys by alluviation from a prior channel of the Vanapa River, traceable as a series of oxbows leading to the swamp zone. The oxbows occupy a relatively low-lying tract between the Brown and Vanapa Rivers, subject to severe flooding.

Piunga land system consists of the lowest-lying parts of the stable plains and is subject to general seasonal flooding. It generally borders the swamp zone, as along the lower margin of the southern plains, but it also occurs as small piedmont back-plain margins of higher fluvial plains (as near Inawauni), where it is subject to flooding from intermittent side streams, and in such situations it is partly formed of red alluvial clays derived from volcanic rocks. Well-drained sites in Piunga land system are restricted to terraces of large rivers.

(ii) *Land Systems of the Unstable Plains*.—The main unstable flood-plains have been included in Vanapa land system (Plate 8, Fig. 1), which naturally embraces a wide range of flood-plain dynamics and land forms. Features in common are shifting channels, lower parts subject to frequent floods and to alternate erosion and deposition, more stable higher flood-plains, and minor back-plain depressions and swamps. Changes of river courses are indicated by oxbows and by prior levees.

All the perennial rivers rise in the uplands. They range from the Angabunga and Vanapa, with upland catchments of up to 1000 sq miles, mean discharge of 4000 cusecs,* and mean annual flood discharge of 15,000 cusecs, to the Veimauri and Laloki, with mean discharge of about 1000 cusecs. In the upper flood-plain sectors discharge is variable, with spates of short duration throughout the year, although more frequent and larger in the wet season. Over-bank flooding of riparian

* All stated discharges are approximate.

tracts is generally of short duration and may occur only at intervals of a year or more, but the plains may be inundated throughout each wet season. Large back swamps tend to equalize discharges in lower sectors.

The flood-plains of Vanapa land system fall into valley, upper plains, and lower plains reaches, with contrasts resulting from differences in gradient and regime. The valley flood-plain, which may extend a mile or so into the open plains, is typically a steeply bounded river flat up to $1\frac{1}{2}$ miles wide, with a gradient of about 1 in 250. The channel is slightly braiding rather than meandering, and channel shifts form large elongate gravel islands. The channel tends to be irregular, with gravel banks and fordable rapids alternating with deep pools, and it is normally less than 75 yd wide, although it may attain 150 yd during floods. There is generally a low or shelving bank to an uneven, possibly swampy flood-plain with low banks and flood channels. These features are well exemplified by the Aroa River.

The upper plains reaches, with gradients between 1 in 250 and 1 in 1000, account for most of Vanapa land system, and comprise the tracts of shifting meanders. The degree of meandering varies from strong, as in the Angabunga River, which has a meander belt up to $1\frac{1}{2}$ miles wide, to moderate as in the Laloki River; meander wave-lengths follow general laws, being 10 to 15 times channel width (Leopold and Wolman 1957). The meanders occupy a flood-plain which may be entrenched up to 10 ft below the stable fluvial plain. Where meandering is strong, the lower part of the flood-plain is dominated by its effects, with meander scrolls, discontinuous levees, and oxbows, as in the Angabunga below Inawauni, all these features being subject to destruction and replacement as the meanders shift (a comparison of air-photos from 1939 and 1957 indicates meander shifts of between 10 and 15 ft per annum in the Angabunga). Where meandering is less strong, as in the Laloki River, the river is flanked by an uneven lower flood-plain with multiple levees and flood channels. The banks here are almost everywhere steep, and not alternately steep and shelving as in the Angabunga.

In the lower plains reaches, with gradients less than 1 in 1000, the river tends to build itself above the swampy or seasonally flooded land systems which flank it. During floods the river maintains its flow through standing water—conditions which favour the growth of prominent, continuous, paired levees. These eventually restrict the frequency of over-bank flooding, aided by the regulatory effects of adjoining swamps which act as recharge and discharge reservoirs, and the channel may be narrower and more contained here than upstream, as demonstrated by the recently abandoned Angabunga channel. Under these conditions meander shifts become less important, but the relatively high-lying river course becomes potentially unstable and eventually crevassing of the levees occurs, resulting in major changes of course as in the Angabunga River in 1956–57. The former lower course of the Angabunga (now Babiko land system) represented the completion of such a process. The new channel, with low levees and frequent flooding of adjoining back plains, represents an early stage, as do the lower Biaru and Brown–Laloki Rivers. These lower plains reaches commonly traverse the swamp zone and constitute outliers of the fluvial plains zone.

(b) *Swamp Zone*

Swamps are here defined as areas with permanent or seasonal standing water. The greater extent of swamps in the north of the area reflects increasing emergence southwards in the coastal lowlands, upon which cross-warping is superimposed, with structural depressions in the area of Galley Reach and in the north of the survey area. The sectors of the swamp zone may hence be regarded as incompletely filled parts of tectonic depressions. In the north, swamps extend unbroken from the upland foot to the coastal hills, but further south they are restricted by lobes of the fluvial plains, and they eventually end in small lateral swamps in valley embayments of the southern hills.

Permanent swamps predominate, but areas of open water are small. From their forms, lakes can generally be explained as effects of prior drainage, the lines of which are generally traceable on air-photos. Such lakes include oxbows and abandoned channels, lateral levee lakes, arcuate scroll lakes, back-plain and meander-core lakes, and lakes in blocked tributary valleys. Lakes formed in old river channels normally have steep banks, whereas back-plain lakes have shelving shores subject to seasonal shifts.

The swamps are largely blocked by fluvial deposits and are extensively subject to flooding from main streams; hence they are greatly influenced by river levels. They play an important role in the hydrology of the coastal lowlands in that they receive flood waters from main rivers and from their own feeder streams during the wet season, whilst reverse flow may occur at times of low river level, and in this way they moderate discharge in the lower sectors of the rivers. Seasonal variations in water levels of between 3 and 6 ft are common in swamps.

Some larger swamps connect directly with estuarine land systems of the littoral plains zone, but this is not an important distinction in the differentiation of land systems.

The swamps are areas of clay deposition from still water, with silty alluvium in deltas of influent streams and in levees of through-going channels. Organic contribution to swamp sediments is small, except in sago swamps.

In land-system grouping, differentiation has been made into mainly permanent and mainly seasonal swamps, with corresponding differences in amounts of through drainage and in resultant land forms. Channel tracts generally form higher, seasonally dry ground, and swamps with such elements represent a more advanced stage in swamp infilling.

(i) *Mainly Permanent Swamps*.—Waigani land system comprises swamps with very few organized river channels (Plate 5, Fig. 2). It is very extensive in the northern swamps, but is elsewhere restricted to back swamps on the margins of fluvial plains or to depressed areas within higher-lying swamps. It contains most of the permanent lakes. There is much evidence of prior rivers, now disorganized and submerged, suggesting a subsequent rise of water level; this may locally be explained by continuing upbuilding of an alluvial barrier, but sea-level rise and/or coastal shifts may be responsible where the swamp connects directly with the sea.

Two swamp land systems are characterized by through-going river channels and by subsequent land-unit differentiation between levee and back swamp. In Engepa land system, which occupies an elongate depression between the Akaifu and

Inawafunga Rivers, the riverine element is limited to a very small tract. In Akaifu land system the riverine element varies from small in the lower Dilava swamps to moderate in the northern swamps along the Akaifu River. Seasonal swamps are also relatively more extensive in these two land systems.

(ii) *Mainly Seasonal Swamps*.—These higher-lying marginal parts of the swamp zone consist mainly of back plains of large rivers. Biaru land system occurs on the seaward margin of the zone, upstream from the estuary reach of the Biaru River, and its back-plain swamps range from freshwater to brackish downstream, with small mangrove flats in the lowest parts. Doura land system, on the inner margin of the southern swamps, consists largely of back plains which are only periodically flooded. It is traversed by the Brown–Laloki channels and there is much evidence of former river courses such as prior levees and oxbows.

(c) *Littoral Plains Zone*

(i) *Beaches*.—Complexes of sand beach ridges, mapped as far as possible into Hisiu land system, occur on many open coasts. Under the prevailing south-east winds the coast receives a strong southerly swell which abates with the short north-westerly season, from December through March. Beach drift on open coasts is northwards, but is modified by variations in exposure or in coastal trend; on sectors protected from the south, for example, as on the north shore of Redscar Bay and on the coast south-east of Cape Possession, which are in lee of Redscar Head and Yule Island respectively, drift is easterly or south-easterly. Maximum fetch is mainly from the south-west, and beach orientation is accordingly north-west to south-east or north-north-west to east-south-east. The present beaches are gently sloping, formed of medium and fine sand with triturated coral and shell. Prevalent winds are onshore, and a low, irregular foredune is typically present. A fringing coral reef occurs as far north as Yule Island, where it ends, probably owing to the combined effects of increasing turbidity towards the head of the gulf, unconsolidated foundations, and coastal instability near the large river outlets.

The beach complexes occur as beach plains, compound spits, or barrier beaches. A fine example of a beach plain occurs on the north shore of Redscar Bay, where favourable conjunction of south-westerly exposure and abundant sediment from Galley Reach has resulted in coastal progradation of almost 3 miles, with between 25 and 30 evenly spaced, parallel sand ridges. The ridges are most prominent near the present shore, where they may attain a height of 5 ft, and are generally more subdued inland, locally passing into sand plain. Size grading of the sands on the crests of ridges indicates some sorting by wind, and the ridges must be regarded as joint products of beach formation and foredune growth, whilst continuing modification by strong south-easterly winds may account for the more subdued form of older ridges inland.

Sand spits are well developed in the former embayment at Lesi Inlet, where three north-west-trending spits have formed, separated by mangrove flats. Each spit typically consists of from one to three beach ridges with recurves. Barrier beaches are exemplified on the south shore of Redscar Bay, where former rocky islands have been tied to the land.

The larger rivers tend to be deflected by beach extension, but commonly breach the beach barriers, and many of the tidal inlets are old river outlets; Lesi Inlet, for instance, was a former mouth of the Biaru River. Where lesser drainage has been ponded by beach growth, small, mainly seasonal freshwater swamps have formed, and these are included in Hisiu land system.

Only on the coast north of Pinupaka Point has important coastal erosion occurred in Hisiu land system, and this is seen in the truncation of beach ridges near Waima (Plate 2, Fig. 2), bringing the beach swales under tidal influence.

(ii) *Tidal Flats.*—The main occurrence of tidal flats is in former embayments behind protective barrier beaches and spits, as in Redscar Bay and Lesi Inlet, and in the naturally protected Hall Sound in the former delta of the Angabunga River. The flats may attain 5 miles in width in these areas. There are small examples of open tidal flats on protected prograding coasts as at Delena. At the land system level, the chief differences relate to frequency and depth of tidal inundation. The tides are semi-diurnal with a range of from 5 ft at ordinary spring tides to 2 ft at neaps. The flats range from below low water-springs to the extreme upper limit of tidal penetration.

Sediments within tidal flats show a transition from the outer coast, where wave scour and tidal currents are capable of moving the finer materials and where deposits are sandy, through a range of intermediate textures in protected tidal flats, to mainly clay deposits in the highest areas of shallow inundation and quiet water. Silts are important only where there has been deposition from rivers.

Aggradation has not been a continuous and simple process in the littoral plains zone, and land-unit patterns are complicated by the occurrence in the flats of stranded beach ridges, many of them almost obliterated by tidal deposition. Such flats are small chenier plains. Further, most of the larger areas of tidal flats also serve as river outlets, and tidal regimes and aggradational patterns are complicated accordingly.

Observations in this area support the general view that mangroves colonize areas naturally subject to aggradation: they are not initiators of sedimentation although they subsequently hasten its rate through the trapping effect of their roots. Crabs are important in the reworking of tidal sediments and the evolution of microrelief, and crab-built mounds are increasingly prominent from mean sea level up to high-water mark, culminating in closely spaced platforms up to 4 ft high and 5 yd across (Plate 1, Fig. 2), with a maze of interconnecting tidal leads.

Drainage is by tidal creeks, which taper gradually inland, the lower sectors being particularly funnel-shaped. This represents an equilibrium form, adjusted to increasing tidal discharge seawards. Tidal scour is considerable at creek outlets, for currents up to 3 knots are common here, and may be stronger where reinforced by river flow. The creeks meander like the rivers of the area, and many of the meanders have in fact been inherited from rivers. Creek meanders show the same relationships to channel width and are subject to growth and shift in the same way as river meanders, as indicated by erosion of mangrove flats on concave banks. Levees are unimportant, however, for over-bank flooding is associated with the quiet advance of the tide and not with flood currents; for this reason meander intercepts are not sealed off and interconnecting creeks remain active.

Galley Reach land system (Plate 1, Fig. 1) comprises the main tidal flats below high-water mark and dominates most of the areas of widespread mangrove development.

Lesewalai land system consists of higher tidal flats, mainly above high water of ordinary tides and extending to the limits of tidal influence. It tends to lie inland from Galley Reach land system and is also characteristic of smaller areas of restricted tidal ingress behind beach barriers. Its tidal creeks are smaller and less organized. A feature of Lesewalai land system, even in its highest parts, is transcurrent, stranded beach ridges, commonly forming subdued sandy rises and swales, elsewhere shown only by alternation of sandy and clayey sediments. The overlying sediments may be fluvial locally, as near Rapa, but in so far as they are lagunal they probably indicate a slight positive movement of sea level.

The unusual occurrence of Lesewalai land system on the open coast south of the Angabunga River mouth is due to coastal recession and the destruction of protective beaches.

Kido land system is the highest of the main areas of tidal flats, situated behind barrier beaches in the south of Redscar Bay (Plate 1, Fig. 1). Flats below high-water mark are here restricted to the margins of characteristic tightly meandering creek systems, and the highest intercreek areas are bare salt flats reached only by the highest tides. Their arcuate patterns indicate that they may have originated as levees of the Laloki River, a former course of which can be traced across many stranded beach ridges to within two miles of the present coast. The evolution of the littoral plains has here been complex, with an earlier phase of littoral progradation and fluvial deposition followed by renewed tidal invasion, with present creek and mangrove patterns partly adjusted to and partly transgressive of the former river pattern. The tidal invasion may be explained in part by the northward shift of the river, but a positive movement of sea level is indicated by the burial of beach ridges beneath lagunal clays in the north of the land system.

On the embayed reef-fringed coast of the southern hills sector, beach ridges and tidal flats occur in narrow littoral complexes mapped as Papa land system. In the protection of the reef, mangroves may colonize the sandy outer tidal flats. Where the coast is steep, only the outer flat and beach units are present; the lagunal inner flats occur only in lowland embayments, commonly with an inner beach ridge marking an older shore.

(iii) *Estuaries*.—The term is used to designate channels subject to interaction of tidal and river flow. Levees may extend downstream well into the tidal zone, even below high-water mark, flanked by lower-lying back plains which are truly tidal and which drain away independently through creek systems. The back plains show the interaction of flooding from the main channel and of tidal effects, and there is a range downstream from freshwater swamps inland to increasingly saline flats near the coast.

Nipa land system represents such an estuarine setting. It is almost wholly below high-water mark, and tidal influences predominate in the back plain. It occupies the tidal reaches of the Brown–Laloki Rivers and extends as back plains to the heads of the major tidal inlets on either side. It also comprises the lowermost reach of the Biaru River and the flats to the north which mark a former river outlet. Increasing importance of littoral processes downstream is reflected in a transition from silty sediments inland to sandier deposits near the coast.

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PART VII. SOILS OF THE PORT MORESBY–KAIRUKU AREA

By R. M. Scott*

I. General Features

This Part is based on field observations supported by chemical analyses,† the field and laboratory pHs showing good agreement. The chemical analyses given with some of the soil family descriptions are based mainly on one or two samples and therefore must be taken only as a guide.

The soils show a marked variation in pedogenesis within the area. In the moderate to high-rainfall areas, pedalfer weathering prevails, and the consistence and base exchange capacity of the soils suggest that they are dominated by 1 : 1 clay minerals. In the lower-rainfall areas, the soils show a greater affinity with the underlying rock and tend to exhibit pedocal weathering. Their consistence and cation exchange capacity suggest that they are dominated by 2 : 1 clay minerals.This range in rainfall is reflected in the percentage saturation of cations of the soils, those in the higher-rainfall areas being excessively leached in contrast to those of the lower-rainfall areas, which are moderately to fully saturated.

Along the coast and in estuaries the soils are greatly influenced by wind and by wave and tidal action, which generally give rise to sandy and saline soils.

The alluvial soils show a textural relationship to their source. Those derived from volcanic and sedimentary rocks are fine-textured, while those derived from metamorphic rocks, which mainly occur outside the area, show a textural range from sand to clay according to the land form. A similar relationship has been noted by Andriesse (1960). Some of these soils are subject to tidal influence, while others undergo varying degrees of freshwater flooding.

There is a close relationship between soil families and land forms, as is well shown in the land unit descriptions in Part III. The correlation between vegetation and soils is mainly apparent at soil group level, where both vegetation and soils reflect differences in drainage, droughtiness, or tidal influence. However, at family level within a group the correlation is often not so apparent.

The organic content of the soils throughout the area is generally low.

II. Soil Classification

The soils have been separated into 13 groups (Table 18) based on profile form and drainage, each group showing the effects of environment and genesis. These groups have, in turn, been separated into families based mainly on texture, colour, and soil reaction.

Descriptive names have been used for the soil groups and for the regosols and lithosols at family level. The remaining families have been given place names. No attempt has been made to relate these soils to those found elsewhere.

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† The chemical analyses were carried out by the Royal Tropical Institute, Amsterdam.

TABLE 18
SOIL GROUPS AND FAMILIES IN THE PORT MORESBY–KAIRUKU AREA

Soil Group	Family
Beach soils	(1*a*) Grey fine sands
	(1*b*) Brown fine sands
	(1*c*) Grey sands
Mangrove soils	(2*a*) Grey sandy peats
	(2*b*) Grey loamy peats
	(2*c*) Grey clayey peats
Intertidal alluvial soils	(3*a*) Grey to brown silty clays
	(3*b*) Brown sticky clays
	(3*c*) Grey silty clays
Very poorly drained alluvial soils	(4*a*) Grey sticky clays
	(4*b*) Grey loams
	(4*c*) Relic olive silty clays
Imperfectly drained alluvial soils	(5*a*) Alkaline olive grey silty clays
	(5*b*) Neutral olive grey silty clays
	(5*c*) Alkaline olive grey stratified soils
	(5*d*) Neutral olive grey stratified soils
	(5*e*) Alkaline grey sticky clays
	(5*f*) Neutral grey sticky clays
	(5*g*) Acid brown clays
Moderately well-drained alluvial soils	(6*a*) Alkaline olive silty clays
	(6*b*) Neutral olive silty clays
	(6*c*) Alkaline olive stratified soils
	(6*d*) Neutral olive stratified soils
	(6*e*) Alkaline/neutral olive stratified soils
	(6*f*) Alkaline olive brown sands
	(6*g*) Neutral olive brown sands
	(6*h*) Neutral relic grey silty clays
	(6*i*) Alkaline relic olive grey stratified soils
Dark cracking clay soils	(7*a*) Boroko
	(7*b*) Jackson
	(7*c*) Inapi
Lithosols	(8*a*) Alkaline dark lithosols
	(8*b*) Neutral brown lithosols
	(8*c*) Neutral red lithosols
	(8*d*) Acid brown lithosols
Acid red to brown clay soils	(9*a*) Diulu
	(9*b*) Sogeri
	(9*c*) Uberi
	(9*d*) Tiviki
	(9*e*) Koitaki
Red gravelly clay soils	(10*a*) Nebire
	(10*b*) Bom
Brown clay soils	(11*a*) Fairfax
	(11*b*) Bomana
Texture-contrast soils	(12*a*) Ouou
	(12*b*) Ward
	(12*c*) Nikura
	(12*d*) Laloki
Alkaline reddish clay soils	(13) Obu

III. Descriptions of the Major Soil Groups and Soil Families

The terminology used in the following descriptions is that of the United States Department of Agriculture (1951). All soil colours refer to the moist condition and are those defined in the Munsell colour charts. The soil descriptions are all based on auger sampling, and therefore the structure of the subsurface horizon in many cases could not be properly observed.

(1) *Beach Soils*.—These sandy regosolic soils owe their genesis to both wave and wind action. They have been subdivided into three groups based on colour and profile development which reflect age, stability, and water-table relationships, which vary with distance inland. They cover about 50 sq miles in the littoral plains zone.

(1*a*) *Grey Fine Sands*.—These consist of uniform grey, loose, fine, wind-sorted sand which becomes mottled at depth. They have not developed an A horizon and are very unstable, fine sand continually being added to or removed from them. They occur on foredunes and are alkaline throughout; the depth at which mottling appears depends on their height above high-water mark, the higher foredunes being excessively drained.

(1*b*) *Brown Fine Sands*.—These account for more than 90% of the beach soils. Like the grey fine sands they are of uniform texture throughout but differ in that they are stable enough for profile development to have begun, as demonstrated by a weak A horizon and by the browner colour. They consist of up to 12 in. of black to dark brown, loose granular to weak crumbly fine sand overlying dark greyish brown to olive brown, loose, structureless, fine sand. The soil reaction of the surface soil is neutral to very strongly alkaline, and the substratum is usually very strongly alkaline. These soils are greatly influenced by the water-table, since it controls the drainage and its associated mottling as well as the soil reaction at the surface. The drainage varies from excessive to poor, the poorly drained soils being highly mottled and very strongly alkaline to the surface. In the vicinity of the water-table the soil becomes grey. Brown fine sands occur on inner beach ridges and sand plains, mainly in Kido and Hisiu land systems, the sand plains possibly being beach ridges which have been levelled by wind action.

(1*c*) *Grey Sands*.—These consist of grey loose variable sands with frequent shell fragments, and are regularly inundated by tides. They occur on the outer beach, and the fine sand fraction is removed by wind during low tides. White sand derived from coral was seen locally, but the occurrences were so small that they have been included in this family.

(2) *Mangrove Soils*.—These soils cover about 120 sq miles, mainly in the littoral plains zone, and are characterized by a subsurface mangrove peat layer consisting mainly of a fibrous root mass, and by an absence of leaf litter despite the dense foliage above. Another feature of the soils is that they are worked by crabs. These workings vary from mounds of about 4 ft in height to small craters around crab-holes. The mounds, which are most prominent on mid-tidal flats, are continually being added to (Plate 1, Fig. 2), and therefore each tide must gradually erode them or they would have grown out of all proportion. This mound-building

constitutes a mixing of the soil material since the soil texture on the mounds is similar to that in the intervening depressions. This mixing may well be the mechanism for the burial of the peat layer and the reason for the absence of leaf litter. Alternatively, the leaf litter may be washed out by each receding tide.

All the mangrove soils are inundated by the tide in varying degrees, and all are therefore poorly drained. They have been separated into three families on a textural basis with sandy peats on the coast and loamy and clayey peats in turn inland. This textural differentiation could be the result of littoral sorting on crab workings. Those soils nearer the coast are subject to greater wave action and tidal influence than those of the inland families, with the removal of the finer fractions.

(2*a*) *Grey Sandy Peats.*—These have up to 2 ft of very dark greyish brown, loose loamy sand to sand, with varying amounts of shell fragments, overlying mangrove peat. The sand fraction varies from fine to coarse. The crab workings are of the small crater type which are demolished with each tide. This family occurs on outer tidal flats in Papa land system, and has an area of about 25 sq miles.

(2*b*) *Grey Loamy Peats.*—A dark greyish brown to grey, massive, mottled, sandy loam to sandy clay loam overlies mangrove peat at a depth varying from 12 in. to 14 in. The transition between the upper layer and the peat appeared in most cases to be abrupt, although a transitional loamy peat layer was occasionally noted. The crab workings here are of the mound type, being up to 4 ft high, and cover up to half the land surface. Grey loamy peats are found on tidal flats behind beach ridges and are covered at high tide by 3–4 ft of water. They are the most extensive of the mangrove soils and cover about 60 sq miles, mainly in Galley Reach land system and to a lesser extent in Kido and Nipa land systems.

(2*c*) *Grey Clayey Peats.*—These have a dark grey to dark greyish brown, massive mottled sandy clay from 18 to 36 in. thick overlying mangrove peat. The boundary between the upper horizon and the peat may be diffuse, and in many cases the peat layer is mixed with some sandy clay. Crab mounds in this zone range up to 3 ft high, but may be absent. In areas of only occasional tidal inundation these mounds are stable, with a vegetative cover over them, and are low and rounded and presumably have been abandoned by the crabs. These soils occur on innermost tidal flats, where tidal inundation is shallow and confined to very high tides. They extend over about 50 sq miles, mainly in Galley Reach land system, but also as small areas in most other land systems of the littoral plains zone.

(3) *Intertidal Alluvial Soils.*—These alluvial soils are subject to tidal influences and are typically saline. They cover about 50 sq miles.

(3*a*) *Grey to Brown Silty Clays.*—A dark greyish brown to dark grey, massive mottled silty clay passes into an olive brown to grey, mottled silty clay at between 8 in. and 12 in., the grey colour being caused by a high water-table at depths varying from 18 in. to 36 in. There may be an abrupt transition at varying depths to an olive brown to grey, fine sand to sandy clay horizon which represents buried beach ridges or swales. These buried layers are a result of coastal or river changes. This family is subject to inundation by occasional very high tides and is very strongly alkaline throughout. It occurs on alluvial tidal flats in Lesewalai and Kido land systems, and has an extent of about 25 sq miles.

(3*b*) *Brown Sticky Clays.*—A black to very dark greyish brown, angular blocky sandy to heavy clay with prismatic surface cracking merges into a dark brown to dark greyish brown, prismatic, mottled, sandy to heavy clay between 6 in. and 12 in. The soil colour becomes grey in the vicinity of the water-table. Some of these soils may pass abruptly at varying depths into sand or sandy loam, representing buried littoral deposits. Many of these soils have a very thin surface layer about $\frac{1}{8}$ in. thick which curls up from the edges of the cracks when the soil is drying and which eventually becomes detached when dry.

These soils are subject to inundation by very high tides as well as occasional flooding from the land. They are very strongly alkaline throughout and occur in pans or depressions, some of which could be former lagoons, in Kido land system and to a lesser extent in Papa land system.

(3*c*) *Grey Silty Clays.*—These have 6–12 in. of a dark grey to dark greyish brown, massive mottled silty clay loam to silty clay above a dark grey massive mottled silty clay loam to silty clay. Often a fibrous root mat is present at depth, but this is not nearly so pronounced as in the mangrove soils. They are neutral throughout and occur in estuarine tidal flats and back plains, mainly in Nipa land system. They are inundated at each high tide by a mixture of fresh and sea water, or by fresh water during flooding of the river. A thin brown surface mud deposit is a frequent feature.

(4) *Very Poorly Drained Alluvial Soils.*—These alluvial soils are characterized by being permanently waterlogged. They have been subdivided into three families based on textural differences. The group covers about 280 sq miles, mainly in the swamp zone.

(4*a*) *Grey Sticky Clays.*—These consist of grey to dark grey massive sticky clays which may or may not be mottled. In some sites gleying was apparent at depth. A surface peaty layer of varying thickness may occur, with composition varying from a raw fibrous root mat to a peaty clay. These soils have all been sampled at swamp fringes in various depths of water and this may account for the absence of or poor development of a peat layer since there is always the possibility that the areas sampled may dry out at times. They are neutral and have about 90% saturation with total exchangeable metal ions of about 25 m-equiv. per 100 g. Exchangeable calcium and magnesium are the dominant cations, the latter tending to be greater. The organic matter is about 1·5%. They occur in swamps and river cut-offs and a deposit of clay is added to these depressed areas with each river flooding. They are by far the largest family in this group, being very extensive in Waigani, Akaifu, and Engepa land systems.

(4*b*) *Grey Loams.*—These consist of a grey massive mottled sandy loam to silt loam which may become very sandy at depth. These are again neutral throughout and occur on aggrading river banks, stabilized by a grass vegetation, in Doura and Vanapa land systems. They are continually being added to as the vegetation traps the fine sand and silt held in suspension by the river.

(4*c*) *Relic Olive Silty Clays.*—A dark grey, massive mottled silty clay overlies a dark greyish brown to olive, massive mottled silty clay. They are neutral throughout and occur on formerly dry back plains in Vanapa land system which have become permanently flooded owing to a change in river course. Deposition of clay takes place with each river flooding. The soils retain the olive colour of a former drier environment, but they will gradually become grey, like the other swamp soils.

(5) *Imperfectly Drained Alluvial Soils.*—These soils, which cover about 300 sq miles, are frequently inundated by rivers for short periods or throughout the wet season, with deposition taking place with each flood. Because of the level terrain, run-off is comparatively slow and there is a tendency to pond. Many of these soils have a water-table within 4 ft of the surface during the dry season. In the first instance, they have been separated on texture, which shows a close relationship with land form. Each of these textural classes has been subdivided at family level according to soil reaction, those inland being neutral to slightly acid while those near the coast are very strongly alkaline. There is no abrupt boundary between the neutral and alkaline families, but a gradual change which may extend over a mile. The source of this alkalinity is thought to be cyclic salt, since the presence of a strong on-shore wind for nearly the whole year and the occurrence locally of a coral reef close to the shore, favouring the generation of surf spray, would appear ideal for transport of cyclic salt.

(5*a*) *Alkaline Olive Grey Silty Clays.*—A dark grey to dark greyish brown, massive to weak crumbly silty clay varying in thickness from 2 in. to 18 in. merges into an olive grey to olive, massive mottled silty clay. This in turn passes into a grey massive silty clay at a depth depending on the water-table. The soil reaction ranges from neutral to very strongly alkaline in the surface horizon, and from moderately to very strongly alkaline in the subsurface horizon. The soils exhibit slow permeability. They extend over some 30 sq miles and occur in back swamps and back-plain depressions in Biaru, Doura, Akaifu, Beipa, Pinu, and Vanapa land systems.

(5*b*) *Neutral Olive Grey Silty Clays.*—These soils have similar morphology and land-form relationships to the alkaline olive grey silty clays, but since they occur inland from them they differ in soil reaction, the surface and subsurface horizons varying from neutral to slightly acid. They cover about 150 sq miles, mainly in Piunga land system but also in Doura, Biaru, Bebeo, and Vanapa land systems.

(5*c*) *Alkaline Olive Grey Stratified Soils.*—These soils are stratified, each layer being homogeneous and usually showing an abrupt transition to the adjacent layers. The texture of the layers varies from silty clay to coarse sand. This stratification occurs in no apparent order and is presumably due to variations in river behaviour.

These soils have a dark brown to grey surface horizon between 4 in. and 15 in. thick, overlying mottled subsurface horizon which is olive grey to olive in the upper part, becoming grey with depth. The soil reaction is usually mildly alkaline at the surface and moderately to very strongly alkaline at depth. Soil structure varies from loose single grains to massive, mainly depending on the texture. The permeability of these soils probably varies, but generally would appear to be slow. They occur on wet levee tracts and in prior drainage channels in the swamp zone.

(5*d*) *Neutral Olive Grey Stratified Soils.*—These differ from the soils above only in soil reaction, which is neutral to slightly acid throughout. They are mainly confined to the swamp zone.

(5*e*) *Alkaline Grey Sticky Clays.*—A black to very dark grey, cracking, sandy to heavy clay merges at 6 in. to 12 in. into an olive grey to grey, mottled sandy to heavy clay. These soils appear to have a prismatic structure and are sticky and plastic when wet. They are moderately to very strongly alkaline throughout. They are fully saturated, exchangeable magnesium (about 10 m-equiv. per 100 g) being greater than exchangeable calcium (about 5 m-equiv. per 100 g). Exchangeable sodium is high, being over 30% of the total exchangeable metal ions, which range from 25 to 30 m-equiv. per 100 g. Organic matter is less than 1%. The permeability of these soils would appear to be slow. They are found on seasonally flooded swamp fringes in Hisiu and Biaru land systems.

(5*f*) *Neutral Grey Sticky Clays.*—These show the same morphology as the alkaline grey sticky clays but are neutral to slightly acid. They were observed only in Waigani land system.

(5*g*) *Acid Brown Clays.*—A dark brown crumbly, friable, sandy to heavy clay between 6 in. and 14 in. thick merges into a brown, yellow-brown, or dark reddish brown, weak subangular blocky to massive, mottled friable sandy to heavy clay. Manganese concretions are frequently present at depth. The soils are slightly acid throughout and have a low saturation (about 15% in the surface and 5% in the subsurface horizons) with 3% organic matter. They appear to be moderately permeable, but the drainage is restricted by a high water-table, even during the dry season. Those with a reddish brown subsurface horizon are mainly confined to the tributary valleys and valley heads, while the browns and yellow-browns are found in the main valleys and flood-plains, which are presumably inundated for longer periods. This family has an area of about 80 sq miles and dominates in Inaukina land system. It also occurs in Piunga land system and in land systems in the foothill and upland zones.

(6) *Moderately Well-drained Alluvial Soils.*—These soils owe their moderate drainage to their occurrence on relatively high-lying sites on alluvial plains, hence they are flooded only for short periods at long intervals. Unlike the imperfectly drained alluvial soils, deposition has practically ceased. During a wet period they are liable to have a high water-table, which recedes during dry periods. This soil group is mainly confined to the fluvial plains zone, where it covers about 300 sq miles. As the terrain in general is almost level, run-off is slow, and as the majority of soils in this group appear to have a slow permeability, water may lie on the surface for short periods. These soils have been separated on the same basis as the imperfectly drained alluvial soils, i.e. on texture and soil reaction. Included in this group are soils of a formerly wetter environment, which still exhibit characteristics of this environment although this has altered because of a change in river course.

(6*a*) *Alkaline Olive Silty Clays.*—A dark greyish brown to dark brown, weakly crumbly to massive silty clay between 6 in. and 12 in. thick merges into a dark yellowish brown to olive, massive silty clay. A grey massive silty clay occurs below the latter horizon in wetter sites, at depths regulated by the water-table. Slight mottling, which gradually becomes more prominent with depth, may occur at depths varying from 6 in. to 36 in., depending on the wetness of the site. The soil reaction varies from moderately to very strongly alkaline in the surface horizon, while the subsurface horizons are very strongly alkaline. Calcareous concretions may be present. Occasionally a darker-coloured horizon, which could be a buried humic horizon, is encountered at depths varying from 3 ft to 4 ft. The soils are fully saturated, exchangeable calcium (decreasing from 18 to 8 m-equiv. per 100 g) being greater than exchangeable magnesium except under very alkaline conditions, where the reverse occurs. Exchangeable sodium is moderate (about 6%), but possibly increases nearer the coast. Organic matter is about 2·5% at the surface. These soils would appear to have a slow permeability. They cover about 100 sq miles in the fluvial plains zone, chiefly in Beipa, Epo, and Pinu land systems, where they are the main soils.

(6*b*) *Neutral Olive Silty Clays*.—These have similar morphology and land-form relationships to the above family, but differ in soil reaction, which is neutral to slightly acid. Locally a moderately alkaline, very thin surface layer was seen, which appears from observation to be related to recent burning of the grass vegetation. This effect appears to be very ephemeral, the thin surface horizon possibly being quickly leached or blown away. The saturation of these soils increases with depth (45–72%), with calcium the main exchangeable cation. Total exchangeable metal cations also increase with depth (8–15 m-equiv. per 100 g) and organic matter is less than 1·5%. These soils cover about 80 sq miles and are the main soils of Keviona land system.

(6*c*) *Alkaline Olive Stratified Soils*.—Like the olive grey stratified soils, these consist of homogeneous layers of differing thickness, which vary in texture from silty clay to fine sand. The colours range from dark greyish brown to brown in the surface 6 in. to 14 in., becoming dark yellowish brown to olive below. In wet situations, grey colours become apparent at depth. Mottling is seen at depths varying from 6 in. to 30 in. Structure varies from single-grain to massive. Soil reaction varies from mildly to very strongly alkaline at the surface, and is very strongly alkaline at depth. The permeability is again variable, but usually at least one fine-textured layer occurs, which causes it to be slow. This family has an area of about 25 sq miles and occurs on levees and in prior channels, mainly in Vanapa land system.

(6*d*) *Neutral Olive Stratified Soils*.—These are similar to the alkaline olive stratified soils apart from soil reaction, which is here neutral to slightly acid. They mainly occur in Vekabu, Piunga, and Vanapa land systems.

(6*e*) *Alkaline/Neutral Olive Stratified Soils*.—The upper layer or layers of these stratified soils range from silty clay loam or fine sandy clay loam to silty clay or fine sandy clay. These always overlie a fine sand or loamy fine sand layer at depths between 12 in. and 30 in. Occasionally rounded gravel was found with the sands. Colour ranges from dark greyish brown in the surface horizon, which varies in depth from 6 in. to 24 in., to dark yellowish brown to olive in the subsurface horizon. Grey colours were seen at depth on wetter sites. Mottling appears at depths of between 3 in. and 28 in. The structure of the surface horizon varies from weakly crumbly to massive, becoming massive below 6 in.; the sandy lower horizon has a loose, single-grain structure. Because of the presence of a sandy substrate, these soils would appear to have moderate permeability. Soil reaction was unusual, being strongly alkaline at the surface and neutral to slightly acid below. This may be due to the leaf litter, since all these observations were taken under forest. These soils are fully saturated at the surface, but saturation decreases with depth to about 70%. Total exchangeable metal cations decrease from about 30 to 5 m-equiv. per 100 g with depth, the dominant exchangeable cation being calcium. Organic matter varies between 2 and 4%. These soils occur on plains in Vekabu land system and it is hard to explain why they differ in texture from other soils on similar sites in the fluvial plains zone. It is possible that the difference is due to the proximity of hills, for a sample taken in grassland more distant from the hills, but within the same land system, showed the silty clay texture typical of the plains of this zone.

(6*f*) *Alkaline Olive Brown Sands*.—A very dark grey to very dark brown, fine to medium sand merges at 8 in. to 13 in. into a very dark greyish brown, olive brown, or dark yellowish brown, fine to medium sand or loamy fine to medium sand. The structure throughout the profile is loose single-grain. Mottling may occur below 20 in. and gravel was occasionally noted at greater depths. They are moderately to strongly alkaline in the surface horizons and strongly alkaline below. They occur in Bebeo and Epo land systems, on raised prior channels which have tended to become indistinct and which have possibly been affected by wind-sorting. Because of their raised position and texture, they would appear to have rapid permeability.

(6*g*) *Neutral Olive Brown Sands*.—These are similar to the above family, but have a neutral soil reaction. This family occurs in Babiko and Keviona land systems.

(6*h*) *Neutral Relic Grey Silty Clays*.—A dark grey to very dark grey, massive silty clay merges at about 12 in. into a grey to dark grey, massive silty clay. Mottling is apparent from the surface, and soil reaction is neutral. Permeability appears to be slow. These soils occur in Babiko land system, on back plains which were formerly flooded seasonally but which are now only occasionally flooded because of changes in river course.

(6*i*) *Alkaline Relic Olive Grey Stratified Soils*.—These show various textural layers from silty clays to fine sands. They have a dark grey to dark greyish brown surface horizon up to 18 in. thick, with a dark grey to olive grey subsurface horizon. Included in this family are a few better-drained olive brown stratified soils. The structure of these soils varies from loose single-grain to massive. Mottling was observed from a depth of between 2 in. and 18 in., and soil reaction was strongly alkaline throughout. These soils occur in Babiko land system, on levees of recently abandoned river channels.

(7) *Dark Cracking Clay Soils*.—These soils, which cover about 110 sq miles in the coastal hill zone, exhibit weakly hydromorphic conditions for short periods, followed by periods of drying out. They are derived from older alluvium, on plains subject only to slight deposition or erosion. They are areas of accumulation of bases from seepage and from run-on. Their texture and structure preclude any significant leaching, and there is an accumulation of bases in the subsurface horizon. They exhibit seasonal cracking, varying from very slight to marked. All appear to have slow permeability; hence, run-on and precipitation tend to pond in depressions, but only for short periods owing to the high evaporation.

(7*a*) *Boroko Family*.—This family has up to 3 ft of black to very dark grey, very plastic, sticky heavy clay, usually with a thin fine angular blocky surface horizon. In wetter sites there was a thicker surface horizon, up to 6 in. deep, with more organic matter and consequently more friable. On drying, these soils show marked surface cracking up to $1\frac{1}{2}$ in. wide, giving a prismatic structure. They are mildly to moderately alkaline at the surface, becoming strongly alkaline at depth. They are fully saturated, exchangeable calcium being dominant (about 60 m-equiv. per 100 g out of the total exchangeable metal ions of about 70 m-equiv. per 100 g). Organic matter is about 2%. Calcareous concretions are frequently present, usually being few in the upper part of the profile and becoming more frequent with depth. Rounded gravel and stones may occur at depth, showing the alluvial origin of the soils. They occur on minor alluvial plains in the coastal hill zone. Included in this family are black clays which show the same profile morphology as those just described but which occur on a raised coral reef.

(7*b*) *Jackson Family*.—This is similar to Boroko family but is neutral to a depth of 3 ft, below which it may become mildly alkaline.

(7*c*) *Inapi Family*.—This is a black or dark greyish brown to brown, very plastic, sticky sandy to heavy clay, with a thin hard crumbly surface horizon, merging between 6 in. and 18 in. into a dark greyish brown or dark yellowish brown to brown, very plastic, sticky sandy to heavy clay. In wetter sites a more organic and friable surface horizon was seen. The saturation increases with depth (80–100%), as does the exchangeable magnesium (15–25 m-equiv. per 100 g), while exchangeable calcium decreases (35–20 m-equiv. per 100 g). Organic matter is about 3%. Calcareous concretions frequently occur at depth, and slight mottling may also be present. When dry, these soils show very slight cracking on the surface, but cracking is more prominent below. Inapi family occurs on valley plains upslope from Boroko and Jackson families and would appear to be a younger variant of them.

(8) *Lithosols*.—This group, which extends over 600 sq miles, comprises very shallow slope soils overlying bed-rock at varying stages of weathering. Lithosols occur on ridge crests and slopes over a wide range of climate and lithology, those in the coastal hill zone having a more marked relationship to the parent rock than those of the wetter zones. Lithosols have been separated into four families, using as the main criteria colour and soil reaction as controlled by parent rock and climate. With steep dips and frequent changes in rock type, as within the Port Moresby group, different lithosols may occur on the same hill slope. Run-off is rapid as a result of the steep slopes on which these soils occur.

(8*a*) *Alkaline Dark Lithosols*.—These are derived from crystalline and muddy limestone, calcareous tuff, and calcareous sandstone. They are black, dark grey, or greyish brown, firm crumbly to fine subangular blocky, sticky, sandy loam to clay up to 6 in. deep, passing abruptly or gradually into parent rock at various stages of weathering. They are moderately alkaline. Gravel and/or stones as well as rock outcrop may be present. They cover about 230 sq miles and are the main soils in Tovobada, Hanuabada, Pokama, Diumana, and Palipala land systems.

(8*b*) *Neutral Brown Lithosols*.—These are mainly derived from gabbro and tuff. They are dark brown to greyish brown, crumbly to fine subangular blocky, neutral, sticky, sandy clay loam to clay overlying weathered rock at depths between 6 in. and 12 in. Stones and/or gravel may be present. They have an area of about 350 sq miles and are the main soils of Kopu, Dubuna, and Edebu land systems.

(8*c*) *Neutral Red Lithosols*.—These are derived from cherty shales and consist of a thin brown to reddish brown, crumbly, neutral, sticky sandy clay loam to clay surface horizon with frequent gravel, overlying red-weathering rock. They are mainly confined to Kabuka land system.

(8*d*) *Acid Brown Lithosols*.—These soils are derived from agglomerate and phyllite. A dark brown to dark reddish brown, slightly acid, friable clay up to 12 in. deep overlies weathering parent rock. Surface and embedded stones are a common feature of these soils. Included in this family are shallow regosolic soils which occur in association with the lithosols. Acid brown lithosols occur in most land systems of the upland zone as small pockets on steeper ridge slopes or in the vicinity of rock outcrops.

(9) *Acid Red to Brown Clay Soils*.—These soils, which cover an area of more than 650 sq miles, are deep uniform clays dominated by 1 : 1 clay minerals and are mainly derived from red-weathering volcanic rock, and they mainly occur on ridges in the foothill and upland zones. They have a rapid permeability. These soils occur in moderate- to high-rainfall areas, and the range in rainfall is reflected in soil reaction: the higher the rainfall the more acid are the soils. They have been separated into five families, colour and soil reaction being the main criteria.

(9*a*) *Diulu Family*.—These soils have a dark reddish brown to brown, crumbly friable clay up to 14 in. thick, merging into a red to dark red, subangular blocky, friable clay. Iron and manganese concretions are frequently present, and clay skins were also noted. The soil reaction varies from medium to strongly acid, always becoming more acid with depth. These soils occur in areas with about 60 in. annual rainfall and are possibly only slightly to moderately leached. During the dry season the moisture content probably approaches wilting point. This family covers about 50 sq miles in the foothill zone and is the main soil of Diulu land system.

(9*b*) *Sogeri Family*.—A dark reddish brown to dark brown, crumbly, strongly acid, friable clay merges between 2 in. and 14 in. into a yellow-red to red, subangular blocky, very strongly acid, friable clay. Clay skins were frequently noted in the latter horizon, which may extend to a depth of about 15 ft. These soils occur under a rainfall of about 80 in. per annum, and are at or near field capacity for much of the wet season. They are moderately leached, and have a saturation of about 40% in the surface horizon, decreasing to 25 to 30% at depth. The total exchangeable metal ions are low (about 5 m-equiv. per 100 g) and exchangeable magnesium becomes greater than exchangeable calcium at depth. Organic matter is about 2%. This family extends over about 200 sq miles and is the main soil of Sogeri, Rubberlands, and Vouku land systems.

(9*c*) *Uberi Family*.—These consist of a dark brown, dark yellowish brown, or reddish brown, crumbly, very strongly acid, friable clay, merging at between 8 in. and 14 in. into a yellow-red, subangular blocky to massive, extremely acid, friable clay. This in turn may merge, at depths varying from 24 in. to 36 in., into a red friable clay, but this horizon is not always present. They occur under a rainfall of about 100 in. per annum and are at or near field capacity throughout the year. They are very leached soils, with a saturation of about 10% in the surface horizon, decreasing to about 5% at depth, with total exchangeable metal ions of about 1 m-equiv. per

100 g throughout. The organic matter is 3%. This family, with an area of about 350 sq miles, is the main soil in Subitana, Owers, Iawarere, and Uberi land systems.

(9*d*) *Tiviki Family*.—This has a dark brown to brown, crumbly, very strongly acid, friable clay, merging at about 14 in. into a yellowish brown, extremely acid, friable clay. This family, which was only encountered at the extreme end of a traverse into an area with about 120 in. annual rainfall, is at or near field capacity all the year round, and may well be the dominant soil in the higher-rainfall areas. These soils are excessively leached, with a saturation of less than 2% throughout, with total exchangeable metal ions of less than 1 m-equiv. per 100 g. Organic matter is 6%. These soils occur only in Mariboi land system.

(9*e*) *Koitaki Family*.—A dark yellowish brown to dark brown, crumbly, strongly acid, friable clay merges at between 12 in. and 18 in. into a strong brown to brown, very strongly acid, friable clay. These excessively leached soils have a saturation of less than 5%, with total exchangeable metal ions of less than 1 m-equiv. per 100 g. Organic matter is 5%. Manganese concretions and mottling frequently occur in the lower horizon. They occur on foot slopes, terraces, and undulating terrain in most land systems of the upland zone, as well as in some land systems of the foothill zone, and since they are usually commanded by higher ground they are frequently subject to seepage, resulting in poor drainage at depth.

They are mainly derived from colluvium and alluvium from volcanic and metamorphic rocks, although those on the undulating terrain in Sogeri land system are partly sedentary.

(10) *Red Gravelly Clay Soils*.—These soils have reddish brown gravelly or stony upper horizons and gravel-free, red lower horizons. Many of the soils in this group appear to be polygenetic, with upper horizons developed from more recently transported colluvium and lower horizons which are sedentary. This is suggested by the occurrence of an incipient stone line and by the frequent gravel in the upper horizon, in contrast to the gravel-free lower horizon. The colluvial horizon appears to be mainly derived from cherty shale, while the lower horizon is from shale or tuff. However, some soils not showing these two contrasted layers have been included in this group. These soils are mainly confined to upper foot slopes and lower hill slopes in the coastal hill zone, and receive seepage and run-on from higher ground. They have been separated into two families—an alkaline and a neutral to slightly acid type. This difference in soil reaction may be due to parent material, but it is possible that the alkalinity could be inherited from adjacent limestone bands which occur within the cherty shales.

(10*a*) *Nebire Family*.—This family has between 3 in. and 8 in. of dark brown, very gravelly and/or stony, sandy clay loam to clay merging into a reddish brown, very gravelly, sticky sandy clay loam to clay. This in turn overlies, at depths varying from 6 in. to 30 in., red to dark red, massive, sticky, plastic clay which may include fragments of weathered rock. An incipient stone line was occasionally seen at the upper boundary of the latter horizon. These soils are moderately alkaline throughout and would appear to have only moderate permeability. They have a surface saturation of about 80%, which increases with depth. Total exchangeable metal ions increase from 10 m-equiv. per 100 g at the surface to about 35 m-equiv. per 100 g at depth.

Exchangeable magnesium tends to be greater than exchangeable calcium at depth. Organic matter is about 2%. Soils of Nebire family extend over an area of about 10 sq miles in Tovobada, Hanuabada, and Kopu land systems.

(10*b*) *Bom Family*.—This family exhibits the same morphology as Nebire family, but is neutral to slightly acid. It covers an area of about 10 sq miles in Kopu, Kabuka, Fairfax, Bomana Creek, and Ward land systems.

(11) *Brown Clay Soils*.—These soils, which cover an area of about 65 sq miles, are mainly gravel-free sedentary soils of moderate depth. The underlying parent rock tends to be soft-weathered, giving a greater root range to plants. The soils fall into two families based on soil reaction, which in turn reflects the nature of the underlying rock. They are mainly found in the southern hills of the coastal hill zone.

(11*a*) *Fairfax Family*.—These soils have a black to very dark greyish brown, hard, medium crumbly, plastic sandy clay to clay, merging at 4 in. to 8 in. into a brown to very dark brown, subangular to angular blocky, sticky, plastic sandy clay to clay. A few calcareous concretions are usually present in this horizon. Weathered rock occurs at depths ranging from 18 in. to 48 in., and varies in colour from yellowish brown to dark greyish brown, with a sandy to sandy clay texture depending on the degree of weathering. This weathered material, which is derived from calcareous tuff or coral, has frequent carbonate concretions. The soil reaction is usually mildly alkaline at the surface, becoming moderately alkaline at depth. These soils are fully saturated, with total exchangeable cations varying from 50 to 55 m-equiv. per 100 g, of which exchangeable calcium is about 35 m-equiv. per 100 g. Organic matter is about 2%. Chert and quartz gravel are occasionally present. This soil family, which has only moderate to slow permeability, occurs on undulating plains and on upper foot slopes.

(11*b*) *Bomana Family*.—Similar to Fairfax family but neutral to very strongly acid, and calcareous concretions are absent. It is mainly derived from tuff and gabbro, and occurs on undulating plains, upper foot slopes, and rounded rises.

(12) *Texture-contrast Soils*.—These soils, which extend over about 165 sq miles, have a coarse-textured surface horizon passing abruptly into a fine-textured subsurface horizon. The surface horizon is massive and very hard when dry, and may or may not contain a bleached A_2 horizon. Quartz and chert gravel, which tend to become concentrated in the A horizon, are present in some profiles but absent from others. Some of these texture-contrast soils are alkaline while others are neutral to slightly acid. They all appear to have a very rapid run-off and slow permeability, and towards the end of the dry season they are probably at wilting point, while in the wet season they are ill-drained and often boggy. Texture-contrast soils occur on foot slopes mainly between 2° and 5°, and on stable interfluves in the coastal hill zone and in part of the foothill zone. They have been subdivided in the first instance on soil reaction, thus breaking down into solonetzic and solodic types. These in turn have been further differentiated on the presence or absence of a bleached A_2 horizon. Finally, a gravelly phase of each family has been distinguished, the occurrence of gravel appearing to be related to the nature of the bed-rock or of the rock on adjacent hill slopes.

(12*a*) *Ouou Family*.—This family consists of a very dark grey to brown, weak crumbly sandy loam to sandy clay loam, merging between 3 in. and 8 in. into a grey to light greyish brown, massive compact, sandy loam to sandy clay loam, in which slight rust mottling is frequently present. An abrupt transition between the A_2 and B horizons occurs between 8 in. and 18 in. The B horizon, which has a weakly developed columnar structure, varies in colour from very dark grey through brown to yellowish brown and usually becomes greyer with depth. The texture in this horizon varies from a sandy clay to a heavy clay which is frequently mottled, the mottling varying in abundance from few to many and in colour from yellow-brown to red. The soil reaction varies from neutral to mildly alkaline in the A horizon to strongly alkaline in the B horizon, where carbonate concretions are frequently present.

(12*b*) *Ward Family*.—This is very similar to Ouou family, but no A_2 horizon or mottling is apparent in the A horizon, which is usually from 6 in. to 14 in. thick. The absence of mottling may indicate that these soils are slightly better drained than Ouou family. The saturation increases from 75% to 100% with depth, with total exchangeable metal ions increasing from 30 to 40 m-equiv. per 100 g. Exchangeable calcium (20–50%) tends to be greater than exchangeable magnesium, although the reverse sometimes occurs at depth. Organic matter is 1·5%.

(12*c*) *Nikura Family*.—This family is very similar to Ouou family in profile form, colour, texture, and mottling. However, it differs in that iron and manganese concretions frequently occur in both A_2 and B horizons. In some cases these concretions may become cemented in the A_2 horizon to form a slight lateritic pan. The soils are usually neutral to slightly acid in the A horizon and medium acid in the B horizon. The saturation of these soils is about 70% in the A_1 horizon, falls to about 60% in the A_2 horizon, and rises to over 80% in the B horizon. This fall and rise with horizons is reflected in all the exchangeable metal ions (e.g. Ca 7 to 3 to 15 m-equiv. per 100 g). Organic matter is 1·5%.

(12*d*) *Laloki Family*.—This is similar to Nikura family but the A_2 horizon and mottling are absent. This again may reflect better drainage conditions.

(13) *Alkaline Reddish Clay Soils*.—(13) *Obu Family*.—This has a dark reddish brown to brown, crumbly, sandy to heavy clay, merging between 4 in. and 6 in. into a dark red to dark reddish brown, subangular blocky, friable, sandy to heavy clay. This in turn passes abruptly into coral at depths varying from 18 in. to 36 in., the upper surface of the coral being very irregular. These soils are moderately alkaline throughout, and at this stage it is difficult to say whether they are sedentary or transported. They occur on raised coral reefs in Tsiria land system, in association with black clays of Boroko family.

IV. Soil Distribution

The map showing the distribution of soils shows clearly the pattern of environmental zones, the main soils of one zone being very different from those of another. In the littoral plains zone the soils are generally sandy and saline, while those of the swamp and fluvial plains zones are characterized by regosols with differing degrees of wetness and subject to varying flood regimes. In the coastal hill zone, shallow sedentary soils are found on the hills, and soils of varying depth derived from colluvium

TABLE 19

DISTRIBUTION OF SOILS IN RELATION TO LAND SYSTEMS OF THE LITTORAL PLAINS, SWAMP, AND FLUVIAL PLAINS ZONES*

Soil Group	Littoral Plains Zone						Swamp Zone					Fluvial Plains Zone									
	Hisiu	Papa	Galley Reach	Lesewalai	Kido	Nipa	Waigani	Engepa	Akaifu	Doura	Biaru	Piunga	Vanapa	Vekabu	Bebeo	Beipa	Pinu	Epo	Babiko	Keviona	Inaukina
Beach soils	B	D		D	C												E				
Mangrove soils	E	D	A	C	C	C					E										
Intertidal alluvial soils			D	C	B	C											E				
Very poorly drained alluvial soils	D						A	B	A	D	E	C	C	D		E					C
Imperfectly drained alluvial soils	E						C	C	B	B	C	A	C		C	D	E				D
Moderately well-drained alluvial soils									D	E		B	B	A	C	B	C	B	B	B	
Dark cracking clay soils														D							
Lithosols																					
Acid red to brown clay soils																					B
Red gravelly clay soils																					
Brown clay soils																					
Texture-contrast soils																					
Alkaline reddish clay soils																					

* A, > 50 sq miles; B, 20–50 sq miles; C, 5–20 sq miles; D, 2–5 sq miles; E, < 2 sq miles.

TABLE 20

DISTRIBUTION OF SOILS IN RELATION TO LAND SYSTEMS OF COASTAL HILL, FOOTHILL, AND UPLAND ZONES*

Soil Group	Coastal Hill Zone														Foothill Zone						Upland Zone							
	Boroko	Tsiria	Ouou	Nikura	Ward	Bomana Creek	Fairfax	Diumana	Kabuka	Kopu	Palipala	Pokama	Hanuabada	Tovobada	Edebu	Rouna	Dubuna	Aropokina	Kanosia	Diulu	Vouku	Sogeri	Rubberlands	Subitana	Mariboi	Uberi	Owers	Iawarere
Beach soils		E																										
Mangrove soils																												
Intertidal alluvial soils																												
Very poorly drained alluvial soils																						E		E	E			
Imperfectly drained alluvial soils	E															D		E	D	D	C	E	E	E	C	E		E
Moderately well-drained alluvial soils	C				E		E			D							D											E
Dark cracking clay soils	B	D	E	C	C	E		D		E	C	E	D	D	E		D											
Lithosols				B	E	D	C	B	C	B	A	B	A	C	B	A	A	B		E	D		D	C	C	C		D
Acid red to brown clay soils																	D	C	C	B	B	B	A	B	A	B	B	A
Red gravelly clay soils					E	E	D		D	C			E	E														
Brown clay soils					E	B	D		C	C			D		E				D									
Texture-contrast soils			D	A	B		D		C	C	C		D					E	C									
Alkaline reddish clay soils		E																										

* A, > 50 sq miles; B, 20–50 sq miles; C, 5–20 sq miles; D, 2–5 sq miles; E, < 2 sq miles.

occur on the foot slopes. The upland zone is dominated by deep reddish soils. The foothill zone is intermediate between the coastal hill and upland zones and the soils of this zone are transitional between those of the two adjacent zones, representing the wetter part of the coastal hill zone and the drier part of the upland zone.

The soil map and Tables 19 and 20 show the distribution of the soils in the area from different view points. The soil map is based on the dominant or co-dominant soil groups of each land system, which in turn have been grouped together into associations for simplicity in mapping. Where two such associations are intermixed and cannot be separated because of the scale of the map, they have been represented as stripes, the thickness of each stripe representing approximately the proportions in which these associations occur. In some cases, a soil group has been too small to map.

Tables 19 and 20 show the extent of the soil groups within each land system. For simplicity, the soil group has been used rather than the soil family since in some of the land systems a number of soil families of one group occur in complex and thus it is difficult to assess the extent of each family. The areas are based on judged proportions of each land unit, and must be considered very approximate. Tables 19 and 20 show more clearly than the soil map how some of the land systems are transitionary between the environmental zones. Examples of this are found in Biaru and Piunga land systems.

V. References

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PART VIII. VEGETATION AND ECOLOGY OF THE PORT MORESBY–KAIRUKU AREA

By P. C. HEYLIGERS*

I. INTRODUCTION

The structure of the vegetation was recorded and notes were made on floristics. The majority of the plants were recognized only at genus level; hence few specific names are used. Material for further identification was collected and has been deposited in the Herbarium Australiense, Canberra. The knowledge of native assistants was often drawn upon, and their names for the trees (Amele language) are given in inverted commas when identifications are not yet available.

II. CLASSIFICATION

As can be seen in Tables 21 and 22, relating the vegetation with land systems, a primary division into major groups was made on structural characteristics of the dominant life forms. At a lower level, distinctions between vegetation types are mainly floristic, especially in less complex vegetation. It is stressed that these vegetation types have by no means the same status as associations, as defined by several schools; they are less strict groupings of related vegetations. In most cases the vegetation types are named after two genera or species. The occurrence of the same plant name in several vegetation types within one major group shows the affinities between these types. The genera chosen for the names do not belong to any particular storey, except for the savannahs, where the first name refers to a characteristic grass and the second to a characteristic tree.

In the land system descriptions these vegetation types are referred to by stating the name of the major group first, followed by the name of the vegetation type between brackets.

III. DEFINITION AND DISCUSSION OF THE MAJOR GROUPS

(a) *Mixed Herbaceous Vegetation*

Mixed herbaceous vegetation comprises those types in which non-graminoid herbs are important. The vegetation types in this group form a heterogeneous assemblage; some are pioneer or seral vegetations, others occur in environments very marginal for plant growth.

(b) *Grasslands*

Grasslands are vegetation types dominated by grasses. They are subdivided according to their height into low grassland, up to 2 ft high; mid-height grassland, up to 5 ft high; and tall grassland, more than 5 ft high. Scattered shrubs or trees mostly occur in them and some grasslands grade into savannah, which is discussed below.

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Low grasslands are confined to salt marshes. Mid-height grasslands owe their existence to the influence of repeated burning, which prevents woody regrowth. The same is true of one type of tall grassland; the other types occur in seasonally or permanently inundated situations.

(*c*) *Savannah*

Savannah has an open tree storey and a ground cover of grasses. Structurally, and to a certain degree also floristically, savannah is similar to the woodlands of northern Australia.

It is not possible to give an exact number of trees per unit of area to distinguish a savannah from a grassland, but in a savannah the trees dominate in the impression which the landscape makes on the observer; in a grassland the grasses are the most striking feature and the trees do not obstruct the view over the landscape. However, there will always be cases in which a decision is difficult, and here floristic affinities may help in classification.

Savannah occurs in a range of environments, but has its main distribution in the coastal hill and foothill zones. Both grasses and trees have a high resistance to fire and the vigour of the grasses is in fact increased by the burning of the old litter. Though fires caused by lightning are not to be excluded, most of the fires are lit by man. Straight boundaries between savannah and semi-deciduous thicket, which do not coincide with changes in soil conditions or topography, suggest that thicket is replaced by savannah through human interference. On the other hand, there are cases in which boundaries can be correlated with such changes, and on some crests of ridges in the foothill zone, which are otherwise forested, small tracts of savannah give the impression that adjacent forest and savannah are a natural occurrence.

(*d*) *Palm and Pandanus Vegetation Types*

Palm vegetation includes types which are structurally rather different but which are all dominated by palms. The pandanus vegetation, which could not satisfactorily be classified with any of the other woody vegetation types, is also considered under this heading.

Excessive water is one of the features which the habitats of these types have in common.

(*e*) *Scrub and Thicket*

Scrub comprises vegetation types dominated by shrubs and/or low gnarled trees, often densely interwoven by climbers. Thicket differs from scrub in that an open tree storey is present above the scrub layer. A subdivision has been made into evergreen and semi-deciduous thicket.

Scrub and thicket occur in a wide range of habitats which are usually unsuitable for forest growth owing to severe stress as a result of some environmental factor.

(*f*) *Forest*

Vegetation types classified as forest are dominated by trees forming one or more distinct layers, in one at least of which the crowns are more or less interlacing. A subdivision has been made between deciduous forests, in which a conspicuous propor-

TABLE 21

DISTRIBUTION OF VEGETATION TYPES IN RELATION TO LAND SYSTEMS OF THE LITTORAL PLAINS, SWAMP, AND FLUVIAL PLAINS ZONES*

Vegetation	Littoral Plains Zone						Swamp Zone					Fluvial Plains Zone									
	Hisiu	Papa	Galley Reach	Lesewalai	Kido	Nipa	Waigani	Engepa	Akaifu	Doura	Biaru	Piunga	Vanapa	Vekabu	Bebeo	Beipa	Pinu	Epo	Babiko	Keviona	Inaukina
Mixed herbaceous vegetation																					
Spinifex–Canavalia	m	m			m																
Sesuvium–Tecticornia		m		m	m																
Nymphaea–Azolla	m						m		m	m	m		m					m			
Leersia–Hanguana	m						S		S	m	m		m	m		m					m
Hyptis–Imperata	m	m			m																
Grassland																					
Low grassland																					
Sporobolus–Eriochloa	m	m			m												m				
Mid-height grassland																					
Ophiuros–Imperata														m	S		*D*				
Ophiuros–Themeda australis	*D*																m			*D*	
Imperata–Themeda australis		m																			
Tall grassland																					
Saccharum spontaneum–Imperata	m						m		m	m			m			m		*D*	S		
Phragmites–Saccharum robustum							*D*	*D*	*D*	m	m	m	m			m		m	S		
Saccharum robustum							m			m			m						m		
Savannah																					
Themeda australis–Eucalyptus																					
Themeda australis–Timonius																					
Ophiuros–Eucalyptus alba																					
Ophiuros–Eucalyptus papuana																m					
Ophiuros–Eucalyptus tereticornis																					
Ophiuros–Timonius																					
Themeda novoguineensis–Eucalyptus																					
Imperata–Eucalyptus																					

Palm and pandanus vegetation types																					
Metroxylon–Artocarpus											m										
Metroxylon–Macaranga							m	S	m			m	m								m
Nypa						*D*					m										
Pandanus																					m
Scrub and thicket																					
Scrub																					
Lumnitzera					m																
Premna–Scaevola		m																			
Pluchea–Flagellaria				m						m	m						m				
Evergreen thicket																					
Clerodendrum–Flagellaria	m	m		m	m												m				
Hibiscus–Flagellaria	m			m			m			S	S		m			m	m	m	m		
Acacia–Myoporum				m	m																
Semi-deciduous thicket																					
Gyrocarpus–Harpullia	S				m					m							m				
Garuga–Rhodomyrtus																					
Adenanthera–Colona																					
Eucalyptus–Acacia																					
Forest																					
Strongly deciduous forest																					
Bombax–Celtis																					
Bombax–Terminalia																	m				
Albizia–Maniltoa																					
Slightly deciduous forest																					
Garuga–Brachychiton																					
Intsia–Celtis																					
Planchonia–Adenanthera																					
Spondias–Celtis												m	m	S							
Intsia–Spondias																					
Albizia–Canarium																					
Low evergreen forest																					
Sonneratia acida						m					m										
Avicennia–Sonneratia			m		m																
Ceriops					m																

TABLE 21 (*Continued*)

Vegetation	Littoral Plains Zone						Swamp Zone					Fluvial Plains Zone									
	Hisiu	Papa	Galley Reach	Lesewalai	Kido	Nipa	Waigani	Engepa	Akaifu	Doura	Biaru	Piunga	Vanapa	Vekabu	Bebeo	Beipa	Pinu	Epo	Babiko	Keviona	Inaukina
Low evergreen forest (*Continued*)																					
Avicennia–Ceriops	m	S		*D*	S																
Avicennia–Excoecaria			m	m	m						m										
Althoffia–Endospermum												m				m		m	S	m	
Artocarpus–Ficus								m	m				m			m					
Mid-height evergreen forest																					
Rhizophora–Bruguiera		S	*D*	m	m	m															
Heritiera–Bruguiera			m			S				m											
Excoecaria–Hibiscus	m			m							m						m				
Melaleuca–Excoecaria										S											
Melaleuca–Nauclea	m						m	m	m		S	S	m								
Nauclea–Kleinhovia							m	m	m		m	S	m	m	m	m		m	m		
Ficus–Myristica										m											
Tall evergreen forest																					
Octomeles–Artocarpus							m			m		m	S			m			m		m
Cerbera–Alstonia									m			m	m		S	S		m			S
Cananga–Pometia												S			m						
Pometia–Celtis												m		S		S					S
Casuarina–Dysoxylum																					
Alstonia–Kleinhovia																					
Pometia–Artocarpus																					
Pometia–Canarium																					
Castanopsis–Elaeocarpus																					
Lithocarpus–Elaeocarpus																					

* *D*, dominant, area occupied larger than 50% of land system; S, subdominant, area occupied between 15 and 50% of land system; m, minor, area occupied smaller than 15% of land system.

tion of the trees is bare for a part of the year, and evergreen forests, in which the aspect is dominated by a green canopy all the year round but in which sporadic deciduous trees may also occur.

In the deciduous forests a further division is made into strongly and slightly deciduous, according to the proportion of deciduous trees. Strongly deciduous forest occurs only in low-rainfall areas and is almost limited to the coastal hill zone. It occupies large areas only in Tovobada land system and is elsewhere restricted to rocky crests, steep slopes, re-entrants, valley heads, and boulder valley floors, semi-deciduous thicket or savannah being the predominating vegetation types on the other land forms. These habitats have in common more than average rockiness, which would presumably permit deeper water penetration and favour root development. Moreover, localities such as re-entrants and valleys receive run-on. Accordingly, supplies last longer and permit forest growth. Slightly deciduous forest occurs in those parts of the coastal hill and foothill zones where water stress is less severe owing to higher rainfall or better soil-moisture conditions. It extends also on droughty, rocky crests in areas where the rainfall is otherwise adequate for evergreen forest growth.

The evergreen forests are subdivided into low, mid-height, and tall. Low evergreen forests mostly have a single tree layer up to 30 or 40 ft high; mid-height evergreen forests are generally up to 80 ft high and usually have two tree layers; tall evergreen forests are multi-layered, with a height often exceeding 100 ft. Low evergreen forests are either types of mangrove vegetation or types of woody regrowth. Mid-height evergreen forest comprises types of taller mangrove vegetation together with a number of other types occurring on estuarine margins or in swamps. These habitats have in common waterlogged soils, causing anaerobic conditions. Tall evergreen forest has its greatest distribution in the areas with high rainfall, but extends in low-rainfall areas where soil moisture is adequate the whole year round.

IV. Description of Vegetation Types

The lists of names in these descriptions do not necessarily include all the species present and are in fact very incomplete for the more complicated vegetation types. Generally, the names of the more important plants are given first.

At the end of each description a general statement on the distribution is given. The land systems in which the vegetation types occur are shown in Tables 21 and 22.

(*a*) *Mixed Herbaceous Vegetation*

(i) *Spinifex–Canavalia*.—In optimal development this is a rather dense vegetation of creeping, sand-binding grasses (*Spinifex*, *Thuarea*, *Remirea*, and minor *Sporobolus*, *Digitaria*, *Apluda*, *Setaria*, and *Imperata*) with creeping herbs (*Ipomoea*, *Canavalia*, *Cassytha*, *Passiflora*) and scattered erect *Crotalaria*. It occurs on sand beaches above high-water mark and on low foredunes. On beaches with much moving sand only a few plants of this vegetation type are found.

(ii) *Sesuvium–Tecticornia*.—*Sesuvium portulacastrum*, alone or in combination with *Tecticornia*, grows in patches in flats only occasionally inundated by salt water and with poor drainage, so that the surface is often covered with a crust of salt.

TABLE 22

DISTRIBUTION OF VEGETATION TYPES IN RELATION TO LAND SYSTEMS OF THE COASTAL HILL, FOOTHILL, AND UPLAND ZONES*

Vegetation	Coastal Hill Zone														Foothill Zone						Upland Zone							
	Boroko	Tsiria	Ouou	Nikura	Ward	Bomana Creek	Fairfax	Diumana	Kabuka	Kopu	Palipala	Pokama	Hanuabada	Tovobada	Edebu	Rouna	Dubuna	Aropokina	Kanosia	Diulu	Vouku	Sogeri	Rubberlands	Subitana	Mariboi	Uberi	Owers	Iawarere
Mixed herbaceous vegetation																												
Spinifex–Canavalia		m																										
Sesuvium–Tecticornia																												
Nymphaea–Azolla	m																											
Leersia–Hanguana																												
Hyptis–Imperata																												
Grassland																												
Low grassland																												
Sporobolus–Eriochloa																												
Mid-height grassland																												
Ophiuros–Imperata					m	m					m													m				
Ophiuros–Themeda australis																												
Imperata–Themeda australis																												
Tall grassland																												
Saccharum spontaneum–Imperata	S	m	m		m	S		m	m	m			m				m		m									
Phragmites–Saccharum robustum	m																											
Saccharum robustum																												
Savannah																												
Themeda australis–Eucalyptus	m		S	S	*D*	S	*D*		*D*		S		*D*	m			S	m		S								
Themeda australis–Timonius			S					m																				
Ophiuros–Eucalyptus alba	S			m	S	S	m		S	S	S		m				m	m		S			m					
Ophiuros–Eucalyptus papuana											m						m	m										
Ophiuros–Eucalyptus tereticornis																S					S	*D*						
Ophiuros–Timonius								m				S																
Themeda novoguineensis–Eucalyptus				m	m								m			m	S	S	S									
Imperata–Eucalyptus			S	S				m			S				m													

Palm and pandanus vegetation types																										
Metroxylon–Artocarpus																										
Metroxylon–Macaranga																										
Nypa																										
Pandanus																					m					
Scrub and thicket																										
Scrub																										
Lumnitzera																										
Premna–Scaevola		m																								
Pluchea–Flagellaria																										
Evergreen thicket																										
Clerodendrum–Flagellaria																										
Hibiscus–Flagellaria			m																							
Acacia–Myoporum																										
Semi-deciduous thicket																										
Gyrocarpus–Harpullia				m			m	m			m	*D*	m													
Garuga–Rhodomyrtus										*D*			m													
Adenanthera–Colona				m			m	m							S											
Eucalyptus–Acacia		*D*	m	S	m			*D*									m		S							
Forest																										
Strongly deciduous forest																										
Bombax–Celtis				m				m			m	m	m	*D*				S								
Bombax–Terminalia		S	m			S		m		m	m		m						S	S						
Albizia–Maniltoa		m		m				m																		
Slightly deciduous forest																										
Garuga–Brachychiton				m							m				*D*		m	S				m				
Intsia–Celtis		S						m		m	m	S														
Planchonia–Adenanthera	m				m	m			m				m	m	m				m							
Spondias–Celtis																		m		m						
Intsia–Spondias																						S		S		
Albizia–Canarium															m	*D*	m	m	S			m		m	m	m
Low evergreen forest																										
Sonneratia acida																										
Avicennia–Sonneratia																										
Ceriops																										

TABLE 22 (*Continued*)

Vegetation	Coastal Hill Zone														Foothill Zone						Upland Zone							
	Boroko	Tsiria	Ouou	Nikura	Ward	Bomana Creek	Fairfax	Diumana	Kabuka	Kopu	Palipala	Pokama	Hanuabada	Tovobada	Edebu	Rouna	Dubuna	Aropokina	Kanosia	Diulu	Vouku	Sogeri	Rubberlands	Subitana	Mariboi	Uberi	Owers	Iawarere
Low evergreen forest *(Continued)*																												
Avicennia–Ceriops																												
Avicennia–Excoecaria																												
Althoffia–Endospermum																												
Artocarpus–Ficus																												
Mid-height evergreen forest																												
Rhizophora–Bruguiera																												
Heritiera–Bruguiera																												
Excoecaria–Hibiscus																												
Melaleuca–Excoecaria																												
Melaleuca–Nauclea	m																											
Nauclea–Kleinhovia																												
Ficus–Myristica																												
Tall evergreen forest																												
Octomeles–Artocarpus	m			m	m												m									m		m
Cerbera–Alstonia																	m											
Cananga–Pometia																												
Pometia–Celtis																												
Casuarina–Dysoxylum										m						m	m				m	m		m				
Alstonia–Kleinhovia			m	m							m												m					
Pometia–Artocarpus																					m			m	m	m	m	m
Pometia–Canarium																							*D*		*D*			
Castanopsis–Elaeocarpus																					S			*D*		*D*	*D*	*D*
Lithocarpus–Elaeocarpus																					m				S	S	S	

* *D*, dominant, area occupied larger than 50% of land system; S, subdominant, area occupied between 15 and 50% of land system; m, minor, area occupied smaller than 15% of land system.

It often occurs on low hummocks or on the slight rises at the fringes of the flats, where it forms the transition to grasslands or to *Avicennia–Ceriops* vegetation. In such places some *Sporobolus* commonly occurs among the *Sesuvium*.

Distribution patterns suggest that *Tecticornia* occurs mostly in lower-lying situations.

(iii) *Nymphaea–Azolla*.—This vegetation, which is typical of standing or slowly running fresh water, consists of submerged plants (*Ceratophyllum*, *Nymphaea*) and floating plants (*Nymphaea*, *Nymphoides*, *Pistia*, *Azolla*, *Lemna*, *Spirodela*, *Utricularia*).

In marginal environments such as shallow pools or in brackish water, *Lemna* and *Spirodela* may be the only genera in this vegetation type.

(iv) *Leersia–Hanguana*.—This vegetation, up to 6 ft high, is found floating or rooting in organic material in inundated or permanently wet environments such as swamps and oxbows. It consists of grasses, among which *Leersia*, *Hymenachne*, and *Echinochloa* dominate, and coarse sedges, e.g. *Thoracostachyum* and *Scleria*, with herbs (*Hanguana*, *Ludwigia*, *Polygonum*), ferns (*Cyclosorus*, *Blechnum*), and twiners (Convolvulaceae, *Lygodium*, *Stenochlaena*). Scattered *Phragmites* may occur.

This vegetation type represents intermediate stages in the succession from open water to *Phragmites–Saccharum robustum* vegetation: if the succession series is complete a zonation is commonly observed, with *Hymenachne*, *Echinochloa*, and *Leersia* in the zone next to the *Nymphaea–Azolla* vegetation and with coarse sedges and *Hanguana* as a succeeding zone. In other swamps, any one of these stages may cover the whole surface.

(v) *Hyptis–Imperata*.—This vegetation consists of weeds (*Hyptis*, *Sida*, *Crotalaria*, etc.) and grasses (*Imperata*, *Heteropogon*, *Themeda australis*, *Rhynchelytrum*, *Eriachne*, and *Saccharum spontaneum*), with some scattered shrubs or trees (*Hibiscus*, *Premna*, *Pandanus*, *Albizia procera*, *Timonius*, *Leucaena leucocephala*). It occurs on old, previously gardened beach ridges and sand plains.

(*b*) *Grasslands*

(i) *Low Grassland*

(1) *Sporobolus–Eriochloa*.—This occurs as dense cover of *Sporobolus virginicus* 4 in. high, with scattered tussocks of *Eriochloa procera* and *Chloris barbata* up to 1½ ft high. *Cassia* up to 6 ft high is commonly scattered through this vegetation, and *Pluchea indica* or *Imperata cylindrica* may also occur. In spots not covered by grass, *Sesuvium portulacastrum* and *Tecticornia cinerea* may be found.

This vegetation commonly occurs as broad fringes where salt flats rise to higher ground, but it may also cover the whole flat.

Themeda novoguineensis, sometimes mixed with *Heteropogon* and often with scattered *Pandanus*, characteristically occupies the transition zone to higher ground, which is typically covered by a *Themeda australis–Eucalyptus* savannah.

(ii) *Mid-height Grassland*

(1) *Ophiuros–Imperata*.—This grassland has a dense ground cover of *Ophiuros* and *Imperata* up to 5 ft high, mixed and generally in about equal quantities. *Saccharum spontaneum* or *Themeda novoguineensis* is common near forest fringes or in

slightly depressed areas. Generally other grasses are absent, but *Cyclosorus* is common. Scattered low shrubs (*Melastoma*, *Crotalaria*, *Glochidion*, *Cycas*) are common throughout this vegetation, as high as or slightly higher than the grasses. A very open tree layer is nearly always present; *Timonius*, *Antidesma*, and *Pandanus* up to 20 ft and *Nauclea* up to 30 ft are the genera most commonly encountered.

The *Ophiuros–Imperata* vegetation occupies large areas in low-lying fluvial plains and also extends onto the lower plains and valley floors in the hills, probably replacing the forests after prolonged gardening and burning.

(2) *Ophiuros–Themeda australis* (Plate 6, Fig. 2).—These are grasslands 3–5 ft high dominated by *Ophiuros*. *Themeda australis*, invariably present, is often co-dominant. Other grasses are *Imperata*, *Capillipedium*, *Heteropogon*, and, in depressed areas, *Saccharum spontaneum* and *Phragmites*. Scattered shrubs occur (*Timonius*, *Antidesma*, *Premna*) and an extremely open layer of *Pandanus* up to 25 ft high gives this vegetation a very characteristic appearance.

It occurs only on plains north-west of Galley Reach.

(3) *Imperata–Themeda australis*.—This grassland is closely related to the *Hyptis–Imperata* vegetation, but *Themeda* and *Imperata* have become the dominant grasses. It occupies sand plains in Papa land system.

(iii) *Tall Grassland and Grass Vegetation*

(1) *Saccharum spontaneum–Imperata* (Plate 5, Fig. 1; Plate 7, Fig. 1).—These grasslands are formed by *Saccharum spontaneum* 7–9 ft high, alone or in mosaic with *Imperata cylindrica* 3–6 ft high. In depressed areas a slight admixture of *Phragmites karka* may occur. Usually other herbs are absent, but occasionally other grasses, e.g. *Leptochloa* or *Polytoca*, or *Cyclosorus* ferns may be found. Twiners are remarkably scarce.

Trees or shrubs are commonly present, in some places as very scattered individuals, in other places in such numbers that the vegetation becomes almost a savannah. Of the 15 taxa recorded, *Albizia procera*, *Nauclea*, *Antidesma*, *Melaleuca*, and *Pandanus* are the commonest.

The *Saccharum spontaneum–Imperata* grasslands are most extensive on fluvial plains which are flooded for a short period each year, but extend into the swamp zone along levee tracts and adjacent back plains and into the coastal hill and foothill zones on alluvial plains and in drainage depressions, where *Imperata* is often dominant and where *Themeda novoguineensis* may come in.

(2) *Phragmites–Saccharum robustum* (Plate 5, Fig. 2).—This vegetation is 8–15 ft high and is dominated by *Phragmites karka*, often mixed with much *Saccharum robustum*. Very few other species occur except for ferns (*Cyclosorus*, *Blechnum*) and twiners (Convolvulaceae, *Cayratia*, *Flagellaria*, *Lygodium*). Some very scattered trees or shrubs may be present (*Melaleuca*, *Nauclea*, *Antidesma*, *Jagera*, *Macaranga*, *Livistona*, *Metroxylon*).

Habitats vary from permanent swamps to badly drained, seasonally flooded areas. Degree of wetness probably determines the extent to which *Saccharum robustum* is co-dominant, for it is unlikely that *Saccharum* will survive a long dry period.

The *Phragmites–Saccharum robustum* vegetation is regarded as the last purely herbaceous stage in the succession from open water to forest. It occurs in swamps, back plains, and oxbows.

(3) *Saccharum robustum* (Plate 5, Fig. 2; Plate 8, Fig. 2).—Pure stands of *Saccharum robustum* up to 17 ft high occur along river levees, on low banks and scrolls, and in waterlogged swales and oxbows, in these last two situations often with an undergrowth of *Cyclosorus* and some scattered twiners.

In the old channel of the Angabunga River, where *Saccharum robustum* was growing on low banks, it was gradually dying and was being succeeded by *Saccharum spontaneum*.

(*c*) *Savannah*

(i) *Themeda australis–Eucalyptus* (Plate 3, Fig. 1; Plate 4, Fig. 1).—This savannah has a grass cover 1–3 ft high in which *Themeda australis* predominates, with a tussock spacing ranging from dense to open. In the latter case, which often occurs on skeletal soils, *Sehima nervosum* is mostly co-dominant and *Eriachne*, *Stipa*, and *Cymbopogon* may occur. Other grasses found mixed with *Themeda* are *Heteropogon*, *Arundinella*, *Imperata*, *Elyonurus*, and *Capillipedium*. Sometimes *Sehima* and *Heteropogon* occur in pure patches in a mosaic with *Themeda*. Forbs are generally scarce and are mainly represented by Papilionaceae. In valley heads, *Themeda novoguineensis* may come in.

The tree storey consists of one or more of the following *Eucalyptus* species: *E. alba*, *E. confertiflora*, *E. papuana*. Their height generally does not exceed 35 ft and is often much less. The factors controlling their distribution could not be determined for in some cases they occur together, at other times one species dominates hill tops and another the lower slopes, which sequence may be reversed on the next hill, or one species may dominate a whole area while the others are strikingly absent. Associated taxa are *Albizia procera*, *Timonius*, and *Antidesma*, but they are less frequent than in the *Ophiuros–Eucalyptus alba* savannah.

The shrub layer, consisting mainly of young eucalypts, is mostly inconspicuous except when *Cycas* is common.

The *Themeda australis–Eucalyptus* savannah is confined to the coastal hill and foothill zones, where it covers extensive areas and is found on a variety of land forms, e.g. ridges and hill crests, slopes, and undulating plains. It is one of the vegetation types most influenced by man, especially in the neighbourhood of Port Moresby, where during the Second World War military camps were established in these savannahs. This may have encouraged the dispersal and local dominance of *Heteropogon*.

In other places a tree storey is almost or completely absent. Ring-barking may be the reason for the lack of trees in extensive parts of Fairfax land system, where the grasslands are used for grazing by cattle. Whether the grasslands frequently occurring on the hills of Hanuabada land system are at least partially natural or wholly induced by man could not be established from the survey data.

(ii) *Themeda australis–Timonius*.—This savannah differs from the *Themeda australis–Eucalyptus* savannah in the absence of *Eucalyptus* species. The tree cover is formed by *Albizia procera*, *Timonius*, and *Pandanus*. It occurs locally in the central hills.

(iii) *Ophiuros–Eucalyptus alba*.—This savannah has a grass cover of *Themeda australis* and *Ophiuros* 1–3 ft high, often in about the same proportions, but sometimes with *Themeda* predominating. Locally associated grasses are *Heteropogon*, *Sorghum*, and/or *Imperata*, which may indicate more human interference than average. Also *Sehima* and *Cymbopogon* are occasionally observed, as well as papilionaceous forbs, e.g. *Tephrosia* and *Crotalaria*. The denseness of the tree layer varies, and a tree layer may locally be almost absent owing to cutting. It always consists of one or two of the *Eucalyptus* species: *E. alba*, *E. confertiflora*, and *E. papuana;* very seldom are all three species encountered together. The environmental factors involved in this distribution could not be established. The height varies between 25 and 45 ft. *Albizia procera* and *Acacia* are uncommon. Commoner, but of lower height, are *Antidesma*, *Timonius*, and *Desmodium*, which may also occur with *Cycas* in a very open shrub layer.

In valley heads and along gullies tufts of *Themeda novoguineensis* may occur between or may dominate the other grasses, and *Pandanus* is found in the shrub layer.

The *Ophiuros–Eucalyptus alba* savannah occurs on undulating terrain, in upper valley floors, and on foot slopes in the coastal hill and foothill zones, with only minor occurrences in the upland zone.

(iv) *Ophiuros–Eucalyptus papuana*.—This savannah is closely related to *Ophiuros–Imperata* mid-height grassland. However, the tree layer is denser and also features *Eucalyptus papuana*. The *Ophiuros–Eucalyptus papuana* savannah has a limited occurrence in the fluvial plains, coastal hill, and foothill zones.

(v) *Ophiuros–Eucalyptus tereticornis* (Plate 10, Fig. 1).—This savannah has a grass cover 2–4 ft high, in which *Ophiuros* and *Themeda australis* are co-dominant, accompanied by *Imperata*, *Eriachne*, *Arundinella*, *Cymbopogon*, and *Eulalia*. *Dianella*, *Melastoma*, and the fern *Gleichenia* are often found, together with a number of papilionaceous forbs, e.g. *Indigofera* and *Tephrosia*. *Heteropogon* is characteristically absent from this vegetation.

In valley heads *Themeda novoguineensis* comes in, and *Polytoca* and *Scleria* may occur in depressions.

The tree layer, at least 50 ft and commonly more than 80 ft high, is formed by *Eucalyptus tereticornis* and *E. papuana*, with minor *E. confertiflora*, frequently accompanied by *Casuarina papuana* and *Melaleuca*. In the shrub layer *Banksia dentata* is conspicuous.

The *Ophiuros–Eucalyptus tereticornis* savannah occurs only on the Sogeri Plateau and on adjacent foothill spurs.

(vi) *Ophiuros–Timonius*.—The grass cover of this savannah is the same as in the *Ophiuros–Eucalyptus alba* savannah. In the tree layer, however, the *Eucalyptus* species are absent and *Timonius* up to 15 ft predominates.

The *Ophiuros–Timonius* savannah occurs on limestone ridges in the coastal hills.

(vii) *Themeda novoguineensis–Eucalyptus*.—*Themeda novoguineensis* 1–3 ft high is a feature of this savannah; *Ophiuros* is always absent and *Themeda australis* is generally so, but may be present in minor quantities. In damper situations *Themeda novoguineensis* dominates, but generally some other species, e.g. *Panicum*, *Arundinella*, *Imperata*, *Heteropogon*, *Eriachne*, or *Eulalia*, are associated, and a variety of forbs is frequently present, e.g. *Indigofera*, *Desmodium*, *Zornia*, *Tephrosia*, *Hyptis*, and *Buchnera*.

The tree layer, which can reach a height of 50 ft but is generally much lower, consists of *Eucalyptus alba*, *E. papuana*, *E. confertiflora*, *Albizia procera*, *Desmodium*, and *Antidesma*. The open shrub layer is represented by *Cycas*, some papilionaceous and myrtaceous shrubs, and young individuals from the tree storey.

The *Themeda novoguineensis–Eucalyptus* savannah occurs on a variety of land forms in the coastal hill and foothill zones, including rocky crests, steep slopes, and drainage depressions.

(viii) *Imperata–Eucalyptus*.—In this savannah a rather open grass cover up to 2 ft high is dominated by *Imperata*, mostly accompanied by scattered *Cymbopogon* and sometimes with some *Heteropogon*, *Eulalia*, *Panicum*, *Capillipedium*, or *Themeda novoguineensis*. Papilionaceous forbs often occur, e.g. *Tephrosia* or *Crotalaria*. The tree storey, up to 45 ft high, consists mainly of *Eucalyptus papuana* and/or *E. alba*. *Albizia procera* is found fairly regularly and *Timonius* is a frequently occurring lower tree. Except for some scattered *Cycas*, no shrub layer of any importance is present.

Imperata–Eucalyptus savannah occurs in the northern parts of the coastal hill zone and in the foothill zone.

(*d*) *Palm and Pandanus Vegetation Types*

(i) *Metroxylon–Artocarpus*.—This vegetation consists of sago palms (*Metroxylon*) 30–40 ft high, in pure dense stands without any undergrowth or in more open stands mixed with some emergent trees up to 60 ft (*Octomeles*, *Artocarpus*, *Sapium*, *Alstonia*) and scattered canopy trees (*Ficus* spp., *Pandanus*, *Endospermum*, *Althoffia*), with a ground cover of *Cyclosorus* and other ferns and some scattered *Heliconia*. It occurs on levees in tidally affected but freshwater reaches of lower river courses.

(ii) *Metroxylon–Macaranga*.—Open stands, 20–30 ft high, dominated by *Metroxylon*, are mixed with *Macaranga*, *Mallotus*, *Kleinhovia*, *Hibiscus*, *Jagera*, *Pandanus*, *Caryota*, *Livistona*, and "lio" palms, interwoven by *Flagellaria* and twining *Cyclosorus*, *Stenochlaena*, and herbs. The ground cover, up to 15 ft high, consists of *Rhynchospora rugosa* or other coarse sedges, *Phragmites*, *Hanguana*, and Zingiberaceae.

This vegetation type occurs as complexes and lines in freshwater swamps.

(iii) *Nypa*.—Dense vegetation formed by fronds of *Nypa fruticans*, 25–35 ft tall, occurs in the lower parts of estuarine tracts and also forms fringes along mangrove forests in sheltered positions.

In slightly higher-lying levee areas scattered emergent trees form an upper storey up to 40 ft high. They are *Xylocarpus*, *Heritiera*, *Bruguiera*, *Rhizophora*, or *Myristica* (species with stilt roots). The undergrowth consists of scattered tall sedge and tree ferns. At still higher levels other species, e.g. *Rhus* and *Barringtonia* together with *Arenga* and *Caryota* palms, come in and represent presumably a successional stage to *Heritiera–Bruguiera* forest.

(iv) *Pandanus*.—This vegetation consists of an open to rather dense layer of *Pandanus* trees, 20 ft high, sometimes mixed with *Melaleuca*, with an undergrowth of coarse sedge and *Hanguana* (Inaukina land system) or of *Isachne, Ischaemum, Rhynchospora, Scleria, Fuirena*, and ferns (Sogeri land system). In the former land system it occurs in choked valleys, in the latter in drainage depressions with standing water more than 1 ft deep.

(e) *Scrub and Thicket*

(i) *Scrub*

(1) *Lumnitzera*.—A scrub 8 ft high, of *Lumnitzera*, pure or with some *Hibiscus* up to 12 ft, occurs on lower inner beach ridges and on the margins of higher ridges, and is flanked by *Avicennia* trees up to 50 ft high where it borders lower-lying mangrove flats.

(2) *Premna–Scaevola*.—This open vegetation, up to 20 ft high, consists of rather isolated tall shrubs and low trees (*Premna, Scaevola, Thespesia, Hibiscus, Clerodendrum, Gyrocarpus, Celastrus, Pandanus*), with scattered herbs in the open places (e.g. *Achyranthes*). Climbers are *Ipomoea* and *Flagellaria*. Patches of denser shrub growth occur locally.

This scrub occurs on sandy beach ridges, enclosed between *Rhizophora–Bruguiera* and/or *Avicennia–Ceriops* forests.

Along open coasts only a *Pandanus* line may occur.

(3) *Pluchea–Flagellaria*.—This is a vegetation of *Pluchea indica* and some low *Hibiscus*, 8 ft high, densely tangled by *Flagellaria*, scrambling shrubs, and thorny vines. Occasional emergents are *Acacia, Livistona*, or *Lagerstroemia*. The ground cover consists of scattered tufts of *Acrostichum aureum* ferns.

Pluchea–Flagellaria scrub generally occurs in brackish back swamps and beach swales.

(ii) *Evergreen Thicket*

(1) *Clerodendrum–Flagellaria*.—In this thicket an open layer of *Acacia auriculiformis* or *Pittosporum* up to 30 ft high emerges from a dense scrub of *Clerodendrum* 10 ft high, tangled by *Flagellaria*. Other shrubs are mostly scarce, but include some *Harpullia, Pluchea*, or *Hibiscus*. The ground cover is formed by scattered *Acrostichum* tufts and some *Chloris*.

This thicket occurs on beach ridges, and sometimes extends into swales, in which case *Ceriops* and/or *Excoecaria* are present in the emergent layer.

(2) *Hibiscus–Flagellaria*.—This is typically a dense scrub, 8–20 ft high and occasionally up to 30 ft, dominated by *Hibiscus*, sometimes almost without other shrubs, and densely interwoven by climbers. The number and composition of the emergent trees vary; their height does not usually exceed 40 ft, but can be as high as 70 ft. Combinations of the following genera are represented in this layer: *Acacia, Melaleuca, Livistona, Nauclea, Althoffia, Ficus, Intsia, Alstonia, Adenanthera, Kleinhovia, Erythrina, Lagerstroemia*, and *Caryota*.

Accompanying genera in the scrub layer are *Macaranga*, *Glochidion*, *Ficus*, *Harpullia*, *Pluchea*, *Arenga*, *Caryota*, and *Premna*. Among the climbers are *Flagellaria*, *Passiflora foetida*, and Compositae. Scrambling shrubs, some with spines, may be present.

Hibiscus–Flagellaria thicket is fairly widespread throughout the littoral plains, swamp, and fluvial plains zones, where it occupies such situations as levee back slopes, back plains, and seasonal swamps. It can stand a low degree of salinity.

(3) *Acacia–Myoporum*.—This rather open vegetation has an upper layer dominated by *Myoporum* 15 ft high and by *Acacia auriculiformis* 25 ft high, with some *Hibiscus*, *Harpullia*, *Glochidion*, and *Pittosporum*, and a lower layer up to 8 ft high dominated by *Clerodendrum*, with some *Myoporum* and *Hibiscus*. The ground cover is formed by scattered *Acrostichum* or by *Panicum*, *Sporobolus*, and *Sesuvium* in more open patches.

This thicket occupies the highest tidal plains and low beach ridges.

(iii) *Semi-deciduous Thicket*

(1) *Gyrocarpus–Harpullia*.—The trees forming the open upper layer are mostly deciduous and about 40 ft high, but some are up to 70 ft high. The lower layer, 12–20 ft high and also rather open, is dominated by gnarled trees and scrambling shrubs and is interwoven with lianes and climbers.

Floristically this thicket is closely related to *Bombax–Celtis* forest, but it is lower, the upper layer is more open, and the shrub layer is denser. Trees in the upper layer are *Bombax*, *Gyrocarpus*, *Garuga*, *Adenanthera*, *Brachychiton*, *Erythrina*, *Intsia*, and *Planchonella*, also occasionally *Acacia*, *Ficus*, *Eucalyptus alba* or *E. papuana*, and *Livistona*. In the second layer are found *Harpullia*, *Colona*, ?*Rhodomyrtus*, *Clerodendrum*, *Santalum*, *Cycas*, *Jagera*, *Micromelum*, *Alstonia*, *Glochidion*, *Pandanus*, *Myoporum*, and a scrambling shrub with spines. Among the climbers *Flagellaria* is common, whilst *Usnea* is conspicuous on the branches of the bare trees.

Gyrocarpus–Harpullia thicket occurs on inner beach ridges as well as in various situations, often with skeletal soils, in the coastal hill zone.

(2) *Garuga–Rhodomyrtus*.—Scattered deciduous trees up to 40 ft and occasionally up to 50 ft high occur over a 25-ft layer of slender, somewhat gnarled trees and tall shrubs with small leaves, tangled by lianes. Among the emergent trees *Garuga* is dominant, others are *Adenanthera*, *Bombax*, *Ficus*, and *Gyrocarpus*. In the lower layer are found ?*Rhodomyrtus*, *Celtis*, *Psychotria*, *Celastrus*, *Antidesma*, *Desmodium*, *Canthium*, *Pittosporum*, *Alstonia*, *Eucalyptus alba*, *Trema*, *Cordia*, and the spiny shrubs *Colubrina* and *Guanea*. Lianes in many forms occur, some with thin smooth bark, others with cork ribs or with spines. In the ground cover *Oplismenus* and ferns are encountered.

This thicket occurs in the southern part of the coastal hill zone on coastal cliffs, ridges, valley floors, and alluvial plains.

(3) *Adenanthera–Colona*.—The scrub layer, 25–35 ft high, is dominated by *Colona*, with *Harpullia*, *Celtis*, *Glochidion*, *Lagerstroemia*, and ?*Rhodomyrtus*, *and* with much emergent *Adenanthera* up to 60 ft high and some *Terminalia*, *Garuga*,

and *Grevillea*. There is an undergrowth of small-leaved shrubs, some with spines, e.g. *Colubrina*. Climbers are common, e.g. *Flagellaria*, and lianes also occur. The ground cover consists of sedges, *Oplismenus*, and scattered tufts of ferns.

It is found on ridges and interfluves, and in tributary valleys in the coastal hill and foothill zones.

(4) *Eucalyptus–Acacia*.—An open layer, 25–60 ft high, of deciduous and evergreen trees (*Acacia*, *Eucalyptus papuana*, sometimes *E. alba* or *E. confertiflora*, *Adenanthera*, *Garuga*, and *Terminalia*) occurs over a dense lower layer of gnarled trees and shrubs up to 25 ft high (*Harpullia*, *Colona*, *Antidesma*, *Lagerstroemia*, *Rhus*, *Santalum*, *Colubrina*, and Myrtaceae). Only a few climbers are found.

It occurs on ridges and interfluves, and on tributary valley floors and plains in the coastal hill and foothill zones.

(*f*) *Forest*

(i) *Strongly Deciduous Forest*

(1) *Bombax–Celtis* (Plate 3, Fig. 2).—This forest consists of an upper layer, 60–90 ft high, which is rather open (at least in the dry season) and dominated by deciduous trees (*Bombax*, *Gyrocarpus*, *Brachychiton*, *Adenanthera*, *Garuga*, *Terminalia* ("samanak", "dsau"), and *Erythrina*), *Planchonella*, and *Intsia*, with a denser second layer, 25–40 ft high, of evergreen and semi-deciduous trees (*Celtis*, *Santalum*, *Micromelum*, *Colona*, *Dysoxylum*, *Harpullia*, *Ficus*, *Terminalia*, *Mallotus*, *Cryptocarya*, *Canarium*, *Sterculia*, *Myristica*, and *Litsea*). The open to rather dense shrub layer consists mainly of scrambling and spiny shrubs. *Cycas* and *Pleomele* are encountered here. The ground cover is of scattered forbs and ferns, together with *Oplismenus*. The lower layers are densely interwoven by *Flagellaria* and lianes. Epiphytes are scarce; sometimes an orchid is found and *Usnea* occurs on the branches of *Bombax*.

Bombax–Celtis forest is confined to the coastal hill and foothill zones, where it is found on rocky ridge crests, steep slopes, valley heads, and benches.

(2) *Bombax–Terminalia*.—The open upper layer, up to 90 ft high, consists of deciduous, semi-deciduous, and non-deciduous trees (*Bombax*, *Serianthes*, *Albizia falcata*, *Brachychiton*, *Terminalia* ("dsau"), *Randia*, *Viticipremna*, *Pleomele*, *Celtis*, *Semecarpus*, *Myristica*, *Maniltoa*, *Caryota*, and *Pandanus*). Low palms, if present, are mainly *Arenga*.

This forest type is almost confined to the coastal and foothill zones. It occurs on foot slopes, valley floors, and drainage plains.

(3) *Albizia–Maniltoa*.—This is a forest 50–80 ft high, mostly with an open upper layer and a more closed storey at 25 or 30 ft, and with a dense shrub layer, tangled by *Flagellaria*, lianes, and scrambling shrubs and spines. Higher trees are *Albizia falcata*, *Erythrina*, *Terminalia* ("samanak", "dsau"), *Sterculia*, *Garuga*, *Bombax*, *Ficus*, and *Serianthes*. Lower trees are *Maniltoa*, *Kleinhovia*, *Syzygium*, *Barringtonia*, *Lunasia*, *Pleomele*, *Pandanus*, *Colona*, *Dysoxylum*, and *Casearia*, and "bali" is a scattered palm.

Albizia–Maniltoa forest occurs on bouldery valley floors in the coastal hill zone.

(ii) *Slightly Deciduous Forest*

(1) *Garuga–Brachychiton*.—This forest is up to 75 ft high, but generally about 35 ft, with emergent trees to 45 ft. It has a rather dense upper tree layer with several deciduous trees, and a well-developed lower layer with *Flagellaria* and lianes. Among the emergents are *Garuga*, *Brachychiton*, *Ficus*, *Albizia falcata*, and *Grevillea*, and in the canopy are *Colona*, *Lagerstroemia*, *Glochidion*, *Bombax*, *Terminalia* ("dsau", "samanak"), and *Harpullia*. Palms ("sal") occur only as scattered individuals. Ferns are the main constituent of the open ground cover.

Garuga–Brachychiton forest covers ridges in the northern part of the coastal hill zone and in the foothill zone.

(2) *Intsia–Celtis*.—This forest has a rather open canopy, 30–70 ft high with emergent trees up to 80 ft, including *Intsia*, *Terminalia* ("dsau" and "samanak"), *Garuga*, *Cedrela*, *Albizia falcata*, *Serianthes*, *Bombax*, *Dracontomelum*, and *Erythrina*. Trees found in the canopy are *Celtis*, *Dysoxylum*, *Syzygium*, *Acacia*, *Myristica*, *Maniltoa*, *Randia*, and *Ficus*. Shrub undergrowth, up to 20 ft high, is dense, with rather frequent *Pandanus*, but palms are scarce. Lianes are scarce to rather numerous, and the ground cover consists of *Oplismenus*, sedges, and ferns.

This forest occurs on ridges and valley floors in the coastal hill zone.

(3) *Planchonia–Adenanthera*.—An open upper layer up to 100 ft high, with *Planchonia*, *Adenanthera*, *Casearia*, *Pangium*, *Nauclea*, *Alstonia*, *Pterocarpus*, *Ficus*, *Sterculia*, *Terminalia*, *Bombax*, and *Garuga*, occurs over a denser lower layer with *Kleinhovia*, *Ficus* ("ana"), *Jagera*, *Barringtonia*, *Semecarpus*, and *Pleomele*. In the shrub and tall herb layer are found *Pseuderanthemum*, *Pandanus*, Zingiberaceae, *Arenga*, and young rattans. Palms are generally sparse. The numerous lianes range from slender rattans to thick bush ropes.

This forest occurs on alluvial terraces and plains throughout the southern part of the coastal hill zone and in the foothill zone.

(4) *Spondias–Celtis*.—This forest has an open upper storey, up to 120 ft high, of *Spondias*, *Celtis*, *Dracontomelum*, *Intsia*, *Terminalia* ("samanak", "o", and "nut"), *Cedrela*, *Alstonia*, *Ficus*, *Bombax*, and *Octomeles*. It has a denser second storey of *Kleinhovia* and a dense lower layer with *Pandanus*, *Arenga* and other palms, and scattered young rattan.

It occurs on valley plains in the foothill zone and in drainage-affected areas in the fluvial plains zone.

(5) *Intsia–Spondias*.—This forest has an open upper storey up to 130 ft high and a lower storey of irregular height (60–100 ft) and closure with many relatively slender trees. Trees are *Intsia*, *Spondias*, *Celtis*, *Tristiropsis*, *Cedrela*, *Ficus*, *Sterculia*, *Pangium*, *Colona*, *Bombax*, *Canarium*, *Alstonia*, *Neonauclea*, and *Pometia*; high palms are *Caryota*, *Orania*, and "limbon". In the undergrowth young palms and rattans are common, and *Pandanus*, *Cycas*, and Zingiberaceae occur in smaller numbers. *Pleomele* is locally abundant. Some lianes are found, but thinner climbers, e.g. *Flagellaria*, occur in greater numbers. There is a sparse ground cover with ferns.

This forest occurs on the crests of ridges in the north backing ranges.

(6) *Albizia–Canarium*.—This forest is 70–100 ft high, locally up to 130 ft high. The canopy is irregular in height and closure, filled in by the second layer, up to 60 ft high, which is rather dense and consists of numerous slender trees. Those encountered were *Albizia falcata*, *Canarium*, *Microcos*, *Neonauclea*, *Pimeleodendron*, *Wrightia*, *Cedrela*, *Bombax*, *Syzygium*, *Dysoxylum*, *Terminalia*, *Celtis*, *Alstonia*, *Pangium*, *Gnetum*, and *Aglaia*, with the palms *Caryota*, *Arenga*, and *Orania*. The shrub layer is also dense, with *Cycas*, *Pleomele*, *Cordyline*, *Maniltoa*, *Harpullia*, *Sloanea*, *Pandanus*, young *Arenga* palms, scattered young rattans, and Zingiberaceae. Bush ropes are frequent, but rattans are scarce. In the ground cover are *Selaginella*, *Oplismenus*, and several ferns.

Albizia–Canarium forest occurs on ridges and slopes in the foothill and upland zones.

(iii) *Low Evergreen Forest*

(1) *Sonneratia acida*.—This vegetation consists of stands of *Sonneratia acida* up to 40 ft high, sometimes mixed with *Nypa* and *Bruguiera*. *Stenochlaena* climbs up to 15 ft on the trunks; locally there is dense *Flagellaria*. The ground between the tall pneumatophores is covered by an araceous species, *Cyperus*, and *Leersia*.

Stands of this vegetation type are always small; they occur on shelving river banks and low scrolls in the tidally affected but freshwater reaches of rivers.

(2) *Avicennia–Sonneratia*.—In this vegetation, open stands of *Avicennia marina* and/or *Sonneratia alba* 6–30 ft high are locally mixed with *Rhizophora* or stands of *Nypa*.

It is a seral vegetation on accreting muddy shores and shelving banks well below high-water mark.

(3) *Ceriops*.—This is pure vegetation of *Ceriops*, up to 30 ft high, in a zone several hundred yards wide along tidal creeks in Kido land system. Further from the creek this vegetation was only 12 ft high and consisted of a very great number of small trees which had died when they reached a certain diameter, as was observed from the numerous dead trunks.

(4) *Avicennia–Ceriops* (Plate 2, Fig. 1).—This forest is dominated by *Avicennia marina*, often mixed with some *Ceriops*, *Aegiceras*, *Xylocarpus*, or *Bruguiera*. Height mainly ranges between 15 and 30 ft, but occasionally some stands of 50 ft occur, consisting of very thick, broad-crowned *Avicennia* trees. The degree of closure also varies, perhaps in response to the environment. In the more open stands dead trees are often found.

In localities regularly flooded by the tides, the pneumatophores form the only ground cover. Where flooding is more irregular a ground cover dominated by *Sesuvium*, sometimes with *Chloris* and *Sporobolus*, is developed.

This vegetation type occurs in extensive forest tracts and also as a fringe round salt pans, where these are bordered by low beach ridges. In such fringing vegetation *Ceriops* is mostly dominant and not higher than 10 ft, while *Avicennia* is mostly about 15 ft.

Avicennia–Ceriops forest is confined to well-drained areas in the littoral plains zone, which are flooded only by the higher tides.

(5) *Avicennia–Excoecaria*.—This is a forest 25–40 ft high, with a rather open canopy, usually dominated by *Avicennia* but sometimes by *Bruguiera* or *Rhizophora*, and invariably accompanied by *Excoecaria*. The undergrowth, 8–15 ft high, of *Aegiceras*, *Ceriops*, *Thespesia*, *Myoporum*, *Hibiscus*, or *Clerodendrum*, is often dense. A ground cover is absent or is formed by scattered *Acrostichum* tufts. In the highest situations *Sesuvium* and *Sporobolus* may occur.

Avicennia–Excoecaria forest occurs in ill-drained brackish higher areas in the littoral plains zone. Along drainage channels in areas covered with *Clerodendrum–Flagellaria* thicket the *Avicennia–Excoecaria* forest is reduced to only a line of trees.

(6) *Althoffia–Endospermum*.—This vegetation consists of woody regrowth, commonly up to 20 or 30 ft high, densely interwoven by herbaceous vines and with a rich ground cover. The tree layer consists of mature trees of *Althoffia*, *Endospermum*, *Macaranga*, *Melanolepis*, *Hibiscus*, *Mallotus*, *Laportea*, *Ficus*, *Timonius*, and of young forest trees (*Myristica*, *Elaeocarpus*, *Canarium*, *Pometia*, *Nauclea*, *Alstonia*, and *Euodia*). Bamboo and *Arenga*, *Caryota*, and "lio" palms occur. Climbers are *Flagellaria*, Convolvulaceae, and a few rattans. Among the epiphytes several Araceae and *Stenochlaena* are found. The ground cover is formed by low and tall Zingiberaceae and by *Heliconia*, *Cyclosorus*, *Acalypha*, *Archiphallos*, *Paspalum*, *Imperata*, *Saccharum spontaneum*, and *Setaria palmifolia*.

Planted *Cocos* and *Areca* palms, *Artocarpus*, and *Terminalia kaernbachii* are often encountered, the last up to 80 ft high.

Althoffia–Endospermum forest is found throughout the fluvial plains zone in slightly low-lying areas.

(7) *Artocarpus–Ficus*.—This forest, up to 40 ft high, contains *Artocarpus* and *Ficus* ("holun") as characteristic trees, accompanied by several other *Ficus* species, *Kleinhovia*, *Alstonia*, *Nauclea*, *Laportea*, "kukul", *Terminalia*, *Melanolepis*, *Macaranga*, and young *Octomeles*. Rattans are common, and in the undergrowth are *Pandanus*, *Cordyline*, tall Zingiberaceae, and climbing *Stenochlaena*. Often there is a dense *Cyclosorus* ground cover.

This forest occurs on low levees, mainly in the fluvial plains zone, and is presumably seral to *Octomeles–Artocarpus* forest.

(iv) *Mid-height Evergreen Forest*

(1) *Rhizophora–Bruguiera* (Plate 1, Fig. 2).—This forest is generally 50–80 ft high with a dense canopy dominated by *Rhizophora* and/or *Bruguiera*, and is subject to frequent tidal inundation. It forms the typical mangrove forests. The lowest-lying stands are almost pure; with decreasing duration of flooding, *Xylocarpus* and *Ceriops* come in, and in the highest parts *Heritiera* is also found.

There is mostly no true second layer under the canopy, but often a rather dense undergrowth of young trees occurs. In lighter stands there may also be scattered *Nypa*. *Avicennia*, *Sonneratia*, *Aegiceras*, and *Nypa* are found where this forest fringes large estuaries and tidal creeks.

In forests lying near high-water mark, large crab-built mounds are found.

These form a substrate for an *Acanthus–Acrostichum* ground layer. On the highest parts *Clerodendrum* and *Flagellaria* also come in. The lower-lying forests have no ground cover.

On spots well above ordinary high-water mark is a vegetation about 30 ft high, dominated by gnarled *Xylocarpus* with a lower, denser shrub layer of *Bruguiera*, *Ceriops*, and young *Xylocarpus*. Trunks are densely covered by mosses and lichens, and a ground cover of scattered *Acrostichum* is present. Papilionaceous climbers occur.

On some sandy foreshores a forest, 20–40 ft high, occurs, consisting of giant shrub-like specimens of *Rhizophora*, pure or with *Bruguiera*.

Rhizophora–Bruguiera forests are found in the lower parts of the littoral plains zone, where they occupy the tidal flats and some sandy foreshores.

(2) *Heritiera–Bruguiera*.—This is a forest 50–80 ft high, with a fairly open upper storey dominated by *Heritiera*, *Bruguiera*, and *Xylocarpus*. Other trees are *Aglaia*, *Rhus*, *Myristica* (species with prominent stilt roots), *Intsia*, and *Excoecaria*. The lower storey varies in density and is formed by young trees of the upper storey together with *Boerlagiodendron*, *Jagera*, *Barringtonia*, *Hibiscus*, *Schefflera*, *Arenga*, *Nypa*, *Pandanus*, and tree ferns. The ground cover consists of *Stenochlaena*, *Asplenium*, and scattered coarse sedges; in areas with stronger salt-water influence *Acanthus* also occurs. Generally much *Flagellaria* twines through the lower storey.

This forest grows on back plains and low levees in areas of brackish or fresh-water tidal inundation.

(3) *Excoecaria–Hibiscus*.—This forest, 35–80 ft high, has an open canopy of *Excoecaria agallocha*, mostly pure but sometimes with *Livistona* palms and *Myristica*. Often there is a fairly dense lower storey of *Hibiscus* and *Clerodendrum* tangled by *Flagellaria* and other climbers, some with spines. The ground layer consists of scattered *Acrostichum* and minor *Acanthus*. In some fragmentary occurrences, for instance in small beach swales, the lower storey may be absent.

It occupies ill-drained brackish beach swales and back swamps in the littoral plains and swamp zones.

(4) *Melaleuca–Excoecaria*.—*Melaleuca* dominates the canopy layer in this open forest, up to 80 ft high. A lower open tree layer is formed by *Excoecaria*, *Acacia*, and *Livistona*, and *Hibiscus* dominates the shrub layer. The ground cover, which is generally dense, consists of *Paspalum*, *Eragrostis*, and small sedges.

The vegetation occurs in more or less brackish back swamps which are seasonally flooded. At the base of the *Melaleuca* and *Excoecaria* trunks bunches of adventitious roots are developed, presumably as a response to this flooding.

(5) *Melaleuca–Nauclea* (Plate 6, Fig. 1).—This forest is 80 ft high, with a light, rather less evenly closed canopy, an open second layer, and often a dense lower layer of young palms and rattans. In the canopy are *Melaleuca*, *Nauclea*, "kukul", *Erythrina*, *Terminalia*, *Alstonia*, *Planchonia*, *Ficus*, *Sapium*, and *Acacia*, and *Livistona* palms. In the second layer *Kleinhovia*, *Premna*, *Semecarpus*, *Randia*, *Macaranga*, *Hibiscus*, *Pandanus*, and *Livistona* and *Areca* palms may occur. In the shrub layer are young rattans and other palms (*Livistona* "bali"), *Cordyline*, and tall Marantaceae.

Among the climbers, rattans and *Flagellaria* are common. *Stenochlaena* may occur as a creeper up to 20 ft high, but also occurs locally as ground cover with *Cyclosorus*. In lighter patches *Phragmites* or *Echinochloa* is found.

Melaleuca–Nauclea forest occupies seasonal back swamps, ill-drained plains, and depressions in freshwater environments throughout the depositional zones. Along margins of permanent swamps this forest type is often reduced to a line of *Melaleuca*, *Nauclea*, *Terminalia*, "kukul", *Livistona*, etc.

(6) *Nauclea–Kleinhovia*.—This forest has an open, irregular canopy 60–100 ft high, with *Nauclea, Planchonia, Artocarpus, Ficus, Terminalia, Pterocarpus*, "kukul", and *Alstonia*. The second layer is dense, 35–60 ft high, and dominated by *Kleinhovia* or palms and *Pandanus*. Other trees in this layer are *Myristica, Macaranga, Syzygium*, and *Cordyline*, and the palms *Arenga, Caryota, Licuala*, "sal", and "limbon". Rattans are often dense. The climbing fern *Stenochlaena* is present. The ground cover is sparse and includes *Oplismenus, Scleria*, and Araceae. Zingiberaceae and Marantaceae are scarce or absent.

Nauclea–Kleinhovia forest occurs in the swamp zone on higher levees, and in the fluvial plains zone on back-slope plains and in old meander depressions.

(7) *Ficus–Myristica*.—This forest is up to 80 ft, with an open upper storey of *Ficus* ("bamiso"), *Myristica* (species with stilt roots), *Canarium, Neuburgia, Terminalia, Dysoxylum*, and the tall palms "lio", *Caryota*, and *Livistona*. A dense lower storey is formed by *Boerlagiodendron, Pandanus, Arenga, Cordyline, Kleinhovia, Harpullia*, and tall Zingiberaceae and Marantaceae. *Stenochlaena* is a climber up to 20 ft in height. There is much coarse *Flagellaria* and rattan among the climbers.

This forest occurs on low levees in estuarine tracts subject to freshwater tidal inundation.

(v) *Tall Evergreen Forest*

(1) *Octomeles–Artocarpus*.—This forest has a rather open canopy, up to 120 ft high, of *Octomeles, Artocarpus, Terminalia* ("samanak" and "nut"), *Ficus, Nauclea, Intsia, Pometia, Planchonia, Alstonia, Pterocarpus, Dracontomelum, Serianthes, Spondias, Bischoffia*, etc. In the lower storeys *Kleinhovia* and *Artocarpus* are prominent, with many associates (*Horsfieldia, Ficus, Dysoxylum, Macaranga, Sterculia*, "kukul", etc., and *Livistona* and "lio" palms). Lianes, and especially rattans, are common, and so are araceous epiphytic creepers; *Stenochlaena* covers many trunks to a height of 20 ft. The open understorey consists of *Pandanus*, palms (*Arenga*, "sal", "bali", and young rattan), Zingiberaceae, Marantaceae, and Musaceae, and the rather open ground layer of *Cyclosorus, Stenochlaena*, Araceae, and *Paspalum conjugatum*.

Octomeles–Artocarpus forest occupies banks and levees of the larger rivers throughout the area. Owing to the favourable topography and soil, forests of this type are often disturbed by shifting cultivation.

(2) *Cerbera–Alstonia*.—This forest has a rather open canopy of irregular height, 80 to 120 ft, with a dense lower layer in which erect palms and rattans predominate. There is sometimes an additional, open layer between these two. In the canopy are found *Cerbera, Alstonia scholaris, Terminalia* ("samanak" and "o"), *Planchonia*,

Ficus, Pterocarpus, Tristiropsis, Pometia, Dracontomelum, etc. An occasional *Bombax* or *Garuga* may occur. In the lower layers are *Semecarpus, Kleinhovia, Myristica*, etc., and many palms, e.g. rattan, *Caryota*, "lio", "hek", *Arenga, Licuala*, "bali", and "sal", of which the first four may reach the canopy, as *Pandanus* sometimes does. Tall Zingiberaceae and Marantaceae are found in the understorey, but *Stenochlaena* is rare.

This forest occurs on back plains, swamp margins, and river terraces, mainly in the fluvial plains zone.

(3) *Cananga–Pometia*.—This forest has a fairly evenly closed canopy at 100 ft, emergents (e.g. *Cananga odorata*) up to 140 ft, and many rattans. *Pometia*, "uk", and ?*Pimeleodendron* predominate, associates being *Nauclea, Canarium, Homalium, Alstonia, Mangifera, Neuburgia, Terminalia*, and palms ("lio", "bananak", and *Caryota*). The second layer, at about 50 ft, is rather open and has much *Pandanus*, some *Arenga* palms, and many small trees, among which *Maniltoa* predominates. In the shrub storey are many young rattans, *Arenga*, Marantaceae, and Zingiberaceae. *Stenochlaena*, creeping to 30 ft, is uncommon.

Cananga–Pometia forest has a limited distribution in the fluvial plains zone, where it occurs on prior levee banks and channels which are frequently inundated.

(4) *Pometia–Celtis* (Plate 7, Fig. 2).—This forest is about 100 ft high, with occasional emergents (e.g. *Tetrameles* or *Bombax*) up to 150 ft; it has a dense canopy and an open lower tree layer with scattered rattans and palms. It is very mixed in composition, and the following taxa are relatively numerous: *Pometia pinnata* and other species, *Celtis* (several species), *Alstonia, Canarium*, "nawal", *Pangium, Ficus* (many species), and *Myristica*. Among the others are *Dracontomelum, Mangifera, Dysoxylum, Terminalia, Pterocarpus, Sterculia, Semecarpus*, and occasional tall palms ("lio", "hek"). A few deciduous elements may be present (*Bombax, Garuga, Erythrina*, and *Terminalia*). Among the smaller trees are *Maniltoa, Kleinhovia*, and *Pleomele*. The undergrowth is sometimes rich in young rattans and other palms (*Arenga, Licuala, Caryota*, "sal", "bananak"), together with *Pandanus* and *Cordyline*. Scattered lianes and tall herbs occur.

Pometia–Celtis forest occupies large areas in parts of the fluvial plains zone.

(5) *Casuarina–Dysoxylum*.—This forest has a mixed, rather open canopy up to 90 ft high, with local dominance of *Casuarina*, and a denser lower storey in which *Actinodaphne* or *Wendlandia* is locally common. Among the trees are *Casuarina, Dysoxylum, Gnetum, Rhus, Pangium, Ficus, Aglaia, Calophyllum, Euodia, Terminalia kaernbachii, Cryptocarya, Cedrela, Citrus, Schefflera, Pandanus, Pleomele*, and *Cordyline*. Palms up to 50 ft vary in number and are mainly represented by *Caryota*. Only thin climbers, e.g. *Flagellaria*, are found. In the shrub layer, tree ferns and scattered young rattans occur and there is a rich ground cover of herbs and ferns.

This forest type occurs on steep lower slopes, in tributary valleys, and on minor alluvial terraces, mainly in the foothill and upland zones. Where it borders *Castanopsis–Elaeocarpus* forest it is mixed with elements of this forest type.

(6) *Alstonia–Kleinhovia*.—This forest has an irregularly closed upper storey up to 100 ft high, with emergents up to 150 ft. In the canopy, *Terminalia* ("nut", "o"), *Alstonia, Ficus, Nauclea*, "kukul", *Intsia, Serianthes*, etc., are found. Lower storeys,

up to 60 ft high, are irregularly to almost completely closed, with much *Kleinhovia*, *Myristica*, *Maniltoa*, *Microcos*, *Cordyline*, *Lunasia*, and *Livistona*. "Sal" palms form a rather dense understorey. Rattans, Zingiberaceae, and *Stenochlaena* are absent, and lianes are scarce.

This forest typically occurs on the main valley plains in the northern hills of the coastal hill zone.

(7) *Pometia–Artocarpus*.—This forest is 100–120 ft high, with an open canopy, many epiphytes (Araceae, ferns), and few to many lianes. The lower storeys are dense. Canopy trees are *Pometia*, *Artocarpus*, *Euodia*, *Elaeocarpus*, *Pangium*, *Syzygium*, *Albizia falcata*, *Ficus*, *Planchonella*, *Terminalia* (*kaernbachii* and "nut"), with some elements of the *Castanopsis–Elaeocarpus* forest if the two are in contact. In the lower layers are *Horsfieldia*, *Schuurmansia*, *Schefflera*, *Pleomele*, *Pandanus*, and tree ferns. *Kleinhovia* occurs only locally. *Elatostema* appears in the ground cover.

Pometia–Artocarpus forest is found on lowermost spurs and valley floors in the upland zone.

(8) *Pometia–Canarium*.—This forest has an open upper storey, 130–150 ft in height, and a rather open lower storey of irregular height, 60–100 ft, with mainly thin-stemmed trees. Those listed are *Pometia*, *Canarium*, *Pangium*, *Gnetum*, *Alstonia*, *Diospyros*, *Neonauclea*, *Syzygium*, *Ficus*, *Wrightia*, *Sterculia*, *Pterocarpus*, *Microcos*, *Tristania*, *Dracontomelum*, *Intsia*, *Semecarpus*, *Garcinia*, *Celtis*, *Dysoxylum*, *Cinnamomum*, and an occasional deciduous tree (*Spondias*, *Garuga*). Tall *Pandanus* and palms (*Caryota*, *Arenga*, "limbon") are also present. Scattered low palms and rattans occur in the undergrowth, together with *Cycas*, *Pleomele*, *Maniltoa*, and tall Zingiberaceae and Marantaceae. Ferns form an open ground cover.

This forest type occupies plateau crests, lower ridges, and lower slopes of higher ridges in the north backing ranges.

(9) *Castanopsis–Elaeocarpus*.—This forest ranges in height from 70 to 130 ft, often strongly dominated by *Castanopsis* with only a few associated species. The highest tree storey is rather open; lower tree layers are not differentiated and all stages from unestablished seedlings to relatively mature trees may be found. In the canopy are *Castanopsis*, *Elaeocarpus*, *Syzygium*, *Canarium*, *Myristica*, *Cryptocarya*, and *Ficus* ("bambam", "lalawi", "bigus"). In the undergrowth are tree ferns and *Pandanus* and bamboo, both sometimes climbing; palms and rattans are scarce and only a few lianes occur. Among the rich epiphytic flora, climbing ferns, Araceae, Orchidaceae, and mosses are conspicuous.

This forest occurs on ridges and some higher valleys in the south backing ranges and on the Sogeri Plateau. More mixed forests of this type generally occur on the lower parts of the slopes.

Locally in Subitana land system Dipterocarpaceae, e.g. *Hopea* and *Anisoptera*, become prominent, in which case *Castanopsis* is almost or wholly absent.

(10) *Lithocarpus–Elaeocarpus*.—This forest has emergents up to 120 ft and the main canopy at about 100 ft resembles in structure the more mixed stands of the *Castanopsis–Elaeocarpus* forest. The canopy trees listed are *Lithocarpus*, *Agathis*, *Mangifera*, *Elaeocarpus*, *Dysoxylum*, *Syzygium*, *Cryptocarya*, *Cinnamomum*, *Planchonia*, *Dracontomelum*, *Castanopsis*, *Dryadodaphne*, *Sloanea*, *Chrysophyllum*, and

tall palms ("bananak" and "limbon"). Scattered in the undergrowth are *Cycas*, *Pleomele*, tree ferns, *Pandanus*, rattan, young palms, and Zingiberaceae. Lianes are not numerous. *Stenochlaena* is found as a creeper up to 40 ft high. Many epiphytes occur (Araceae, Orchidaceae, ferns, and mosses). *Selaginella* and *Stenochlaena* form the ground cover.

Lithocarpus–Elaeocarpus forest occurs in the upland zone on ridges above 1300 ft in the north backing ranges and above 2900 ft in the southern part of the zone.

V. Ecology

The surveyed area, situated between the Gulf of Papua and an arbitrary boundary about 20 miles inland, displays in spite of this short distance a great variation in environmental factors. Land forms range from mangrove flats inundated twice daily and fluvial plains to mountains up to 3500 ft above sea level, with sheer cliffs and gorges with deeply incised rivers (Part VI). Soils vary from unconsolidated sands, clays, and peats to black cracking clays and from stony skeletal soils to deeply weathered red volcanic soils (Part VII). Rainfall ranges from 40 in. in coastal areas to 150 in. locally in the upland zone. Each year, for several weeks or even for a few months, drought conditions apply in coastal areas (Part IV).

The varied environment is reflected in the complexity of the vegetation. Optimal conditions are indicated by the most complex vegetation, namely certain tall evergreen forest types, commonly distinguished as "rain forest". These conditions include optimal temperatures, high rainfall evenly distributed throughout the year, unimpeded drainage, and good aeration. Deviations from optimal conditions show in the structure of the vegetation; deciduous forests, for instance, reflect seasonal drought, the severity of which shows in the proportion of deciduous trees. Mid-height and low evergreen forests point to less favourable moisture conditions throughout the year, such as result from impeded drainage or salt water. Semi-deciduous as well as evergreen thicket indicates conditions which are still more unfavourable, and unsuited for forest growth. Under permanently waterlogged conditions tall grassland (*Phragmites–Saccharum robustum*) is the highest developed vegetation, whilst very marginal conditions, such as occur along beaches, in salt pans and in open water, are reflected in the herbaceous vegetation types. Savannah, mid-height grassland, and tall grassland (*Saccharum spontaneum–Imperata*) are not reliable indicators of climate and soil conditions because of the overriding influence of repeated burning.

In Figures 12–14 the relationships between vegetation types and prominent environmental factors are shown. These diagrams are tentative and indicate only general relationships. Many of the forest types and a number of other vegetation types are incorporated in Figure 12. The remaining types, viz. those largely depending on fire for their existence and those subject to tidal inundation, are dealt with separately in Figures 13 and 14. Figure 12, showing vegetation types in relation to moisture conditions, demonstrates how soil water, that is ground water plus run-on, compensates to a certain extent for inadequate rainfall in some situations, such as valleys, and overrides climate in others, e.g. back plains and swamps. For example, slightly deciduous forest has its main distribution in areas where rainfall is inadequate for short annual periods, but it also occurs on edaphically dry ridges in areas where

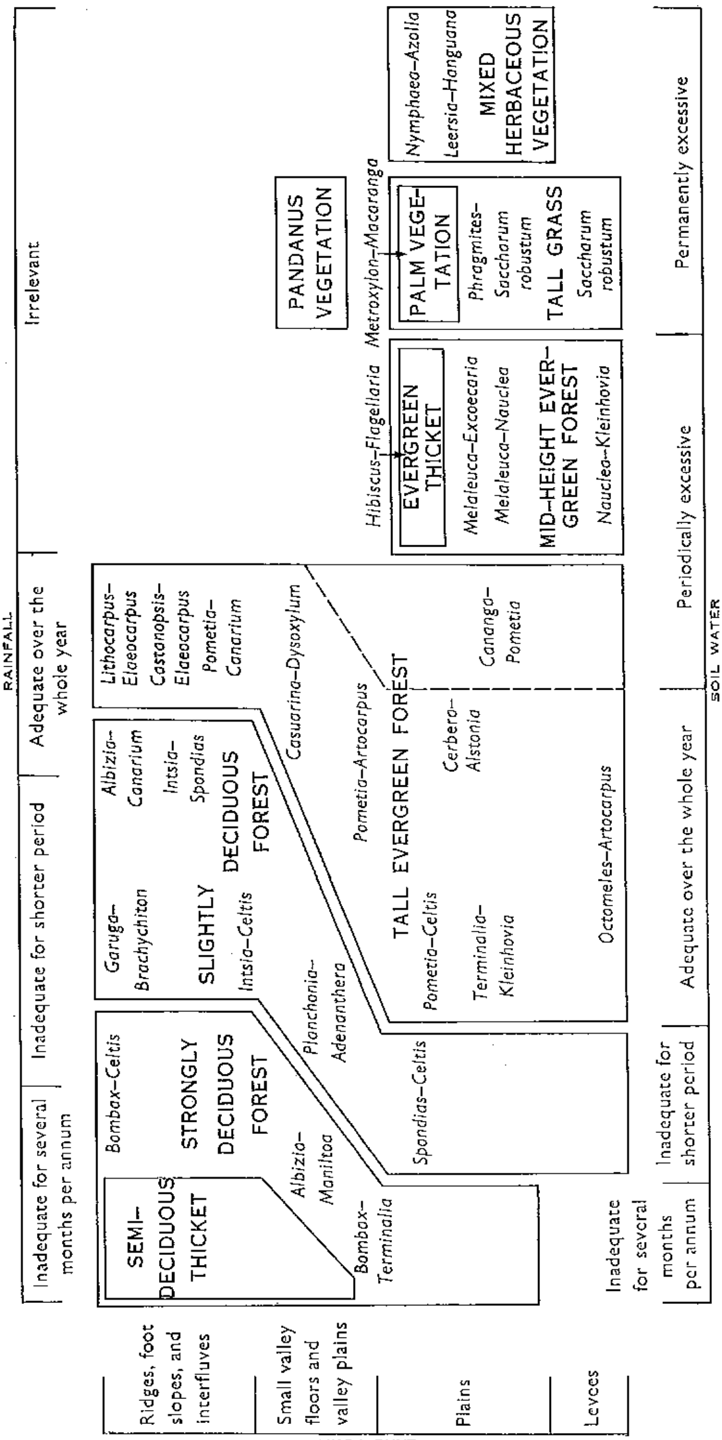

Fig. 12.—Relations between vegetation types and moisture regime.

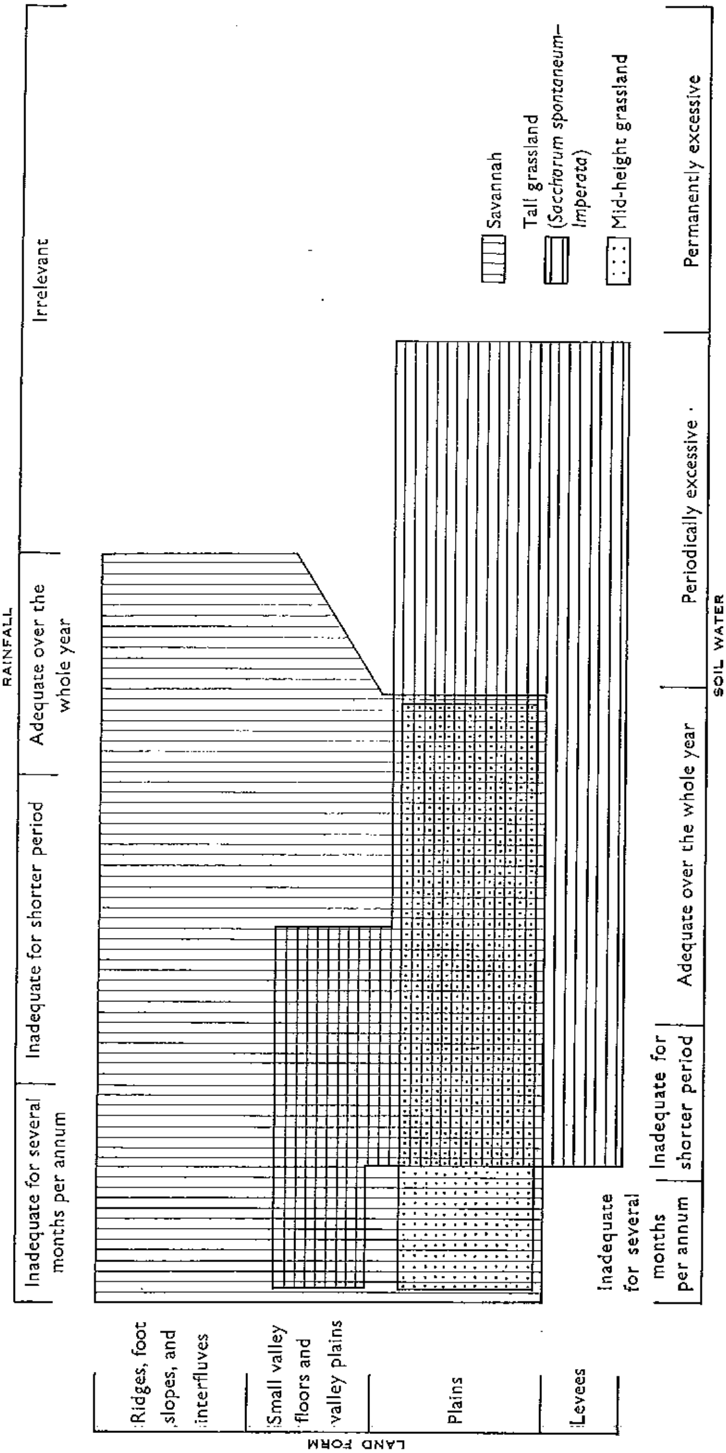

Fig. 13.—Relations between vegetation types influenced by fire and moisture regime.

rainfall is otherwise adequate for tall evergreen forest growth. On the other hand, it extends into valleys and plains in areas of strongly deciduous forest with longer dry seasons, owing to the more favourable moisture conditions of those situations. Figure 13 shows the major groups which are largely caused and maintained by burning, namely savannahs and most of the grasslands, in relation to the same environmental factors as in Figure 12. Figure 14 illustrates the various tidal environments with their characteristic vegetation types.

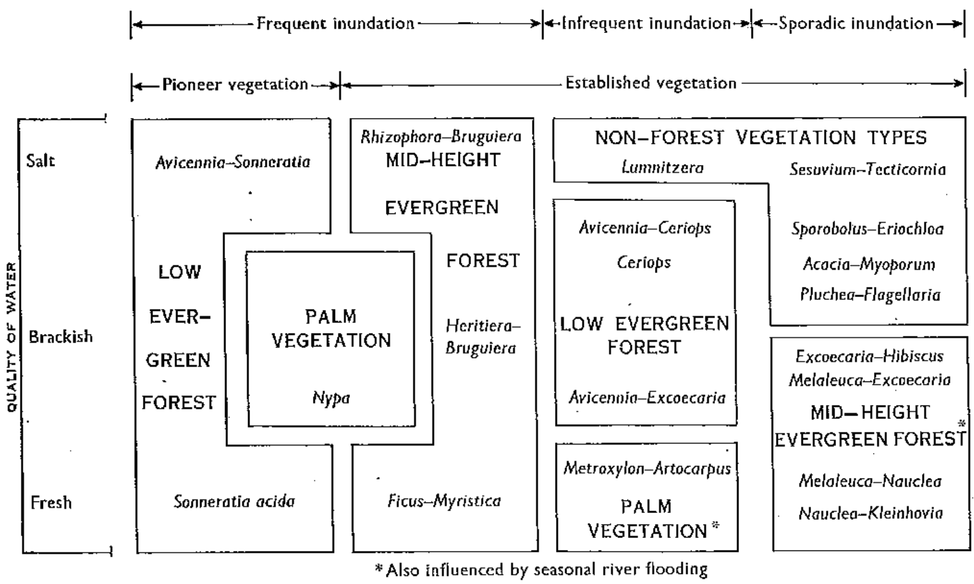

Fig. 14.—Relationships between vegetation types subject to tidal inundation.

The distribution of the major groups of vegetation is shown in an inset to the land system map. In compiling this map only predominating groups in each land system have been considered, and some minor land system occurrences have been omitted because of the map scale. Accordingly, in the erosional environments the vegetation groups mapped are those which occur on the ridges. Figures 12 and 13 show that they are primarily controlled by rainfall and, as far as the savannahs are concerned, also by fire. The vegetation in most of the larger land units in the depositional environments is controlled by soil water; accordingly, the vegetation mapped in the fluvial plains and swamp zones consists of those types shown as being controlled by soil water in Figures 12 and 13. Vegetation types enumerated in Figure 14 feature in the littoral zone on the map. With the aid of the diagrams the vegetation map can be transposed into a moisture-regime map.

VI. Acknowledgments

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PART IX. LAND CLASSES OF THE PORT MORESBY–KAIRUKU AREA

By R. M. Scott*

I. Introduction

Owing to the lack of documentary material on land use and the rapid reconnaissance nature of the survey, the agricultural potential of the lands in the area cannot be treated in detail.

II. Present Land Use

Present land use is almost confined to two types of farming. First, there is commercial, non-indigenous agriculture on large plantations, which rely on a large indentured labour force recruited from outside the area, and on ranches. These plantations and ranches have a zonal distribution, with large rubber (Plate 11, Fig. 2) and minor coffee plantations in the upland zone and part of the foothill zone, copra plantations in the littoral plains and fluvial plains zones, and ranches in the coastal hill zone.

Secondly, there is the local traditional indigenous shifting agriculture based on the family practising subsistence farming. In order of importance, the main food crops are banana, taro, sweet potato, and sugar-cane (Plate 10, Fig. 2). They are interplanted and the garden is fenced against pigs. Coconuts are another important source of food and tend to be planted in small groves. The distribution of indigenous agriculture reflects the pattern of settlement, which is mainly in the littoral plains zone and in the northern plains along the Angabunga River in the fluvial plains zone. The coastal villagers have many coconut groves on the sandy beach ridges, with gardens inland along the narrow river levees with access by canoe. These levee soils have better moisture conditions than the beach sands, and are not saline. On the northern plains along the Angabunga River, subsistence farming is almost confined to forested areas, possibly because the necessary clearing can easily be carried out with knife or axe, whilst digging is confined to that necessary for planting. In contrast, the preparation of gardens in the grasslands involves complete cultivation and removal of grass roots, and more weeding against grass invasion. These relative difficulties, however, no longer apply where machinery is used, and some mechanized clearing of grassland on a community basis has taken place in this area.

Cash crops and community farming are being introduced on a small scale into the subsistence farming economy with the help of agricultural officers. The main cash crops seen were copra, coffee, and cocoa. The copra was mainly confined to the littoral plains zone and communal copra kilns were seen in some of the villages, although most of the coconuts, as mentioned previously, appeared still to be used as food. Coffee is being planted in small holdings of about 100 trees in the forested areas of the northern plains where, once the area has been cleared, shade trees are planted. Near Inawauni a small holding of cocoa was seen on the acid red to brown

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clay soils of Inaukina land system. Here the forest had been cleared communally but only one man persisted to the stage of production (Plate 11, Fig. 1). Attempts have been made to introduce rice on the northern plains but these have been unsuccessful.

Owing to the proximity of Port Moresby, many of the food crops have become cash crops on a minor scale. Betel nut is an important cash crop throughout the area.

III. Land Capability Classification

Land units have been classified into capability classes, based on the system of the United States Soil Conservation Service but modified for the present survey. The classification used here follows closely that proposed by Haantjens (1963).* There are eight classes which indicate the degree of suitability of the land for different types of agricultural production and these are set out in Table 2. Land classes I–IV are all suitable for cultivation but with increasing limitations, class IV being marginal for this form of land use. Classes V–VII are unsuitable for dry-land cultivation and range in land use from pastures to tree crops, while class VIII land is unsuitable for commercial crop production. All classes are defined by limiting factors or hazards which are denoted by symbols with a suffix of that class in which it occurs. The limiting factors are based on varying degrees of erosion, soil moisture, drainage, flooding, surface stones, and fertility. The highest hazard will decide the capability class of any land unit. Thus a unit which has a number of limiting factors of class II and one of class VI will be put into class VI. The capability classes showing the limiting hazards are given in Table 2.

The land capability classification is based on dry-land farming and does not take into account wet-land crops such as rice or sago (some of the lands included in classes IV–VII which are seasonally or permanently flooded would be suitable for this type of cropping). It is based on modern agricultural methods and does not apply to shifting cultivation. It does not give a productivity rating nor does it aim at a productivity prediction for any specific crop. Finally it must be realized that the lands of the area have been classified on brief observations made during the dry season, with little or no information on wet-season conditions.

The extent of the land capability classes and their distribution are shown in Table 23. Although no land units have been rated class I, some small areas of class I land do occur on alluvial terraces within the foothill zone, and in Inaukina land system in the fluvial plains zone. However, these lands are extremely small isolated pockets. No class V land was seen in the survey area.

IV. Distribution of Land Classes

(a) *Lands of the Littoral Plains Zone*

The sandy beach ridges consist of class IV land, for the soils are liable to be droughty and saline and to have low fertility; these are found largely in Hisiu land system. The tidal flats and estuaries consist mainly of class VIII land, which is subject to tidal flooding to a greater or less extent, and little can be done with it short of large-scale engineering projects.

* Haantjens, H. A. (1963).—Land capability classification in reconnaissance surveys in Papua and New Guinea. *J. Aust. Inst. Agric. Sci.* **29**: 104–7.

TABLE 23

AREAS OF LAND CAPABILITY CLASSES, THEIR OCCURRENCES, RELATED SOILS, AND PRESENT LAND USE

Land Capability Class	Approx. Area (sq miles)	Main Occurrence and Distribution	Main Soil Group or Family	Present Utilization
I	< 5	Alluvial terraces in Inaukina land system and within foothill zone	Included in Koitaki family	Rubber nurseries and subsistence farming
II	40	Alluvial terraces in Inaukina land system and also in foothill and upland zones	Koitaki family	Rubber nurseries and subsistence farming
III	380	Levees and back plains in fluvial plains zone	Neutral families of moderately well-drained alluvial soils	Subsistence farming and coconut plantations
		Minor alluvial plains and valley flats in coastal hill zone	Dark cracking clay soils	Some subsistence farming
		Undulating terrain and gentle slopes in foothill zone	Diulu family	Rubber plantations in wetter areas
			Fairfax family	Ranching
IV	320	Foredunes and beach ridges in littoral plains zone	Grey and brown fine sands	Coconut groves and minor subsistence farming
		Levees, back plains, and raised prior channel in fluvial plains zone	Alkaline families of moderately well-drained alluvial soils group	Subsistence farming
		Lower slopes and undulating terrain in coastal hill zone	Texture-contrast soils	Nil
V	Nil	—	—	—

VI	310	Levees and back plains in fluvial plains zone, and valley flats in foothill and upland zones	Imperfectly drained alluvial soils	Some subsistence farming on levees, sago in back plains and swamp fringes
VII	1200	Ridges and steep slopes in coastal hill and foothill zones	Lithosols	Nil
		Ridges and steep slopes in upland zone	Sogeri, Uberi, Tiviki families	Rubber plantations
VIII	500	Tidal flats and salt pans in littoral plains zone	Mangrove soils and intertidal alluvial soils	Nil
		Swamps in swamp and fluvial plains zones	Very poorly drained alluvial soils	Nil
		Ridges and steep slopes in Tovobada land system	Lithosols	Nil
		Ridges and very steep slopes in upland zone	Lithosols	Nil

(b) *Lands of the Swamp Zone*

This zone mainly has class VIII land which is permanently inundated. These permanent swamps, which occur mainly in Waigani land system, are low-lying and there is little chance of draining without control of the flood regimes of the main rivers which supply water to them. Were this done, they would dry out to some extent, as is shown by back swamps affected by the 1956–57 change of course of the Angabunga River. Sago was frequently seen in the shallow-water intake areas of these swamps. The higher-lying parts of the zone are class VII land, subject to seasonal or periodic flooding; Doura and Biaru land systems are the main areas of these lands. Within Akaifu and Doura land systems are small higher levees subject to only occasional flooding and forming class III land.

(c) *Lands of the Fluvial Plains Zone*

The main hazard for land use in the fluvial plains zone is flooding, the greater part of the zone being subject to occasional seasonal floods of short duration, giving a land capability class of III. Within this zone are lower-lying and riverine areas which are subject to more frequent or longer seasonal flooding, as in Piunga land system and in parts of Bebeo and Vanapa land systems, and these have been put in class VI. Large-scale flood control would be required to raise the class of both these lands. Another possible limitation to crop production in those lands nearer the coast is the alkalinity of soils, which is possibly associated with salinity, and this may restrict the types of crops; a rice scheme near Inauabui is reported to have failed on this account. Such lands have been classified as class IV.

The alluvial soils of the fluvial plains zone have a massive structure, and their permeability may therefore decrease with cultivation; also, because of their silty or fine sandy texture, they may be liable to wind erosion during the dry season unless carefully managed.

(d) *Lands of the Coastal Hill Zone*

This zone is characterized by shallow soils on the hills and soils with slow permeability on the foot slopes and plains.

Class III lands occur on the upper foot slopes, the less stable interfluves, and the lowlands mainly in Kopu, Fairfax, Bomana Creek, and Hanuabada land systems. These lands have a moderate erosion hazard and the soils are liable to dry out for short periods. Class III lands also occur in valley flats throughout the area and in the minor alluvial plains of Boroko land system. The soils are mainly dark cracking clay soils with sticky consistence, which are too wet to cultivate in the rainy season and too dry in the dry season. They are very hard to work without heavy machinery unless cultivated when the moisture conditions are most suitable.

Class IV lands are found on the more gentle foot slopes and stable interfluves where texture-contrast soils occur. Texture-contrast soils which are the main soils of Nikura, Ward, and Ouou land systems have a massive, compact, light-textured A horizon which passes abruptly into a heavy-textured B horizon. This combination results in low permeability and high run-off, as well as poor drainage during the wet season. Rooting may be restricted to the A horizon, resulting in droughty conditions during the dry season as suggested by the wide tussock spacing of grasses on these soils. A further limitation of these soils would be difficulty of working due to their compactness in the dry season and to poor drainage in the wet. Finally, should the A horizon be disturbed, these soils are very liable to erode, as shown by badlands formed about old footpaths in Nikura land system. For all these reasons, soils are only marginal for cultivation.

Class VII and VIII lands occur on the ridges, with class VIII land mainly in Tovobada land system and more locally elsewhere. The main limitations of these lands are their steepness and their shallow soils, many of which are stony. Such limitations preclude class VIII land from productive land use, and they are best left alone. The class VII land would be suitable only for limited natural pasture, with strict control against erosion.

(*e*) *Lands of the Upland Zone*

This zone consists mainly of class VII land, the main limitation being the erosion hazard on steep slopes. Areas of class VIII land occur on the steepest slopes, with an added limitation of being very stony.

On the undulating plains and river terraces in this zone are very small but important areas of class II land with a slight erosion hazard. Another limitation of this zone may be low fertility of heavily leached soils under high rainfall.

(*f*) *Lands of the Foothill Zone*

This zone has been left to last as it is intermediate between the coastal hill and upland zones, which transitionary character is expressed in the soils.

In the central foothills, small areas of class II land occur on river terraces in Kanosia and Aropokina land systems, and class III land is found on the undulating terrain of both Diulu and Kanosia land systems. These lands are limited by slight erosion hazards, while those in Diulu land system have the added limitation of being droughty for short periods. Class IV lands with texture-contrast soils are also found on plains in Kanosia land system. Class VII lands occur on steep slopes in Aropokina land system, the eastern part of which has the additional limitation of shallow soils.

In the southern foothills, the main lands are class VII, limited by steep slopes and shallow soils.

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Fig. 1.—Littoral plains zone. The survey area contains six partly discontinuous environmental zones parallel with the coast. The littoral plains zone, embracing 200 sq miles, consists of beach ridges, tidal flats, and estuaries. This aerial view is of lower-lying mangrove flats of Galley Reach land system in the foreground, with mid-height evergreen forest of *Rhizophora* and *Bruguiera*, and meandering tidal creeks. Behind are the complex mangrove and salt flats of Kido land system fronting Redscar Bay, traversed by light-toned stranded beach ridges.

Fig. 2.—Littoral plains zone. *Rhizophora–Bruguiera* mangrove below high-water mark in Galley Reach land system, with prominent crab-built mounds on grey loamy peats.

Fig. 1.—Littoral plains zone. Mangrove flats near the upper limit of the tides, with open low evergreen forest of *Avicennia*, typical of Lesewalai land system.

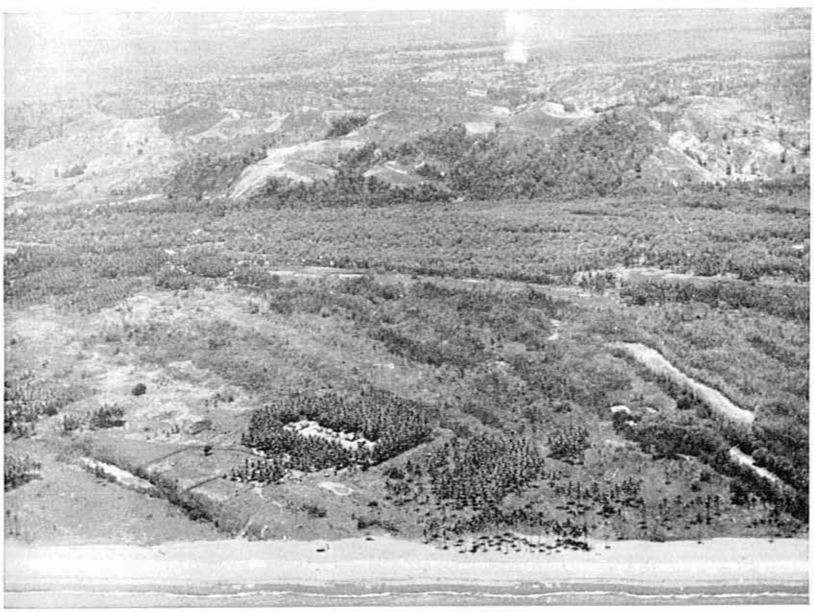

Fig. 2.—Littoral plains zone. The sandy beach ridges of Hisiu land system are here truncated by the coast, and there are tidal flats in some swales. Waima (lower left) is a typical coastal village of the north of the area, with coconut groves and adjacent gardens; little of the original coastal thicket remains. Behind the beach ridges is the inner mangrove of Lesewalai land system, backed by cliffed hill slopes of Palipala land system.

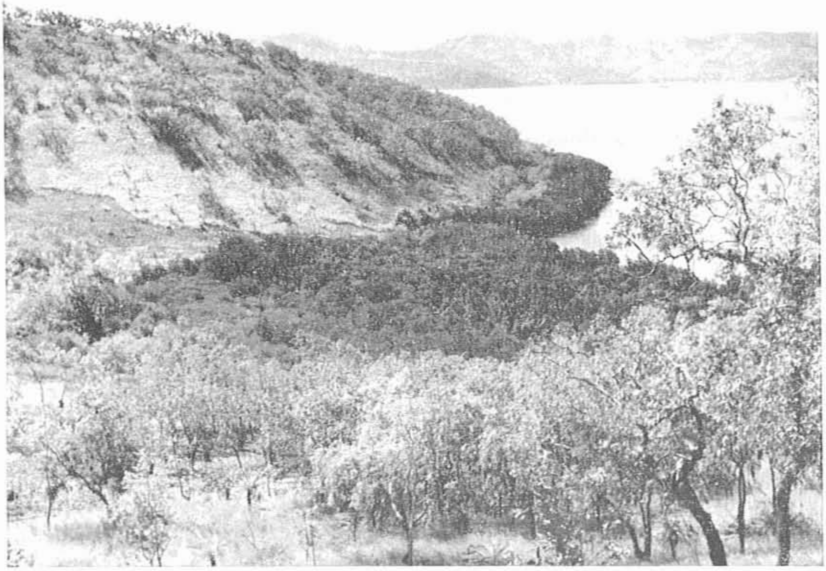

Fig. 1.—Coastal hill zone. The coastal hill zone, 700 sq miles in extent, consists of ridges, mainly of cherty limestone, lowlands on softer sedimentary rocks, and minor alluvial plains. The zone has extensive eucalypt savannah and derived grassland. This view is of coastal ridges of cherty limestone in the south of the area, mapped as Hanuabada land system, with stony slopes with alkaline dark lithosols. In general, the coasts are here rocky and steep, with mangrove flats and sandy beaches of Papa land system in small embayments.

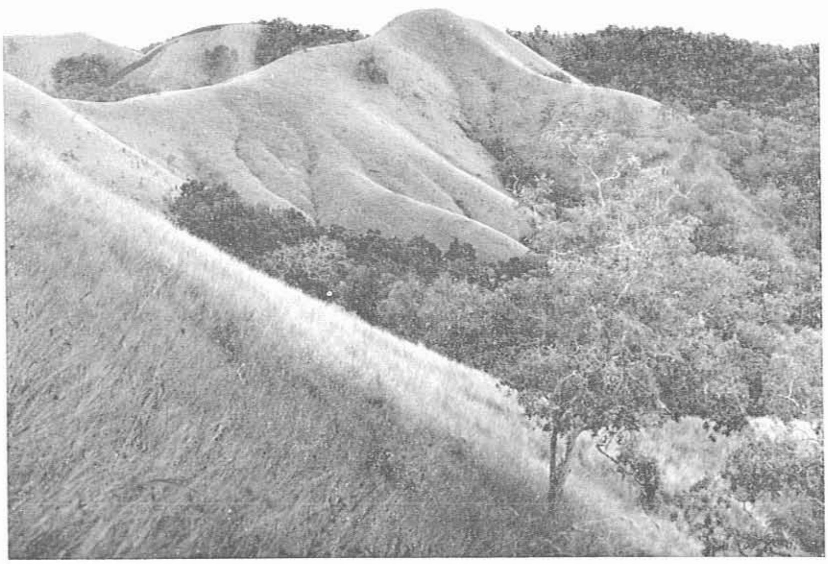

Fig. 2.—Coastal hill zone. Tovobada land system, in the southern hills north of Port Moresby, has areas of strongly deciduous forest (*Bombax–Celtis*) and derived grassland. Limestone and chert form the main crests, with interbedded mudstone which is subject to slumping on steep valley sides.

Fig. 1.—Coastal hill zone. Eucalypt savannah of the coastal hill zone is much influenced by burning in the dry season, and *Cycas* is typical of such areas. Stony hill slopes of moderate steepness are characteristic of the zone.

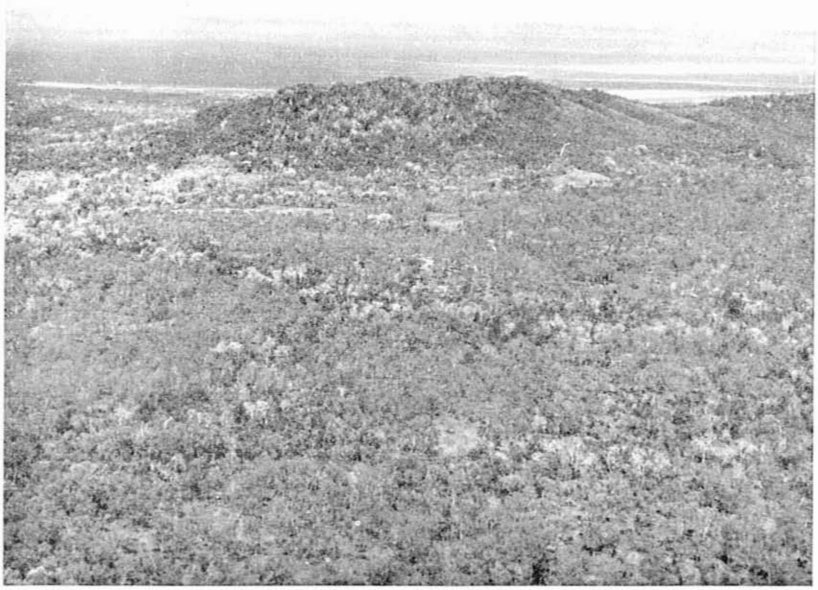

Fig. 2.—Coastal hill zone. Broadly undulating lowlands of Nikura land system in the central hills sector, with eucalypt savannah and semi-deciduous thicket on low interfluves and strongly deciduous forest in the valleys. On the coastal margin are limestone ridges of Pokama land system, covered with deciduous forest.

Fig. 1.—Coastal hill zone. The minor alluvial plains in the south of the coastal hill zone, with dark cracking clay soils and large areas of *Saccharum robustum–Imperata* tall grassland, have been mapped as Boroko land system.

Fig. 2.—Swamp zone. The swamp zone covers 350 sq miles and comprises areas of permanent and seasonal standing water and periodically flooded plains. This view is of the permanent swamps of Waigani land system, with *Phragmites–Saccharum robustum* tall grassland and floating herbaceous vegetation. Swamp grassland patterns commonly show signs of former channels and meander scrolls.

Fig. 1.—Swamp zone. Seasonal swamps have extensive mid-height evergreen forest with *Melaleuca* and *Nauclea* as shown here in Doura land system. The wetter areas, including oxbows, have herbaceous vegetation.

Fig. 2.—Fluvial plains zone. The fluvial plains zone, with an area of 550 sq miles, has been formed by large perennial rivers from the uplands. Large parts of the more stable plains are grasslands, as typified by this view of Keviona land system in the Aroa plains, with *Ophiuros–Themeda australis* mid-height grassland dotted with termite mounds.

Fig. 1.—Fluvial plains zone. Tall grassland (*Saccharum spontaneum–Imperata*) is typical of Epo and Bebeo land systems in the northern plains of this zone.

Fig. 2.—Fluvial plains zone. The southern plains have extensive tall evergreen and slightly deciduous forest, as shown here in Vekabu land system, between the Brown and Vanapa Rivers. This is the chief area of timber extraction, and roads are being extended through it.

Fig. 1.—Fluvial plains zone. The unstable flood-plains have been mapped in Vanapa land system. This view of the Angabunga River is characteristic of the large meandering channels, with point bars, meander scrolls, and forested levees, and with a cut-off meander at top right. Inawi (foreground) is a typical large Mekeo village of the northern plains.

Fig. 2.—Fluvial plains zone. Tall evergreen forest with *Octomeles* and *Kleinhovia* on levees and *Saccharum robustum* on river banks is characteristic of Vanapa land system.

Fig. 1.—Foothill zone. The foothill zone (350 sq miles) is transitional between lowlands and uplands. This view of the gabbro ridges of Rouna land system in the southern foothills shows the change from savannah in the drier western part to increasing forest cover on the higher ridges further inland.

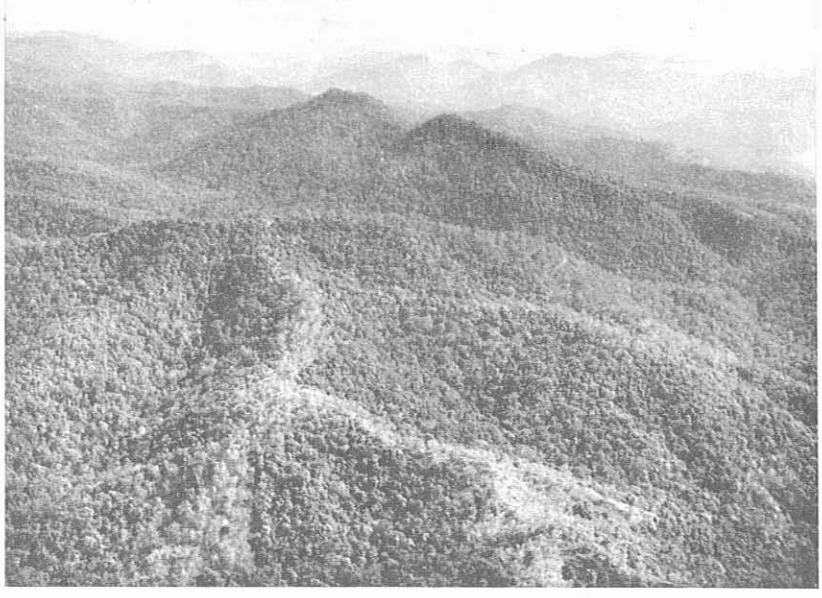

Fig. 2.—Upland zone. The upland zone, 650 sq miles in extent, has between 60 and 150 in. annual rainfall, and is extensively forested. These high phyllite ridges of Iawarere land system in the south backing ranges have tall evergreen forest.

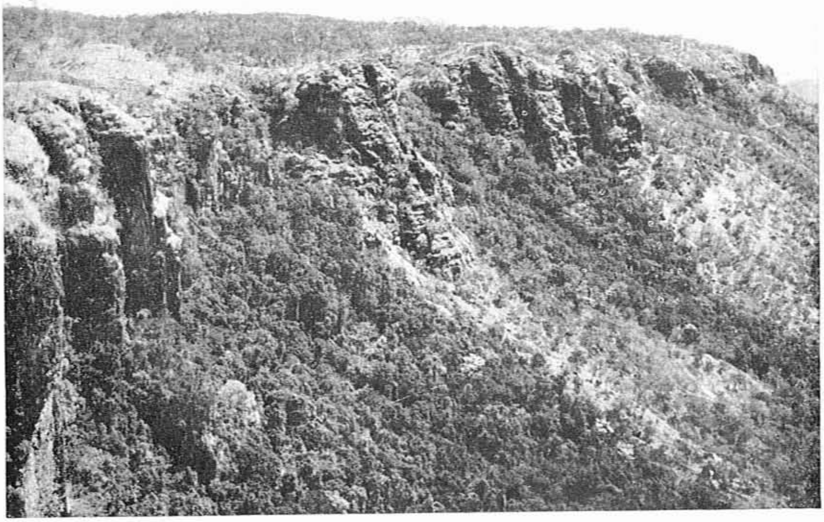

Fig. 1.—Upland zone. Much of the upland zone is formed by flat-lying agglomerate, seen here in the bluffs of the Sogeri Plateau. Tall evergreen forest is here restricted to valley heads; elsewhere there is eucalypt savannah, both on the escarpment and on the low hills of Sogeri land system on the plateau surface.

Fig. 2.—Indigenous agriculture. Indigenous agriculture in the area is mainly of the shifting cultivation type, in which partial forest clearings are burned, leaving tree stumps and many logs, and small plots are fenced against pigs. Crops are planted haphazardly, mainly with the digging stick, with little cultivation of the soil. The food crops shown here are taro, bananas, and sugar-cane.

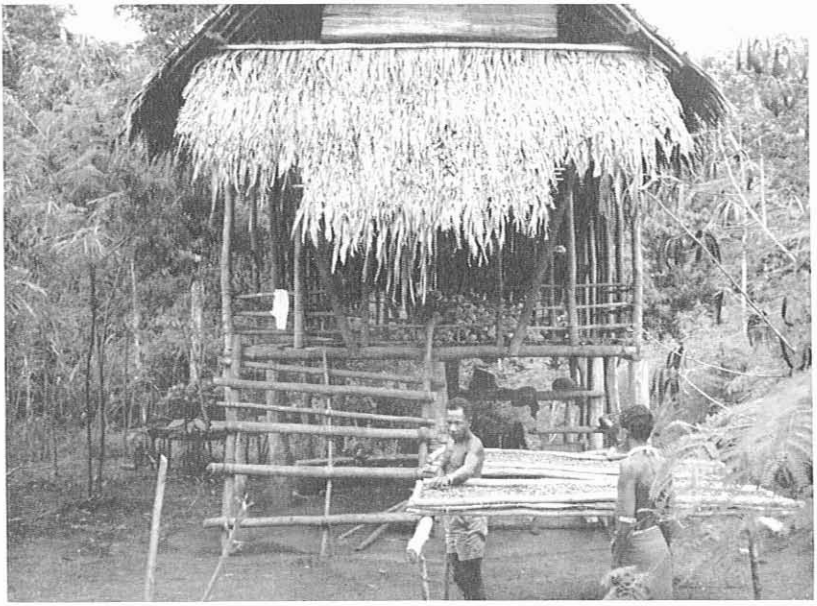

Fig. 1.—Indigenous agriculture. Cash crops, grown by indigenes on a small scale in the area, include coffee, cocoa, betel nut, and staple food crops sold on the Port Moresby market. This view of drying cocoa beans is from Inawauni, where forest clearing and planting of cocoa have been a communal enterprise under encouragement by the local agriculture officer.

Fig. 2.—Plantation agriculture. Rubber plantations worked by indentured labour from the highlands are extensive on acid red to brown clay soils in the upland zone, on the Sogeri Plateau and inland from Galley Reach, mainly in areas with more than 60 in. rainfall. Clearing and terracing in preparation for planting of rubber are shown here in Owers land system, on the Sogeri Plateau. Plantation roads are easily cut in the deeply weathered volcanic rocks. The forested high ridges in the background are part of Uberi land system.

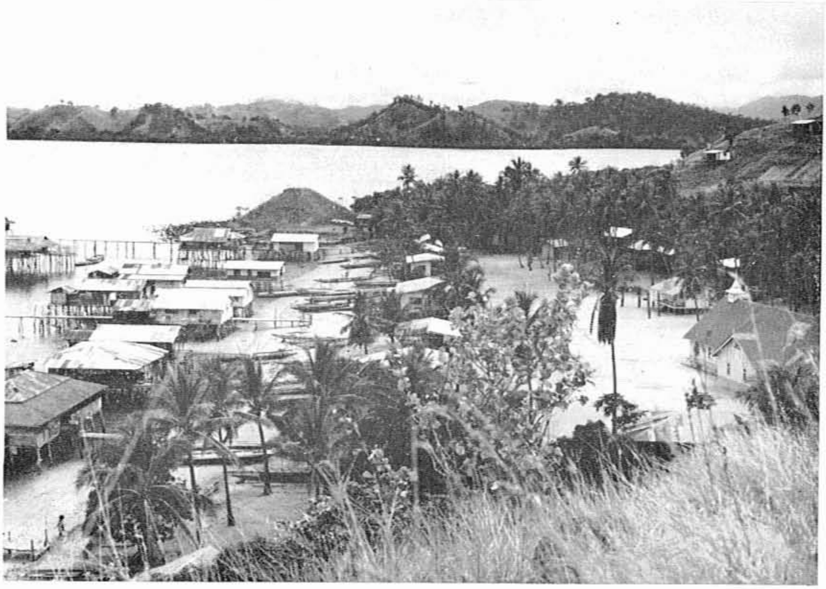

Fig. 1.—Settlement. The indigenous population of the survey area, excluding Port Moresby, numbers 40,000. Most of the villages are on the coast, on restricted littoral plains in the south, as at Tupuselei (above), or on border plains of Hisiu land system in the north.

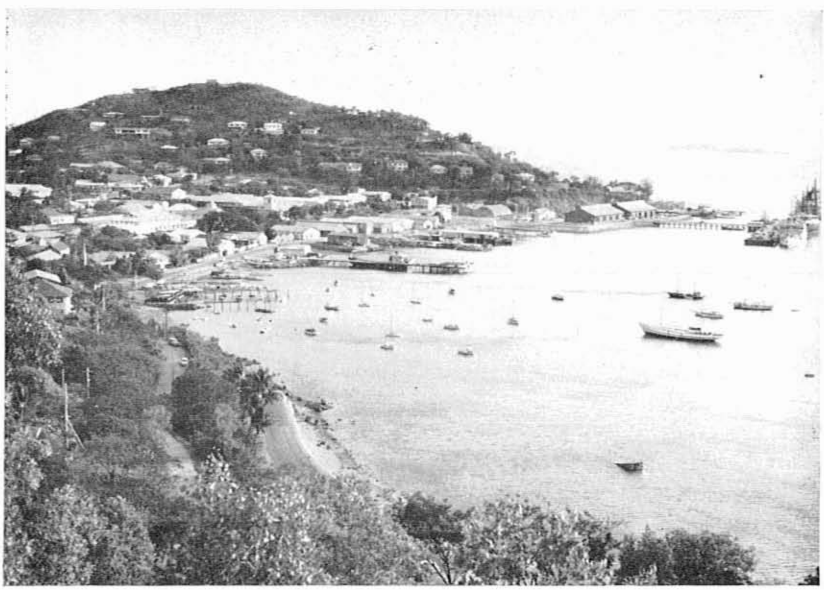

Fig. 2.—Settlement. Port Moresby, with 23,000 indigenes and 5900 non-indigenous inhabitants, is the centre of administration in the Territory of Papua and New Guinea, the main commercial centre of Papua, and the main port linking the Territory with Australia by sea and air.