Lands of Bougainville and Buka Islands, Territory of Papua and New Guinea

Comprising papers by R. M. Scott, P. B. Heyligers, J. R. McAlpine, J. C. Saunders, and J. G. Speight

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MAPS

PART I. INTRODUCTION

By J. R. McAlpine*

I. General

The large island of Bougainville and the adjacent Buka Island, together with a number of small islands and outlying atolls, form Bougainville district, the most easterly administrative district of the Territory of New Guinea. This land resources survey covers the area shown in Figure 1, on which administrative divisions and towns are marked.

II. History

A sixteenth-century expedition under Mendana made the first European discovery of the central Solomon Islands. Bougainville and Buka Islands were not sighted until 1768, during Bougainville's exploration. From then until the beginning of the twentieth century, the only European contact with the islands was made by traders in the late nineteenth century.

A German Protectorate was proclaimed over Bougainville and Buka Islands in 1884, thus separating them politically from the remainder of the Solomon Islands group which became a British Protectorate. A Catholic mission was established on Bougainville in 1902, and this was followed by the introduction of a German Government post at Kieta in 1905. During the period of the German administration prior to World War I, the development of Australian-owned plantations commenced, notably Choiseul Plantations Limited.

The conclusion of the war saw control of the islands pass to Australia through the League of Nations' mandate covering the Territory of New Guinea. Subsequently, there was a considerable expansion of Australian-owned plantations, and further government stations at Buka Passage and Buin were opened. By the commencement of World War II, administrative influence had spread to all but the most isolated pockets of settlement.

The Japanese gained control of the islands during the war but had little chance to consolidate their administration. When the Australian administration was reinstated after the war, Bougainville district headquarters were moved from Kieta to Sohano.

III. Communications

The islands possess four separate road networks with numerous interspersed or unconnected smaller roads usually associated with plantations or cash cropping (Fig. 2). At this date, only the Buka Island and Kieta coastal roads are hard-surfaced. Total road mileage for the islands is given as 618 miles (Anon. 1964).

The most important ports are Kieta and Buka Passage–Soraken, with numerous minor anchorages and wharves concentrated particularly on the north-east coast of

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Fig. 1.—Bougainville district administrative divisions.

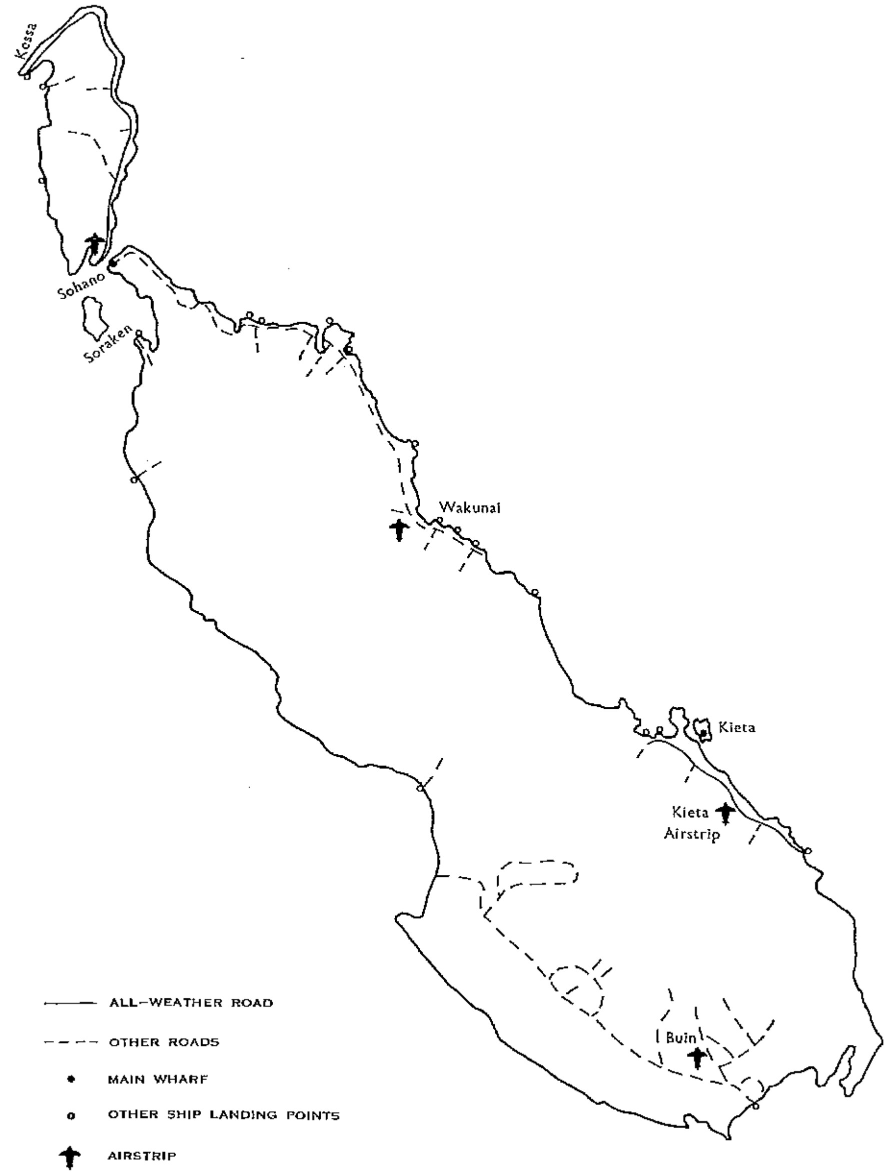

Fig. 2.—Communications on Bougainville and Buka Islands.

the island. These ports are served by frequent small ship services to Rabaul and a six-weekly service by larger vessel to Sydney.

Aircraft communications consist of three services a week linking all the airstrips around the island with Rabaul. An additional weekly service direct to Rabaul and the British Solomon Islands Protectorate operates via Buka Passage airstrip only.

Existing communications are oriented to non-indigenous plantations and administrative centres. Increasing growth of cash cropping is causing an extension inland of this network. Elsewhere internal communications are by walking track.

The three major gazetted towns on the island are Sohano, Kieta, and Buin. Sohano (non-indigenous population 177 in 1961 (Anon. 1964)), the administrative headquarters of Bougainville district, is on a small island in Buka Passage and is closely linked with the trading, mission, airport, and local administrative settlements flanking the north of the passage. Kieta is the main port for southern Bougainville and is the subdistrict headquarters for the south-east region. Buin is situated eight miles inland and is the subdistrict headquarters for the south-west region of Bougainville. The combination of Wakunai patrol post and Numa Numa plantation on the central eastern coast forms the next largest settlement on Bougainville.

IV. Survey Procedure

The object of the survey was the mapping and description of the lands of the islands at reconnaissance level by a pedologist, plant ecologist, forest botanist, and geomorphologist working in collaboration. The basic descriptive unit is the land system, which provides data for an assessment of the potential of the area and recommendations on further research. The general procedure for carrying out these surveys in New Guinea has been covered by Haantjens (1961).

Prior to the commencement of the survey, detailed air-photo interpretation and preliminary mapping were completed. Field sampling was carried out between mid July and mid September 1964, using a helicopter, with boat and motor vehicle where necessary. Typical sampling areas suitable for investigation within each preliminary land system were selected during the photo interpretation. In practice, only 10% of these chosen areas could not be sampled or a satisfactory substitute area found in the field (Fig. 3). For reasons beyond the control of the survey party no ground observations were made in the Boku area, but, as elsewhere throughout the survey, considerable information was collected by low-level flights alone.

The survey was carried out by the authors of this report, with Mr. R. M. Scott as leader. Additionally, Messrs. R. Schodde and L. Craven made a separate botanical survey in the Buin area. Captains G. Treatt and P. Hurst, with Messrs. N. Phillips and R. Harris, engineers, of Helicopter Utilities Pty. Ltd., flew and maintained the helicopter during the survey. Twelve assistants from Madang district under Gabi-Momo provided all other field and camping assistance.

V. Air Photos and Maps

The area surveyed was mostly covered by R.A.A.F. air photographs at varying scales ranging from 1 : 60,000 to 1 : 73,000 (at sea level) taken during July 1962.

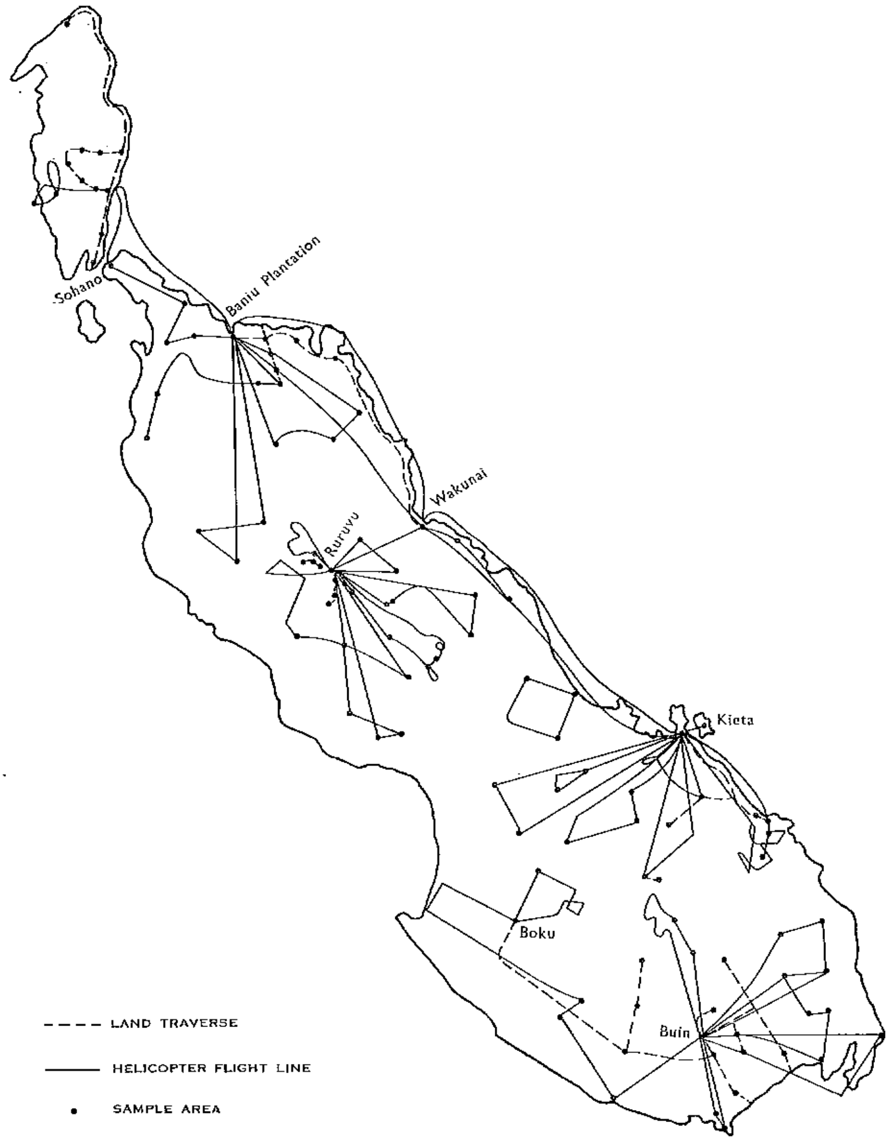

Fig. 3.—Sample areas and traverses.

With two small exceptions, the gaps in this photography were covered by wartime photography.

The base map was prepared by the Division of National Mapping of the Department of National Development, from the Australian Army Survey Corps maps of Bougainville Island North and South 4-mile series, published in July 1945.

The area is also covered by Army Survey Corps maps (now out of print) at a scale of 1 in. to 1 mile with contour and form lines. The index to these maps is shown as an inset on the land system map.

VI. Acknowledgments

The survey was financed by the Administration of the Territory of Papua and New Guinea, through the Department of Territories, Canberra. The prompt and essential cooperation given to the survey party by the Bougainville district administration staff, under District Commissioner P. Mollison, is gratefully acknowledged, as are the accommodation and facilities made available during part of the survey by Mr. K. Turtle of Baniu plantation, through Choiseul Plantations Limited.

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

VII. References

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PART II. GENERAL DESCRIPTION OF BOUGAINVILLE AND BUKA ISLANDS

By J. G. Speight* and R. M. Scott*

I. Introduction

Bougainville and Buka Islands lie between lat. 5°S. and 7°S. in the western Pacific Ocean east of New Guinea, and form the northern extremity of the Solomon Islands archipelago. The two islands, separated by Buka Passage, a strait only half a mile wide, together comprise an independent land mass 150 miles long and 40 miles wide with a north-westerly orientation. The total area is 3475 sq miles including 5 sq miles of lakes.†

The islands have high relief and are dominated by three separate clusters of volcanic cones (Plates 1 and 2), culminating in the dormant volcano Mt. Balbi, 8500 ft high, and including the active Mt. Bagana. Nearly half of the land area consists of hills (Plate 4, Fig. 2) or mountains (Plate 5) with straight slopes that vary from steep to precipitous. The major plains (Plate 8, Fig. 1), formed of volcanic materials distributed by rivers, have quite high gradients, especially at high altitudes (Plate 3, Fig. 1). Their seaward margins (Plate 9, Fig. 1) are subject to frequent flooding and they commonly terminate in swamps (Plate 10) impounded behind sandy beach ridges (Plate 11, Fig. 1). The plains of Buka Island and the north coast of Bougainville, however, are the reef flats and lagoon floors of an uplifted coral reef (Plate 12).

The landscapes of Bougainville and Buka are essentially the product of four influences—climate, geological history, Recent volcanism, and human activity. The land forms, soils, and vegetation have all been affected by them and they determine both the present pattern of land use and the land use potential.

II. Climate

(a) General

The climate is of wet tropical or tropical rain forest type and is markedly equable. Annual rainfall is 132 in. on the southern coast, but only 105 in. on the northern coast where rainfall is reduced during a period of south-easterly winds from May to November. Mean annual temperature at sea level is 80°F and the variation of monthly means is only 3 degF, although the diurnal temperature range is 13 degF. Temperature probably decreases with altitude at a rate of about 3·5 degF per 1000 ft. Cloudiness increases with altitude and varies little through the year. Relative humidity

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† These areas are based on dot-gridding of the base map and represent a more reliable determination than the figure of 4100 sq miles for the Bougainville district (including about 75 sq miles of distant atolls) given in the annual reports of the Territory of New Guinea. This figure appears to be based on older, less accurate charts.

diverges very little from 80%, and potential evapotranspiration exceeds precipitation only occasionally.

(*b*) *Effect on Land Forms*

The land forms of the area show the influence of high rainfall and temperature in the deep incision of streams and the uniformly steep erosional hill slopes produced by intense weathering, landsliding, and stream transport. The persistent rainfall also interacts with volcanism in mobilizing unstable deposits of debris to form volcanic mud flows that have been the major mechanism producing the long flanking slopes surrounding extinct and dormant volcanoes.

(*c*) *Effect on Vegetation*

Vegetation generally is not subject to water stress, and variation of temperature rather than rainfall produces variation in vegetation type. Three of the major environments are distinguished on this basis:

(1) Better-drained lowlands.—A zone from sea level to 2000 ft in which conditions for tropical rain forest are approaching their optimum and *Vitex–Pometia* tall forest is regarded as the climax vegetation.

(2) Lower mountain environment.—A zone from 2000 ft to 4000 ft above sea level in which *Garcinia–Elaeocarpus* mid-height forest is the climax vegetation (Plate 3, Fig. 1; Plate 5).

(3) Upper mountain environment.—A zone above 4000 ft, shrouded in clouds for part of almost every day, that has a *Gulubia–Pandanus* "mossy forest" vegetation (Plate 2, Fig. 2).

(*d*) *Effect on Soils*

No significant variation in the soils appears to depend on climate but rapid leaching and rapid weathering of parent materials occur generally.

(*e*) *Effect on Present Land Use*

The high yield of the main plantation crops of the area, copra and cocoa, in comparison with other districts may result in part from the lack of seasonality. These are also the main indigenous cash crops, but arabica coffee has also been introduced at higher altitudes. Subsistence crops, determined at least partly by climate, include taro, yam, banana, sweet potato, sugar-cane, papaw, edible pit-pit, bread-fruit, coconut, and cassava. The lower temperature at higher altitudes permits some European vegetables to be grown. Subsistence crops may be planted at any time of the year, thus eliminating the need to grow a surplus for storage.

(*f*) *Effect on Potential Land Use*

The climate is favourable for optimal plant growth throughout the year, but the absence of a dry season may be a limiting factor for some crops. The natural forest has no yield potential above 4000 ft.

High soil moisture content is a hazard for engineering works, including the construction of roads.

III. Geological History

(a) General

The geology of the area reveals a history of andesitic volcanism, not markedly different from that of the present day, extending back to the Palaeogene period or earlier. The dominant rocks are andesites, tuffs, and volcanic sandstones, into which diorite has been intruded in some areas. Andesitic agglomerate is important locally as a scarp-forming cap-rock (Plate 6, Fig. 1). Two periods of coral reef building are recorded in the Lower Miocene limestone of the Keriaka Plateau (Plate 4, Fig. 1) and the Middle Pleistocene limestone of the Buka raised reef (Plate 12, Fig. 2).

Continuing tectonic instability has caused upwarping of parts of Buka Island through nearly 300 ft during Upper Pleistocene time, and more severe deformation of older rocks during the time since their deposition.

(b) Effect on Land Forms

Tectonic instability has produced both a very high relief and a high rate of erosion and deposition. Most of the plains of the area are volcano alluvial plains and they characteristically show a downstream sequence from steeper relict plains, now dissected (Plate 8, Fig. 1), through gentler plains at present being flooded and built up by alluviation (Plate 9, Fig. 1), to coastal swamps impounded by beach ridges (Plate 10, Fig. 1; Plate 11, Fig. 1). The Pleistocene raised reefs in the north are virtually unmodified since their uplift, presenting a landscape of escarpments, plains, and undulating depressions inherited from the time of coral growth (Plate 12).

(c) Effect on Vegetation

Apart from the wide climatic variation resulting from very high relief, vegetation is affected by the foregoing only through the continuing existence of large areas of poor drainage and swamps, which form a distinct ecological environment. Stagnant swamps are covered with *Leersia–Hanguana* mixed herbaceous vegetation (Plate 10, Fig. 1) or *Phragmites–Saccharum* tall grassland, except in the centre of larger swamps where *Lycopodium–Gleichenia* mixed herbaceous vegetation is found. Areas under permanently flowing water, or frequently flooded, are covered by *Terminalia brassii–Campnosperma* open tall forest (Plate 10, Fig. 2). Tidally flooded areas have mangrove of *Rhizophora–Bruguiera* mid-height forest.

(d) Effect on Soils

Limestone, the only parent material significantly different chemically from andesite, has given rise to terra rossa soils on Buka Island and to rendzinas on recently exposed littoral platforms. Soils other than ash soils, ash-covered soils, and limestone soils are strongly influenced in these evolving landscapes by the relative stability of the site. On certain stable sites acid clay soils have developed, but many dry land sites are so unstable that lithosols result. Inundated sites have juvenile soils with little profile development—swamp peats, swamp soils, mangrove soils, and alluvial soils.

(*e*) *Effect on Present Land Use*

Subsistence agriculture is not greatly limited by the prevailing steep slopes except in the most rugged areas, but poorly drained areas are avoided. Plantations have been located on flat or gently sloping well-drained land, particularly on parts of the east and north coasts of Bougainville where erosion, tectonism, and coral growth have produced sheltered anchorages (Plate 11, Fig. 2). Indigenous cash crops have been planted on similar land, but often in restricted sites with poorer access (Plate 8, Fig. 2).

(*f*) *Effect on Potential Land Use*

Well-drained, gently sloping, or flat land of high agricultural potential occurs over 25% of the land area of Bougainville and Buka Islands, on volcano–alluvial fans and raised coral reef. This is an unusually high proportion for the Territory but the various areas of high potential are separated by rugged hills and river gorges that will make the maintenance of communications difficult and costly.

Ease of access has been assessed in detail with reference to forestry; 53% of areas classified as forested occur on either rugged terrain or swamps that render exploitation difficult or impossible. A valuable forest type, *Terminalia brassii* forest (Plate 6, Fig. 2), is associated with stream margins in landscapes of diverse character.

IV. Recent Volcanism

(*a*) *General*

Recent lava flows are confined to the neighbourhood of the major volcanic peaks, those of Mt. Bagana being the only ones that have been active in historic times. Hot ash flows have frequently devastated areas at the foot of Mt. Bagana, extending some miles towards the coast, and Mt. Balbi is reputed to have produced a similar flow in the nineteenth century. Volcanic mud flows are apparently carried by the streams radiating from Mt. Bagana at times of more intense activity. All these phenomena are localized near volcanoes, but there are at least seven volcanoes that cannot be considered extinct and each has its areas of hazard.

Volcanic ash deposition has been very widespread, even ubiquitous, in the area. A mantle of ash covers all landscapes except those at the northern and southern extremities and those of rapid morphological activity, such as precipitous slopes and flood-plains. Light ash showers from Mt. Bagana occur occasionally today.

(*b*) *Effect on Land Forms*

Apart from the local activity of lava flows, avalanches, ash flows, and lahars on Mt. Bagana, and the construction of a braided volcano–alluvial plain at its foot (Plate 9, Fig. 2), the main morphological effect of Recent volcanism is by way of the widespread ash mantle. This porous sheet, commonly 2 or 3 ft thick, has radically altered the slope processes by the absorption of surface run-off, leading to a phase of unusual slope stability that may continue until the ash weathers to a less permeable state.

(c) *Effect on Vegetation*

When existing vegetation is destroyed by volcanic eruption it is replaced by pioneer vegetation followed by successional types. The occurrence of several minor eruptions since pre-historic major eruptions has produced a pattern of pioneer vegetation localized near the vents of Mts. Balbi and Bagana (Plate 1) and more widespread successional types such as *Cyathea–Bambusa* scrub further away (Plate 7, Fig. 1).

(d) *Effect on Soils*

Soils related to volcanic ash have been classified as "ash soils" and "ash-covered soils" depending on the thickness of the ash.

Approximately half of Bougainville Island is covered by ash soils, which show little profile development apart from a dark humic surface horizon and are deeper than 3 ft or overlie rock at lesser depths. Buried humic horizons are common, showing the intermittent nature of the ash falls. The ash soils have been separated into four families, grey fine sands, brown loams with lapillitic horizons, brown loams, and brown loams with an ash pan. The youngest and least developed are the grey fine sands that occur on the gentler slopes round the volcanoes of Balbi and Bagana. Adjacent to these very recent ashes of Bagana are the brown loams with lapillitic horizons, which are the predominant soils of the uplands of central Bougainville. In most of the hilly and mountainous country of both north and south Bougainville the predominant ash soils are the brown loams, but these are of minor importance in highly dissected terrain (Plate 5, Fig. 2). Brown loams with an ash pan are mainly confined to the flat or gently sloping lands on the volcano–alluvial fans of south Bougainville (Plate 3).

Ash-covered soils, which normally lie on the periphery of the ash soils, have an ash mantle less than 3 ft thick and overlie soils of a former land surface. The ash mantle, with its dark organic topsoil, appears to vary only in depth so the soils have been separated on the nature of the buried soils—alluvial sands, acid clay soils, and terra rossa soils. Brown loams over sands occur on well-drained, high-lying alluvial plains (Plate 8, Fig. 2); brown loams over brown friable clays are found on the Parkinson Range of Buka Island and the northernmost low coastal hills of Bougainville; brown loams over reddish friable clays are mainly confined to the volcano–alluvial fans and low hills in the Kunua, Teop, and Nasioi census divisions; brown loams over reddish plastic clays occur on the uplifted coral platform on Bougainville.

(e) *Effect on Present Land Use*

Except in areas at present devastated it is difficult to detect any direct relation between volcanism and current land use.

(f) *Effect on Potential Land Use*

No great degree of fertility appears to be associated with soils developed on Recent ash except in the topsoil; possibly some degree of weathering is necessary to make nutrients available to plants. The hazard associated with volcanic eruption depends largely on the (at present unpredictable) future activity of active and dormant volcanoes. In areas away from the immediate vicinity of volcanic vents the main dangers are "glowing cloud" ash flows and lahars. The former threaten any points downslope from a vent, while the latter, though they extend further, are mainly confined to stream valleys.

V. Culture

(a) *General*

At the present time (1963–64), the total population is approximately 62,500 and is increasing at almost 3% per annum. The overall population density is 17 persons per sq mile but much of the land is completely unoccupied, being compensated for by areas of local density up to 300 persons per sq mile on the north-east coast of Buka Island and areas of comparable density on the Buin plain. The non-indigenous population is only 438.

The Melanesian indigenes belong to a number of different cultural groups, as indicated by the existence of 19 regional languages. Each group tends to be concentrated in a compact area and separated from others by unoccupied tracts. This is not to say that such land is unclaimed; virtually all land is "owned", often by more than one group. The main occupation is subsistence cultivation using a system of bush fallowing. Apart from food crops, domestically raised pigs and fowls and wild life also form part of the indigenes' diet. On coral coasts sea foods are of major importance. Recently, cash cropping has become significant, and the use of pidgin as a lingua franca has led to wider social intercourse.

The small non-indigenous population is engaged in administration, missions, and commerce, the last largely concerned with large plantations serviced from the sea (Plate 11, Fig. 2). Four separate road networks exist, but only two major roads are hard-surfaced. There are four aerodromes, each suitable for the operation of DC3 aircraft. Little trace now remains of the aerodromes, roads, buildings, and fortifications built by Japanese and Allied forces during World War II.

(b) *Effect on Land Form*

Indigenous culture has had practically no effect on land form and the effects of European culture have been minimized by the use of the sea for communications. Noteworthy structures such as dams and highways are absent, aerodromes being the most conspicuous land form modifications.

(c) *Effect on Vegetation*

In better-drained lowland areas human disturbance of the vegetation is severe, resulting in widespread secondary vegetation. *Althoffia–Cyathea* young secondary forest and *Artocarpus–Albizia* secondary forest are the most important older stages in regrowth. On Buka Island regrowth dominated by the wild banana—*Musa–Heliconia* tall herbaceous regrowth—is a conspicuous type. Human disturbance is slight in the lower mountain environment and negligible in the upper mountain and swamp environments.

(d) Effect on Soils

No human influence on soils has been seen. The practice of bush fallowing appears to have been adequate protection against soil erosion at the present intensity of cultivation.

(e) Effect on Present Land Use

Within the area it occupies, each cultural group tends to use particular land form facets. The facets most used on Buka Island are the former reef flats (Plate 12, Fig. 2); in northern Bougainville they are ridge crests and upper hill slopes (Plate 7, Fig. 2); in the Buin plain area, plains or plateaux (Plate 3, Fig. 2); in Kieta subdistrict, hill slopes (Plate 4, Fig. 2); and in central Bougainville, low emerged coral platforms, beach ridges, and terraces. About 200 sq miles (approx. 6% of the area) are currently used for subsistence agriculture.

Cash cropping by the indigenes is dispersed and closely associated with the subsistence cultivation (Plate 8, Fig. 2). The main crops are coconuts (24,000 ac) and cacao (5000 ac), and the acreages of these are rapidly increasing. Non-indigenous plantations occupy about 50 sq miles, mainly on the eastern coast of Bougainville. Plantation production is confined to coconuts (32,777 ac) and cacao (18,443 ac), normally interplanted.

(f) Effect on Potential Land Use

Despite the fact that subsistence cultivation does not require land that is of high potential in terms of mechanized commercial agriculture, there is nevertheless a high population density on nearly all land of high potential. Certain areas of good land near Boku and Numa Numa appear relatively free of population; so does the interior of Buka Island, but there the heavy and increasing coastal population may well need the land in the near future for subsistence and particularly for cash cropping. Land already alienated for non-indigenous plantations takes up a large proportion of the remaining good land.

Potential land use for forestry and mining will depend not only on the actual resources present, but also on indigenous property rights and cultural attitudes.

PART III. LAND SYSTEMS OF BOUGAINVILLE AND BUKA ISLANDS

By R. M. Scott,* P. C. Heyligers,* J. R. McAlpine,* J. C. Saunders,* and J. G. Speight*

I. Introduction

For the purpose of the resources survey the islands of Bougainville and Buka have been divided into 40 land systems, which were defined originally by Christian and Stewart (1953) as "areas, or groups of areas, throughout which there is a recurring pattern of topography, soils, and vegetation". Most of the land systems of the survey come within the category of *simple land systems*, each of which is further defined as "a group of closely related topographic units, usually small in number, that have arisen as the products of a common geomorphological phenomenon. The topographic units thus constitute a geographically associated series and are directly and consequentially related to one another".

Land units, the component parts of a land system, within which there is a particular association of topography, soil, and vegetation, may vary in complexity (Christian 1958) according to the selected scale and degree of generalization. In the present survey it has been possible, with some exceptions, to set up land units that are analogous to "sites" as defined by Bourne (1931), being associated with land form elements such as slopes and flats rather than with land forms.

The scope of land systems, recognized in the first instance as distinctive air-photo patterns, is such that they may serve to classify different kinds of hills, plains, coasts, etc., while the land units of this survey include such categories as ridge crests, hill slopes, and flood-plains. The land systems mapped range in area from 355 sq miles down to 10 sq miles. In some land systems it has been possible to make a simple division between ridge crest and hill slope land units; in others the relations between units are more complex, and certain distinctive land forms such as lava flows and dolines have not been broken down to more elementary components.

This report goes beyond earlier reports in the Land Research Series in quantification and categorization of terrain information within the framework of the land system and land unit concepts. Terms and parameters used in land system descriptions have been rigorously defined so as to express the results of the survey in a form of more direct value to those engaged in planning operations of broad scope, particularly in the fields of civil or military engineering. An explanation of all terms and parameters is given in Appendix I.

The sequence of land systems on the following pages, as well as in the reference to the land system map, is based primarily on geomorphology, as discussed in Part VI, but some land systems differ significantly only in mantle characteristics. There is an alphabetical index to land systems at the end of the report.

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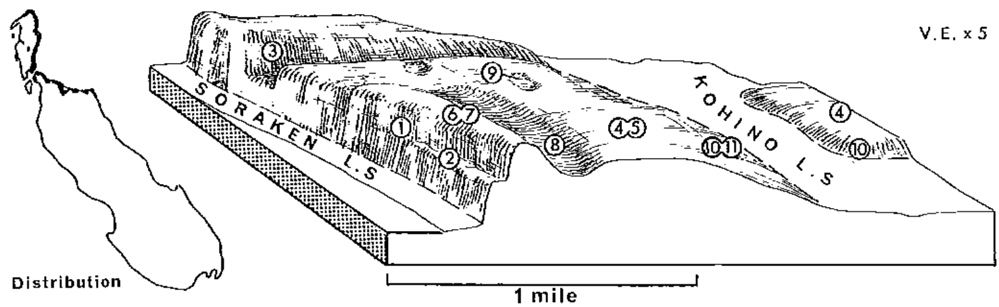
(1) Lonahan Land System (70 sq miles)

Plateaux and scarps of uplifted coral.

Geomorphology.—Upwarped former atoll and fringing reef, comprising reef front (land unit 1) with occasional perched benches (unit 2), reef flat (units 4, 5), lagoon slope (units 10, 11), and large patch reefs (units 4, 5, 10). A deep trough (unit 8) lies about 1000 ft behind the reef front in the most uplifted areas, and remnants of former islands form a discontinuous ridge (units 6, 7) along the summit of the reef front in many places. Several former tidal channels 80 ft deep and 1000 ft wide with steep walls (unit 3) cut the land system near Buka Passage. Scattered dolines (unit 9), more plentiful in the south, indicate the initiation of karst erosion. Uplift is greatest (290 ft) on the east coast of Buka Island and least (10 ft) in the far east and west.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 300 ft. Relief: moderately high (290 ft). Characteristic slope: high gradient. Grain: —. Plan-profile: 1L.

Geology.—Coral; Upper Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	Scarp: up to 280 ft high; precipitous or cliffed (45–90°)	Mainly rock	VIIIr$_8$ R$_H$	Some scattered shrubs and trees
2	½	Bench: very short; moderate slope	Terra rossa soils: shallow reddish plastic clays	IIIe$_3$,w$_2$ A7/R$_H$	Gardens or scrubby regrowth (*Macaranga–Alphitonia*)
3	½	Hill slope: short (160 ft); straight; steep (22–30°)		VIIe$_7$,w$_2$ A7/R$_H$	Tall forest (*Vitex–Pometia*) or cleared
4	46	Plain: high gradient (0°30′); up to 2 miles wide; locally, up to 15 ft undulating microrelief forming local slopes up to 5°; no organized drainage	North of Hantoa mission, terra rossa soils: reddish plastic clays. Water-table near sea level (depth 10–290 ft)	IId$_2$,w$_2$. Locally e$_2$,d$_2$,w$_2$ A7	Tall forest (*Vitex–Pometia*); largely cleared; gardened, but mainly under coconuts with minor cacao
5	6		South of Hantoa mission, ash-covered soils: black loams over reddish plastic clays	IId$_2$. Locally e$_2$,d$_2$ A4/A7	As above, with patches of mid-height grassland (*Imperata–Themeda*)
6	2½	Ridge crest: broad (500 ft); even; very gentle crestal slope	Terra rossa soils: shallow reddish plastic clays. Minor rock outcrop	IId$_2$,w$_2$,r$_2$ A7/R$_S$	Remnants of tall forest (*Vitex–Pometia*), locally under coconuts
7	1½	Ridge slope: very short; straight; moderate or steep		VIe$_6$,w$_2$,r$_2$ A7/R$_S$	
8	1½	Trough: up to 800 ft wide and 100 ft deep; moderate to steep side walls (8–20°) leading to concave undulating floor	Terra rossa soils: trough wall, shallow reddish plastic clays; trough floor, reddish plastic clays	VIe$_6$,w$_2$ A7/R$_H$ IIId$_3$,f$_3$,w$_2$ A7	Tall forest (*Vitex–Pometia*); largely cleared; gardened, but mainly under coconuts with minor cacao; patches of mid-height grassland (*Imperata–Themeda*) south of Hantoa mission
9	7	Doline: 100–200 ft in diameter; generally shallow with gentle side slopes and flat floors, rarely with moderate to cliffed side slopes and irregular rocky floors	Mainly ash-covered soils: black loams over reddish plastic clays Locally on side slopes, terra rossa soils: shallow reddish plastic clays	IIIe$_{1-2}$,d$_2$,f$_3$ A4/A7 VI–VIIIe$_{6-8}$, w$_2$,r$_2$ A7/R$_H$	
10	2½	Inland slope: long (1000 ft); concave; gentle to moderate (3–9°)	North of Hantoa mission, terra rossa soils: reddish plastic clays	II–IIIe$_{2-3}$,d$_2$,w$_2$ A7	As above, with stands of tall herbaceous regrowth (*Musa–Heliconia*)
11	1		South of Hantoa mission, ash-covered soils: black loams over reddish plastic clays	II–IIIe$_{2-3}$,d$_2$ A4/A7	

Inclusions.—Soraken land system.

Population and Land Use.—11,000 people currently using 25·8 sq miles (33% for cash crops) mostly on unit 2. Fishing of considerable importance. 2·7 sq miles of non-indigenous plantations.

Forest Potential.—11 sq miles tall plains forest, high yield on units 3–11. Access category I (except for very steep to cliffed slopes in units 1 and 9).

Observations.—26.

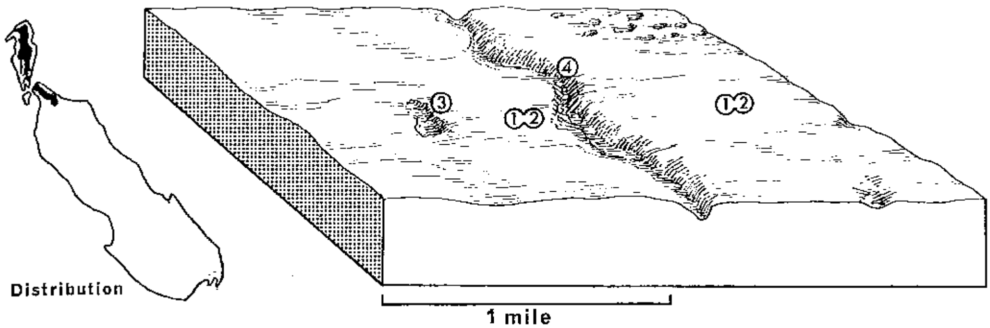
(2) Kohino Land System (140 sq miles)

Plains of uplifted coral lagoon floors.

Geomorphology.—Tectonically uptilted, but little-dissected former coral lagoon floor and tidal passages, consisting of undulating plains with scattered dolines in lower areas. Some sandy stream beds of high gradient commonly 50 ft wide, entrenched 20 ft below the plain.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 180 ft. Relief: ultra-low (30 ft). Characteristic slope: gentle. Grain: —. Plan-profile: 1.

Geology.—Coral; Upper Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	105	**Undulating plain:** high to ultra-high gradient (0°30′–2°); local slopes up to 12°	North of Tsirogei mission, terra rossa soils: reddish plastic clays In depressions, brown plastic clays Locally shallow reddish plastic clays	IIe_2,d_2,w_2 A7 $IIId_2,w_2$ A7 $IIIe_3,w_2,r_2$ A7/R_H	Tall forest (*Vitex–Octomeles*, *Vitex–Pometia* on shallow clays); conspicuous areas of tall herbaceous regrowth (*Musa–Heliconia*); minor areas cultivated and with coconut and cacao plantations
2	28		South of Tsirogei mission, ash-covered soils: black loams over reddish plastic clays	IIe_2,d_2; locally $IIIe_3,d_2$ A4/A7	Tall forest (*Vitex–Pometia*); moderate areas gardens and coconut plantations or under regrowth; some small patches of mid-height grassland (*Imperata–Themeda*)
3	5	**Doline:** about 200 ft in diameter; generally with gentle side slopes and flat floors, rarely with moderate side slopes descending to a pool, stream, or cavern at about 30 ft depth	Ash-covered soils: black loams over reddish plastic clays Locally on side slopes, terra rossa soils: shallow reddish plastic clays	IIe_{1-2},d_2 A4/A7 VIe_6,w_2,r_2 A7/R_H	No observations. Often cleared for water-holes
4	2	**Valley side slope:** very short (50 ft); gentle to moderate	Terra rossa soils: reddish plastic clays	$IIIe_3,d_2,w_2$ A7	Tall forest (*Vitex–Octomeles*) and tall herbaceous regrowth (*Musa–Heliconia*)

Population and Land Use.—800 people currently using 8·3 sq miles (50% for cash crops) mostly on units 1 and 2. 4·9 sq miles of non-indigenous plantations.

Forest Potential.—42 sq miles irregular tall plains forest, low yield, on units 1, 2, and 4. Access category I.

Observations.—8.

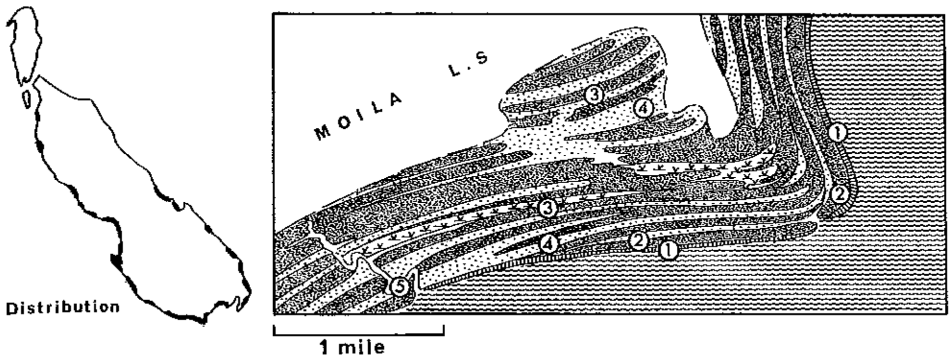
(3) Jaba Land System (60 sq miles)

Sandy coast with beach ridges and swales.

Geomorphology.—Broadly curving prograding coast formed of subparallel beach ridges of sandy volcanic detritus, with crest spacing 200–500 ft, separated by swales; commonly underlain by a coral platform. Rare tortuous tidal creeks.

Terrain Parameters.—Altitude: H.I., I; min., 0 ft; max., 15 ft. Relief: none (microrelief 10 ft). Characteristic slope: gentle. Grain: ultra-fine (150 ft). Plan-profile: 5L//.

Geology.—Volcanic sand and coral; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	**Beach**: 50 ft wide; sloping at 10° to 5–10 ft above high-water mark; sandy	Littoral soils: white sands	$VIIIf_8,a_3$ A3	Above high-water mark, mixed herbaceous vegetation (*Spinifex–Canavalia*)
2	6	**Outermost beach ridge**: 80 ft wide; rising about 2 ft higher than the beach and descending landward at 2–10°		IVe_3,n_2,a_3 A3	Mid-height forest (*Cerbera–Calophyllum*), locally dominated by *Casuarina equisetifolia*; in places fringed by scrub (*Hibiscus–Pandanus*)
3	25	**Beach ridge**: 1–10 ft high, aligned parallel to the shore; width about 150 ft but very variable; slopes gentle (<3°)	Littoral soils: brown sands. Water-table about 3 ft	IIn_2	Tall forest (*Vitex–Pometia*); on isolated inner ridges, scrub (*Hibiscus–Pandanus, Cerbera* variant)
4	28	**Swale**: between beach ridges; with standing water up to 5 ft deep; width about 200 ft but very variable	Swamp soils: neutral peaty sands	$VIIId_8$ A8/A3	Mixed herbaceous vegetation (*Leersia–Hanguana*)
5	<½	**Tidal creeks**: small; up to 200 ft wide and 5 ft deep		$VIIId_8,a_3$ A8/A3	Fringed by palm vegetation (*Nypa*); lower reaches commonly with scrub (*Rhizophora*)

Population and Land Use.—1000 people currently using 1·7 sq miles of unit 3. Subsistence chiefly from fishing and coconuts. 0·4 sq mile of non-indigenous plantations.

Forest Potential.—2 sq miles *Casuarina* forest, low yield, on unit 2. Access category I on units 1–3; access category Is on units 4 and 5.

Observations.—12, including 4 on unit 3, plus 1 aerial observation.

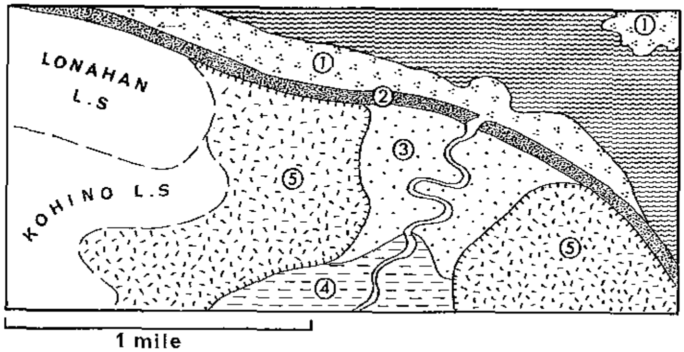
(4) Soraken Land System (85 sq miles)

Coast with mangrove flats, coral reefs, and low emerged coral platforms.

Geomorphology.—Irregular coast with narrow discontinuous beaches protected by either fringing or barrier coral reefs. Tidal flats and brackish swamps occur in bays and inlets, and small low-angle alluvial plains on the landward margins of the land system. There is an extensive emerged coral platform 5–15 ft above high-water mark.

Terrain Parameters.—Altitude: H.I., I; min., 0 ft; max., 15 ft. Relief: none (microrelief 15 ft). Characteristic slope: low gradient. Grain: —. Plan-profile: 7.

Geology.—Coral, coralline and volcanic sand; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	—	**Reef flat:** at high-water mark; 2 ft microrelief formed mainly of dead coral; fringing reefs about 200 ft wide, barrier reefs up to 1 mile wide		R_H	
2	1	**Beach:** narrow; sloping at 7° to 6 ft above high-water mark; formed of coralline or volcanic sand, or rarely coral rubble	Littoral soils: white sands	IVe_4,n_2,a_3 A3	Scrub (*Hibiscus–Pandanus*), locally fringed by mixed herbaceous vegetation (*Spinifex–Canavalia*); lowest-lying beaches with scrub (*Rhizophora*)
3	26	**Tidal flat:** at high-water mark on inlets; 1 ft of channelled or hummocky microrelief; associated brackish swamps	Mangrove soils: shallow alkaline peaty sands or alkaline sands	$VIIIf_8,a_4$ $A8/R_S$ $VIIIf_8,a_4$ A3	Mid-height forest (*Rhizophora–Bruguiera*), local stands of palm vegetation (*Nypa*); swamps with low woody vegetation ecotonal to tall forest
4	8	**Alluvial–littoral plain:** high gradient; 3 ft undulating microrelief; traversed by small streams with channels up to 15 ft wide and 6 ft deep	Alluvial soils: brown mottled sands. Water-table 1–3 ft Locally near streams, stratified mottled loams and clays. Water-table 1–3 ft	IVd_8,n_2,f_4 A3 IVd_3,f_4 A4 or A6	Originally tall forest (probably mainly *Euodia–Pometia*) but large areas cleared. Mainly gardens and associated secondary vegetation types or coconut plantations
5	50	**Coral platform:** low gradient; 5–15 ft above high-water mark; 2 ft undulating microrelief	Rendzinas: shallow greyish brown loams Locally, shallow black clays	$IIIa_3$ $A4/R_S$ $IIIw_2,a_3$ $A7/R_S$	

Population and Land Use.—4400 people currently using 7·9 sq miles (25% for cash crops) of units 4 and 5. Fishing of considerable importance. 16·4 sq miles of non-indigenous plantations.

Forest Potential.—20 sq miles mangrove forest on unit 3; 1 sq mile irregular tall plains forest, low yield, on units 4 and 5. Access category I on units 2, 4, and 5; access category Is on unit 3.

Observations.—20.

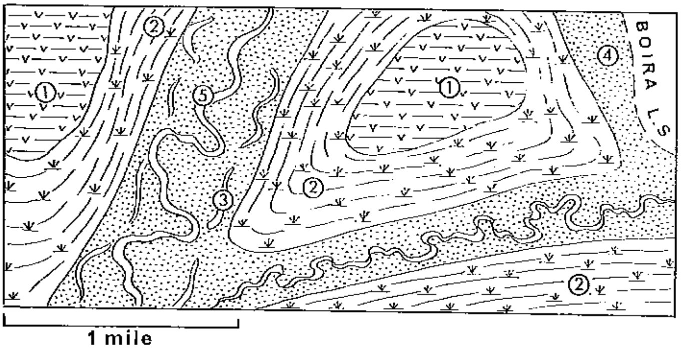
(5) Moila Land System (250 sq miles)

Herbaceous and forested swamps.

Geomorphology.—Swamps impounded by growth of beach ridges or by aggradation of alluvial tracts, with central zones of no flow surrounded by zones of dispersed flow; traversed by swampy flood-plains of meandering streams. Streams normally up to 200 ft wide with pools up to 8 ft deep and riffles up to 3 ft deep.

Terrain Parameters.—Altitude: H.I., I; min., 0 ft; max., 50 ft. Relief: none (microrelief 6 ft). Characteristic slope: low gradient. Grain: —. Plan-profile: 7.

Geology.—Peat; alluvial and littoral sand; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	175	Swamp with stagnant water: plains with low gradient, as closed depressions up to 1 mile square, or zones up to 1 mile wide marginal to shallow lakes; water 0–10 ft deep	Swamp peats: surface peats	VIIId$_8$ A8	Mixed herbaceous vegetation (*Leersia–Hanguana*, in areas of open water *Nymphaea–Azolla*) and tall grassland (*Phragmites–Saccharum*); in central areas of large swamps, mixed herbaceous vegetation (*Lycopodium–Gleichenia*); marginal to units 2 and 3, scattered trees and *Pandanus*
2	38	Swamp with flowing water: plains of low or high gradient, as zones up to 2 miles wide; up to 1 ft hummocky microrelief; water 0–6 ft deep; widely spaced small stream channels up to 30 ft wide and 6 ft deep	Swamp peats: submerged peats	VIIId$_8$ A8	Open tall forest (*Terminalia brassii–Campnosperma*)
3	15	Swampy river tracts and swamp margins: plains of low gradient, as zones up to 1 mile wide, subject to frequent flooding; 10 ft microrelief of levees and abandoned channels	River tracts, alluvial soils: brown mottled sands	IVd$_3$,f$_4$,n$_2$ A3	Mid-height forest (*Euodia–Pometia, Dillenia ingens* variant); tall grassland (*Phragmites–Saccharum*)
4	10		Swamp margins, swamp soils: neutral peaty clays	VIIId$_8$ A8	Mid-height forest (*Euodia–Pometia, Dillenia ingens* variant)
5	12	River bed: low gradient; up to 250 ft wide; 10–15 ft deep; with narrow point bars and occasional levees; sandy or gravelly, some log dams	On point bars, alluvial soils: shallow grey mottled sands	VIf$_8$,n$_2$ A1	On point bars mixed herbaceous vegetation (*Paspalum–Cassia*) and tall grass vegetation (*Saccharum robustum*)

Inclusions.—Jaba land system on seaward margin.

Population and Land Use.—Nil. Villages found here are on inclusions of Jaba land system.

Forest Potential.—62 sq miles open *Terminalia–Campnosperma* forest, low yield, on unit 2; 30 sq miles dense *Terminalia–Campnosperma* forest, high yield, on unit 2. Access category Is.

Observations.—6.

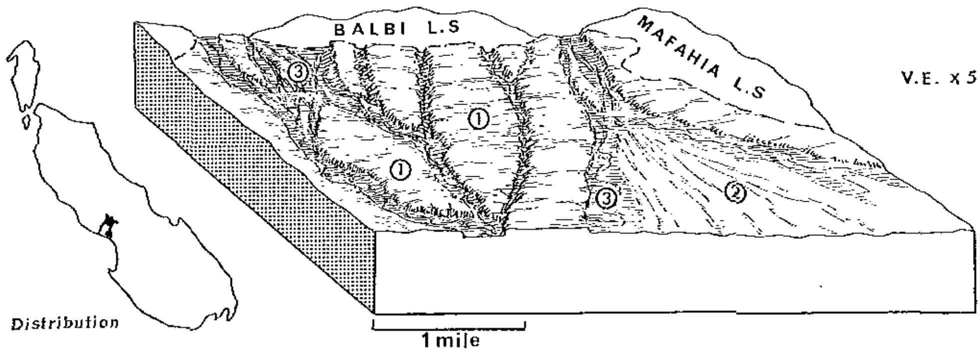
(6) Saua Land System (25 sq miles)

Actively forming volcano-alluvial plain.

Geomorphology.—Coalescing volcano-alluvial plains of Mt. Bagana, including an ash-covered plain standing above bouldery bar plains that are traversed by rapidly migrating braided streams normally up to 30 ft wide and 3 ft deep. Towards the coast large fan-shaped flood-out plains are subject to severe flooding and to invasion by ephemeral stream channels.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 800 ft. Relief: ultra-low (50 ft). Characteristic slope: very high gradient. Grain: coarse (3000 ft). Plan-profile: 2//.

Geology.—Volcanic debris; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	10	**High plain**: very high to ultra-high gradient (0°30′–4°); up to 2 miles wide; 3 ft undulating *microrelief; cliffed margins up to* 50 ft high	Ash soils; grey fine sands. Water-table >15 ft	IVe_1,n_2 A3	Scrub (*Cyathea–Bambusa*), locally with emergent *Albizia falcata*
2	12	**Flood-out plain**: very high gradient (0°30′–1°); up to 2 miles wide; 2 ft terraced and channelled micro-relief standing less than 10 ft above unit 3	Alluvial soils; brown mottled sands. Water-table 5–15 ft	VIf_6,n_2 A3	Tall grassland (*Phragmites–Saccharum*) with stands of woodland (*Casuarina*) near channels
3	3	**Bar plain and river channel**: very high to ultra-high gradient (0°30′–4°); plains up to ½ mile wide; 5 ft channelled microrelief	Mainly cobble gravel with boulders Locally alluvial soils: shallow grey mottled sands	$VIIIst_8$ C VId_5,f_6 A3	Mixed herbaceous vegetation (plains with highest gradient *Lycopodium–Gleichenia*, with lower gradient *Paspalum–Cassia*); local stands of scrub (*Trema*); minor tall grass vegetation (*Saccharum robustum*) along stream channels

Population and Land Use.—Nil.
Forest Potential.—No forest. Access category I on units 1 and 2; access category If on units 2 and 3.
Observations.—6.

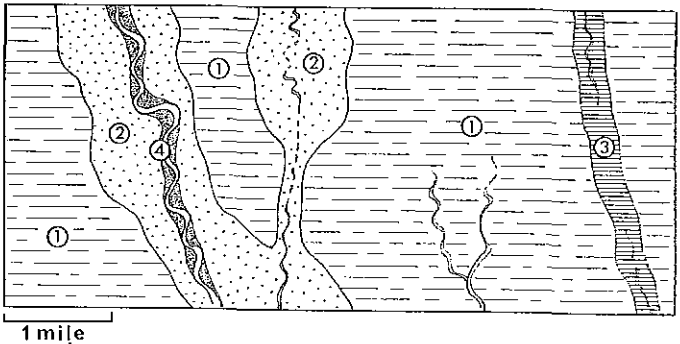
(7) Silibai Land System (240 sq miles)

Low-lying broad coastal alluvial plains.

Geomorphology.—Alluvial plains formed of material eroded from volcano–alluvial fans, drained by ill-defined subparallel small channels following irregular linear depressions, and traversed by flood-plains and gravelly beds of larger rivers with migrating meanders. Rivers normally up to 80 ft wide, 6 ft deep in pools and 3 ft deep at riffles.

Terrain Parameters.—Altitude: H.I., I; min., 0 ft; max., 50 ft. Relief: none (microrelief 15 ft). Characteristic slope: high gradient. Grain: very coarse (15,000 ft). Plan-profile: 7.

Geology.—Volcanic sandy and gravelly alluvium; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	205	**Plain:** low or high gradient (0°5′–0°30′); indefinitely wide; less than 2 ft of microrelief; traversed by small channels up to 50 ft wide and 10 ft deep	Alluvial soils: brown mottled sands. Water-table 2–12 ft, very variable	IIId$_3$,f$_4$,n$_2$ A3	Tall forest (*Vitex–Octomeles*, along channels *Euodia–Pometia*, in driest areas *Vitex–Pometia*)
2	22	**Flood-plain:** along drainage lines or marginal to rivers; low gradient; up to 2 miles wide; 3 ft channelled relief	Alluvial soils: brown mottled sands. Water-table 2–6 ft	VId$_{3,5}$,f$_6$,n$_2$ A3	Open tall forest (*Terminalia brassii–Campnosperma*), with local stands of pandan vegetation (*Pandanus*); some channels with tall grass vegetation (*Saccharum robustum*)
3	3	**Drainage depression:** low gradient; 1000 ft wide; 3 ft channelled relief	Swamp peats: submerged peats. Up to 3 ft water	VIIId$_8$ A8	Tall forest (*Terminalia brassii*)
4	12	**River bed:** low gradient; 300 ft wide, 10–15 ft deep; without levees; banks cliffed on bends; sandy upper point bars, gravelly lower point bars	On upper point bars, alluvial soils: shallow grey mottled sands On lower point bars, gravel	VIf$_6$,n$_2$ A1 VIIIst$_8$ C	Mixed herbaceous vegetation (*Paspalum–Cassia*), with tall grass vegetation (*Saccharum robustum*)

Inclusions.—Jaba land system on seaward margin.

Population and Land Use.—200 people currently using 0·8 sq mile of unit 2 and inclusions of Jaba land system. 0·4 sq mile of non-indigenous plantations.

Forest Potential.—116 sq miles irregular tall plains forest, low yield, on unit 1; 2 sq miles *Terminalia brassii* forest, high yield, on unit 3; 1 sq mile open *Terminalia–Campnosperma* forest, low yield, on unit 2. Access category If.

Observations.—18, including 11 on unit 1.

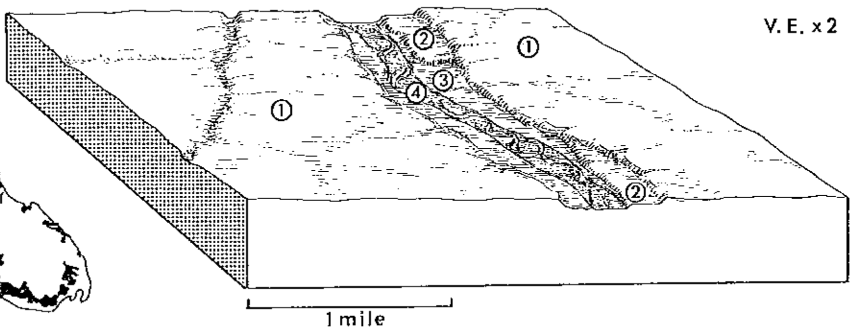
(8) Siwai Land System (355 sq miles)

High-lying broad alluvial plains.

Geomorphology.—Coalescing volcano–alluvial fans formed mainly of fluvial deposits, traversed by terraced valleys of stream entrenchment up to 80 ft deep; also non-volcanic valley plains. Rivers, normally up to 200 ft wide and 3 ft deep, have irregular, angular channel patterns forming occasional alluvial islands.

Terrain Parameters.—Altitude: H.I., I; min., 0 ft; max., 200 ft. Relief: very low (80 ft). Characteristic slope: very high gradient. Grain: very coarse (5000 ft). Plan-profile: 1L//.

Geology.—Sandy and gravelly volcanic alluvium; Upper Pleistocene to Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	345	**Plain**: very high gradient (0°30′–2°) indefinitely wide; less than 2 ft of microrelief; traversed by small stream beds up to 100 ft wide and 20 ft deep, with low-water channels up to 20 ft wide and 1 ft deep	Ash-covered soils: brown loams over sands. Water-table 10–70 ft	IIn_3 A4/A3	Tall forest (*Vitex–Pometia*); moderate areas with gardens and regrowth
2	7	**Terrace**: very high gradient; up to ½ mile wide; up to 10 ft of channelled microrelief	Alluvial soils: brown mottled sands. Water-table 1–20 ft	$IIId_3,n_2$ A3	Tall forest (*Vitex–Pometia, Vitex–Octomeles*)
3	2	**Flood-plain**: "major bed"; very high gradient; up to 1200 ft wide; 5 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase). Water-table 0–10 ft	VIf_3,st_6 A3+B	Tall forest (*Terminalia brassii*)
4	1	**River bed**: very high gradient; up to 400 ft wide and 12 ft deep; bars and flood channels	Gravel	$VIIIst_8$ B	Mixed herbaceous vegetation (*Paspalum–Cassia*), tall grass vegetation (*Saccharum robustum*), and stands of scrub (*Ficus arbuscula*)

Population and Land Use.—7500 people currently using 22·4 sq miles (20% for cash crops), mostly of unit 1. 8·5 sq miles of non-indigenous plantations.

Forest Potential.—131 sq miles tall plains forest, high yield, on units 1 and 2; 11 sq miles irregular tall plains forest, low yield, on unit 2; 8 sq miles *Terminalia brassii* forest, high yield, on unit 3. Access category I.

Observations.—20.

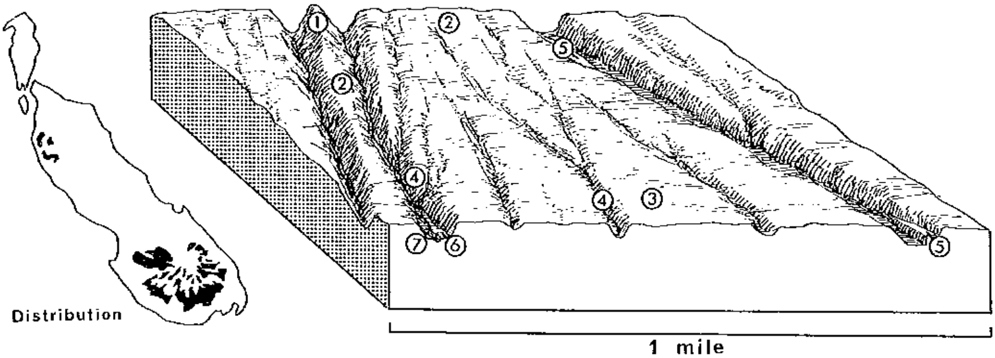
(9) Buin Land System (270 sq miles)

Partly dissected volcano–alluvial fan with ash pan soils.

Geomorphology.—Coalescing volcano–alluvial fans of slightly concave profile formed of intercalated fluvial, laharic, and nuée deposits with superficial airborne ash. Stream dissection has produced very shallow radiating valleys, separated by residual ridges or plateaux at higher altitudes and by plains at lower altitudes. Streams are normally up to 100 ft wide and 1½ ft deep.

Terrain Parameters.—Altitude: H.I., II; min., 100 ft; max., 3000 ft. Relief: low (150 ft). Characteristic slope: very high gradient. Grain: medium (1100 ft). Plan-profile: 1L//.

Geology.—Volcanic debris; Upper Pleistocene and Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	20	**Ridge crest:** very narrow to broad; even; gentle, rarely moderate, crestal slopes	Ash soils: brown loams with an ash pan	II–IIIe$_{2-3}$,d$_2$ A4/R$_S$	Tall forest (*Vitex–Pometia*, above 1500 ft above sea level, *Neonauclea–Sloanea*) grading into mid-height forest (*Garcinia–Elaeocarpus*) at higher altitudes; gardens and cash cropping; extensive areas in various stages of regrowth, mainly young secondary forest (*Althoffia–Alphitonia*) and secondary forest (*Artocarpus–Albizia*)
2	55	**Plateau:** gentle slope (2–6°); up to 1 mile wide; 20 ft undulating microrelief with small shallow gullies	Ash soils: brown loams with an ash pan. Water-table deeper than 100 ft	IIe$_2$,d$_2$ A4/R$_S$	
3	160	**Plain:** very high gradient (>0°35′); up to 1 mile wide between major streams; 3 ft undulating microrelief; local slopes to 3°	Ash soils: brown loams with an ash pan. Water-table 30–100 ft	IId$_2$ A4/R$_S$	
4	20	**Valley side slope:** very short; straight or concave; steep to very steep (15–50°); numerous steep spurs	Slopes: mainly ash soils; brown loams Locally lithosols	VII–VIIIe$_{7-8}$ A4/R$_S$ VIIIe$_8$,st$_6$ R$_S$	As above, with the exception of very steep slopes which have scrub (*Cyathea–Trema*)
5	2½	**Terrace:** very high gradient; about 100 ft wide; up to 50 ft above streams	Ash soils: brown loams with an ash pan	IIe$_2$,d$_2$ A4/R$_S$	As units 1–3
6	10	**Valley floor:** very high gradient (>0°35′); rarely up to 1000 ft wide; 10 ft channelled microrelief	Alluvial soils: mainly brown mottled sands (stony phase) Locally, brown mottled sands	VIIId$_5$,f$_6$,st$_8$,n$_2$ A3+B VId$_3$,f$_6$ A3	Tall forest (*Terminalia brassii*) or as units 1–3; locally secondary scrub (*Saurauja conferta*)
7	2½	**River bed:** very high or ultra-high gradient; up to 150 ft wide and 10 ft deep; channel bars and flood channels	Gravel	VIIIst$_8$ B+C	On some bars, scrub (*Ficus arbuscula*)

Inclusions.—Pauroka and Siwai land systems.

Population and Land Use.—10,800 people currently using 30·0 sq miles (20% for cash crops) of units 1–3 and 5.

Forest Potential.—87 sq miles low-altitude upland forest, high yield, on units 1–6 (in part); 17 sq miles mid-altitude upland forest, moderate yield, on units 1–6 (in part); 1 sq mile *Terminalia brassii* forest, high yield, on unit 6. Access category I.

Observations.—25.

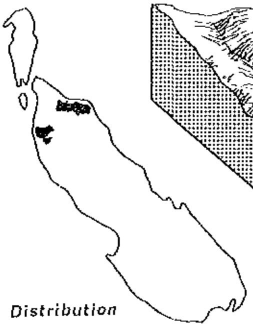
(10) Rugen Land System (75 sq miles)

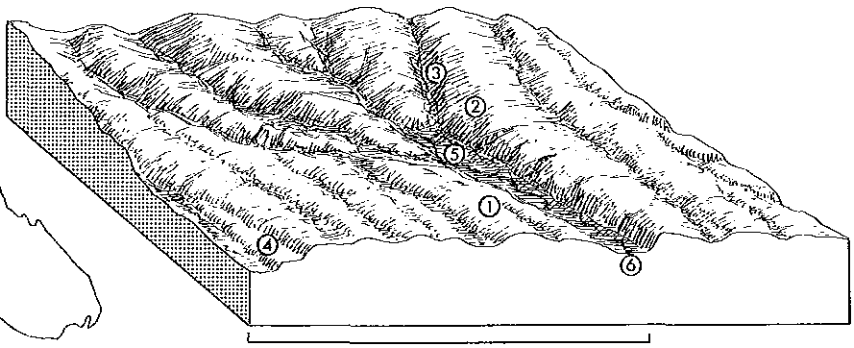
Shallowly dissected older volcano–alluvial fans with red clay subsoils.

Geomorphology.—Volcano–alluvial fans of slightly concave profile formed of intercalated fluvial, laharic, and nuée deposits with thin superficial airborne ash. Stream dissection has produced a pattern of long, low, radiating ridges and narrow valleys. Large rivers normally up to 50 ft wide and 1 ft deep have recessed flood-plains and terraces, and flow in irregular, angular, sometimes multiple channels. Bouldery small streams of ultra-high gradient are normally less than 15 ft wide and 6 in. deep.

Terrain Parameters.—Altitude: H.I., II; min., 100 ft; max., 3000 ft. Relief: low (200 ft). Characteristic slope: low-moderate. Grain: medium (1100 ft). Plan-profile: 4L//.

Geology.—Volcanic debris; Middle Pleistocene.





Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	15	Ridge crest: broad (200 ft); uneven; gentle crestal slope (2–6°, locally 12°)	Ash-covered soils: brown loams over reddish friable clays	IIe$_2$ A4/A6	Tall forest (*Vitex–Pometia*) or secondary forest (*Artocarpus–Albizia*); locally plantations (coconut, coffee, cacao); very restricted areas with mid-height grassland (*Imperata–Themeda*)
2	55	Gentler slope: very short; convex; moderate (8–12°)		IIIe$_3$ A4/A6	
3	3	Steeper slope: very short; convex; steep or very steep	Ash soils: brown loams Acid clay soils: red friable clays	VIIe$_7$ A4/Rs VIIe$_7$ A6	
4	1	Terrace: very high gradient; up to 500 ft wide; up to 10 ft channelled microrelief	Ash-covered soils: brown loams over reddish friable clays. Water-table 1–20 ft	IIe$_3$ A4/A6	Tall forest (*Vitex–Octomeles*)
5	½	Flood-plain: "major bed"; very high gradient; up to 1000 ft wide; recessed; 10 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase). Water-table 0–10 ft	VId$_5$,f$_6$,st$_6$,n$_3$ A3+B	Tall forest (*Terminalia brassii*)
6	½	River bed: very high gradient; up to 200 ft wide and 6 ft deep; channel bars and flood channels	Boulders	VIIIst$_8$ B	Nil

Population and Land Use.—2250 people currently using 8·9 sq miles (20% for cash crops) mainly on units 1 and 2. 2·2 sq miles of non-indigenous plantations.

Forest Potential.—41 sq miles low-altitude upland forest, high yield, on units 1–3; small stands *Terminalia brassii* forest, high yield, on unit 5. Access category Ia (very steep slopes, unit 2).

Observations.—10.

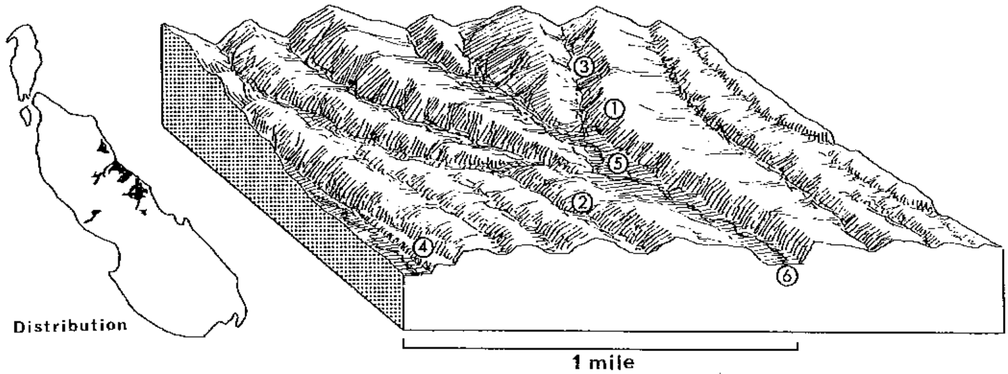
(11) Numa Land System (115 sq miles)

Shallowly dissected volcano–alluvial fans with lapillitic ash soils.

Geomorphology.—Volcano–alluvial fans of slightly concave profile formed of intercalated fluvial, laharic, and nuée deposits with thick superficial airborne ash. Stream dissection has produced a pattern of long, low, radiating ridges and narrow valleys. Large rivers normally up to 50 ft wide and 1 ft deep have recessed flood-plains and terraces, and flow in irregular, angular, sometimes multiple channels. Bouldery small streams of ultra-high gradient are normally less than 15 ft wide and 6 in. deep.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 1000 ft. Relief: low (200 ft). Characteristic slope: low-moderate. Grain: medium (1000 ft). Plan-profile: 4L//.

Geology.—Volcanic debris; Middle Pleistocene to Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	26	Ridge crest: broad (200 ft); uneven; gentle crestal slope (2–6°, locally 12°)	Ash soils: brown loams with lapillitic horizons	IIe_2,n_2 A4/A1/A4	Tall forest (*Vitex–Pometia*) or secondary forest (*Artocarpus–Albizia*); locally plantations (coconut and cacao)
2	80	Hill slope: very short; convex; moderate (8–12°)		$IIIe_3,n_2$ A4/A1/A4	
3	6	Steeper slope: very short; convex; steep or very steep	Ash soils: brown loams	$VIIe_7$ A4/R_S	
4	1	Terrace: very high gradient; up to 500 ft wide; up to 10 ft channelled microrelief	Ash soils: brown loams with lapillitic horizons. Water-table 1–20 ft	IIe_2,n_2 A4/A1/A4	Tall forest (*Vitex–Octomeles*)
5	1	Flood-plain: "major bed"; very high gradient; up to 1000 ft wide; recessed; 10 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase). Water-table 0–10 ft	VId_5,f_6,st_6 A3+B	Tall forest (*Terminalia brassii*)
6	1	River bed: very high gradient; up to 200 ft wide and 6 ft deep; bars and flood channels	Boulders	$VIIIst_8$ B	Nil

Inclusions.—Moila and Leikaia land systems.

Population and Land Use.—850 people currently using 4·2 sq miles (10% for cash crops) mostly on units 1–3. 2·2 sq miles of non-indigenous plantations.

Forest Potential.—37 sq miles low-altitude upland forest, high yield, on units 1–3; 3 sq miles *Terminalia brassii* forest, high yield, on unit 5. Access category Ia (very steep slopes, unit 3).

Observations.—12, including 4 on unit 4.

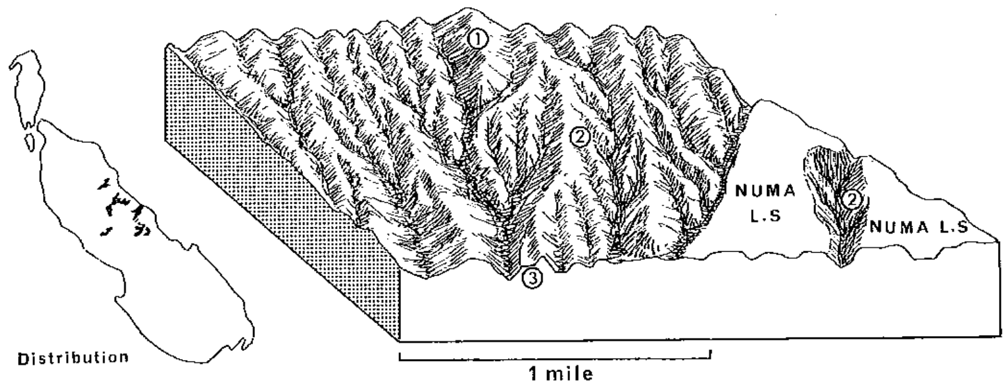
(12) LEIKAIA LAND SYSTEM (60 SQ MILES)

Dissected volcano–alluvial fans with lapillitic ash soils.

Geomorphology.—Volcano–alluvial fans of slightly concave profile formed of intercalated fluvial, laharic, and nuée deposits with thick superficial airborne ash. Stream dissection has produced a pattern of long, moderately high, radiating ridges and narrow valleys. Some areas of badlands occur where there is intense spring sapping. Bouldery small streams of ultra-high gradient normally less than 15 ft wide and 6 in. deep.

Terrain Parameters.—Altitude: H.I., III; min., 200 ft; max., 1500 ft. Relief: moderately high (400 ft). Characteristic slope: very steep. Grain: fine (600 ft). Plan-profile: 4L//.

Geology.—Volcanic debris; Middle Pleistocene to Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	8	**Ridge crest**: narrow (50–150 ft); even; crestal slope gentle to moderate (4–10°)	Ash soils: brown loams with lapillitic horizons	$IIIe_3,n_2$ A4/A1/A4	Tall forest (*Vitex–Pometia*) or secondary forest (*Artocarpus–Albizia*)
2	50	**Hill slope**: short (400 ft); irregular; very steep (30–45°); steep spurs (25°), and precipitous slump alcoves at gully heads. Locally precipitous badlands	As unit 1 or brown loams	$VII–VIIIe_{7–8},n_2$ A4/A1/A4 $VII–VIIIe_{7–8}$ $A4/R_S$	As above, but badlands with scrub (*Cyathea–Trema*); along stream margins, tall forest (*Terminalia brassii*)
3	2	**Bench**: at hill foot; moderately or gently sloping (2–15°); up to 150 ft wide; hummocky; standing less than 50 ft above stream bed	Ash soils: brown loams with lapillitic horizons	VIe_5,n_2 A4/A1/A4	Tall forest (*Vitex–Pometia*)

Inclusions.—Numa land system.

Population and Land Use.—700 people currently using 1·0 sq mile of unit 1 and inclusions of Numa land system.

Forest Potential.—35 sq miles low-altitude upland forest, moderate yield, on units 1–3; 1 sq mile *Terminalia brassii* forest, high yield, on unit 2. Access category III.

Observations.—7.

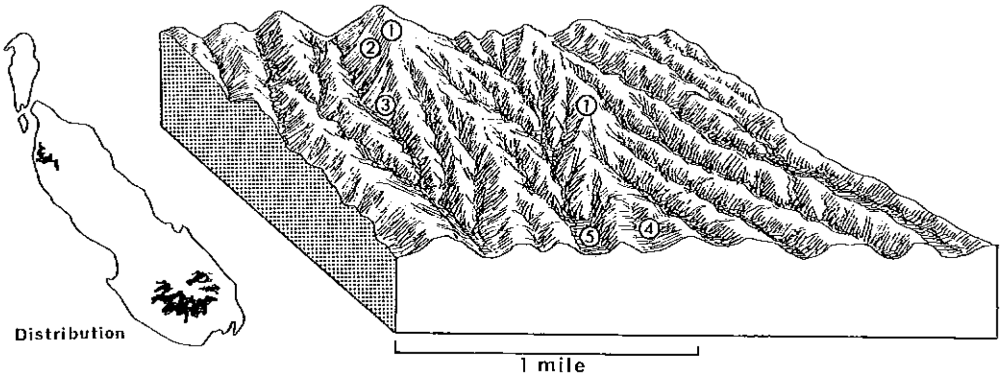
(13) Pauroka Land System (195 sq miles)

Dissected volcano–alluvial fans with ash soils.

Geomorphology.—Former volcano–alluvial fans of slightly concave profile formed of intercalated fluvial, laharic, and nuée deposits with thin superficial airborne ash. Stream dissection has produced a pattern of radiating, moderately deep gorges and dendritic tributary valleys separated by residual ridges, with steeper slopes characteristic of higher altitudes. Bouldery or gravelly small streams normally less than 20 ft wide and 1 ft deep.

Terrain Parameters.—Altitude: H.I., III; min., 200 ft; max., 3000 ft. Relief: moderately high (400 ft). Characteristic slope: steep. Grain: fine (800 ft). Plan-profile: 4L//.

Geology.—Volcanic debris; Upper Pleistocene and Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	20	**Ridge crest**: very narrow to broad; uneven; crestal slope gentle to moderate (2–15°)	Ash soils: brown loams with an ash pan	$II–IIIe_{2-3},d_2$ $A4/R_S$	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); above 2500 ft above sea level, mid-height forest (*Garcinia–Elaeocarpus*); areas with gardens and regrowth up to secondary forest (*Artocarpus–Albizia*)
2	8	**Precipitous hill slope**: (45–60°) short or medium length (300–800 ft); straight	Rock outcrop	$VIIIr_8$ R_H	Scrub (*Cyathea–Trema*)
3	60	**Very steep hill slope**: (30–45°) short or medium length (300–800 ft); straight; some steep spurs (20°) and gullies	Mainly ash soils: brown loams	$VIIIe_8$ $A4/R_S$	Forests as unit 1
4	105	**Steep hill slope**: short; irregular; steep (20–30°); numerous gently sloping (2°) benches up to 150 ft wide	Ash soils: brown loams	$VI–VIIe_{6-7}$ $A4/R_S$	As unit 1
5	2	**Valley floor**: ultra-high gradient (2–6°); up to 500 ft wide; 3–10 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase)	VId_5,f_6,st_6 $A3+B$	Tall forest (*Terminalia brassii*) or as unit 1

Population and Land Use.—5200 people currently using 11·6 sq miles (<5% for cash crops) mostly on unit 1, some on units 3 and 4.

Forest Potential.—84 sq miles low-altitude upland forest, moderate yield, on units 1, 3, and 4; 2 sq miles mid-altitude upland forest, moderate yield, on units 1, 3, and 4; 2 sq miles high-altitude upland forest, low yield, on units 1, 3, and 4; 1 sq mile *Terminalia brassii* forest, high yield, on unit 5. Access category III in higher parts of the land system; IIa (very steep to precipitous slopes, units 2 and 3) in lower parts of the land system.

Observations.—10.

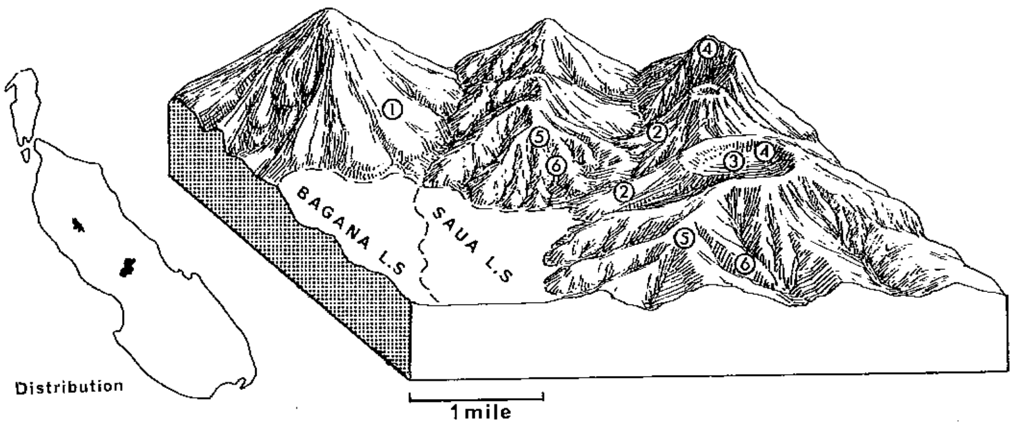
(14) Balbi Land System (30 sq miles)

Active or recently active volcanoes.

Geomorphology.—Very recent volcanic land forms including lava flows, debris slopes, and scarps forming the margins of explosion craters or of spines. Mt. Bagana is an active craterless lava cone; Mt. Balbi is a group of cratered active or inactive ash or scoria cones and spines; Lake Billy Mitchell is a large explosion crater; an unnamed peak east of Mt. Bagana is a dissected lava-flow cone. Lakes and ponds occur both in craters and in valleys blocked by lava flows.

Terrain Parameters.—Altitude: H.I., V; min., 1000 ft; max., 8500 ft. Relief: very high (1500 ft). Characteristic slope: very steep. Grain: very coarse (5000 ft). Plan-profile: 4.

Geology.—Andesite, hornblende–andesite, and hornblende-bearing basalt, as lava and ash; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	8	Lava flow: sinuous stream of rock up to 2 miles long and 1000 ft wide expanding distally to 3000 ft; steep axial slope (17–30°), increasing at the terminus to very steep (42°); cross-section convex except in upper parts which are irregularly concave; commonly bounded by narrow, very steep, marginal ridges up to 50 ft high	Blocks	$VIIIst_8$ B	Bare except for terminal slope with mixed herbaceous vegetation (*Lycopodium–Gleichenia*)
2	3	Debris slope: long (2000 ft); concave; mainly gentle or moderate (2–20°); traversed by stream beds up to 50 ft wide, locally incised 100 ft	Mainly stones and boulders Locally ash soils: grey fine sands (stony phase) or alluvial soils: shallow grey mottled sands	$VIIIst_8$ B+C VIe_2,st_4,n_2 A3+C IVd_3,f_4,n_2 A3	Bare; mixed herbaceous vegetation (*Lycopodium – Gleichenia*, mountain herbaceous vegetation); savannah; and scrub (*Cyathea–Bambusa*, mountain scrub)
3	½	Crater floor: nearly level; up to 500 ft diameter; 1 ft channelled microrelief; ponds	Ash soils: grey fine sands	$VIId_7,n_2$ A3	Bare or with mountain herbaceous vegetation; probably some bogs
4	2½	Scarp: medium length to long (500–2000 ft); irregular; precipitous; commonly with waterfalls	Rock outcrop or ash soils: grey fine sands (stony phase)	$VIIIr_8$ R_H $VIIIst_8,n_2$ A3+C	Bare or with mountain herbaceous vegetation
5	1	Ridge crest: knife-edged or very narrow; very uneven; steep crestal slope	Ash soils: grey fine sands (stony phase)	$VIIIst_8,n_2$ A3+C	As unit 2, locally palm and pandan vegetation (*Gulubia–Pandanus*)
6	15	Erosional hill slope: short or medium length; straight; very steep to precipitous	Boulders or ash soils: grey fine sands (stony phase)	$VIIIst_8,n_2$ B or A3+C	As unit 2, locally mountain low forest

Population and Land Use.—Nil.

Forest Potential.—No forest. Access category III.

Observations.—2, plus 4 aerial observations.

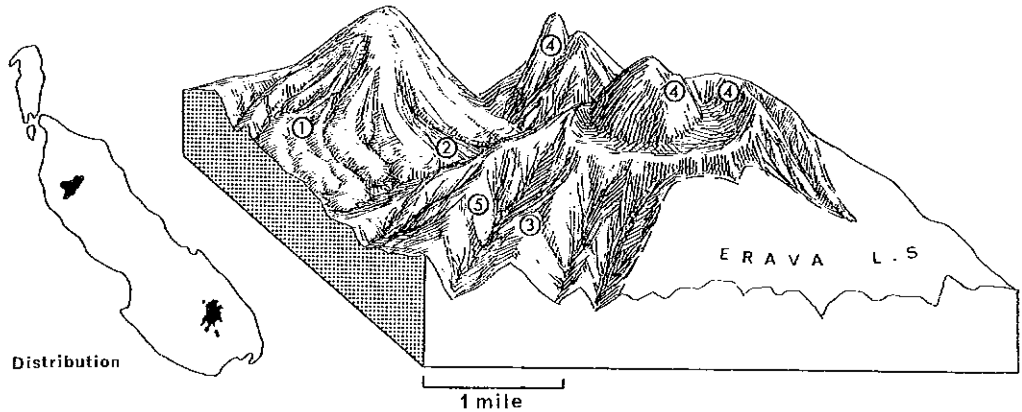
(15) Takuan Land System (75 sq miles)

Extinct or dormant volcanoes.

Geomorphology.—Largely undissected Upper Pleistocene volcanic land forms including lava flows, debris slopes, and scarps forming the margins of explosion craters, notably that occupied by Lake Loloru; also erosional ridges and slopes on former ash and lava cones and on disintegrating tholoids. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., V; min., 1000 ft; max., 7500 ft. Relief: very high (5000 ft). Characteristic slope: steep. Grain: coarse (3000 ft). Plan-profile: 4.

Geology.—Andesitic lava, ash, and agglomerate; Upper Pleistocene or Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	36	Lava flow: sinuous; up to 5 miles long and ¾ mile wide; moderate to steep axial slope (6–30°), increasing at terminus and margins to very steep or precipitous (40–50°); commonly bounded by very steep linear ridges up to 200 ft high	Ash soils: brown loams On very steep or precipitous slopes; lithosols	III, VI, VIIe_3, e_{6-7} A4/R_S VIIIe_8 R_S	Palm and pandan vegetation (*Gulubia–Pandanus*), ridges with scrub (*Cyathea–Bambusa*), distal zone mid-height forest (*Garcinia–Elaeocarpus*) and tall forest (*Neonauclea–Sloanea*)
2	5	Debris slope: gentle slope (2–6°); up to 1 mile long; 10 ft channelled relief; traversed by gullies up to 500 ft wide and 50 ft deep, with mainly steep side slopes	Ash soils: brown loams with an ash pan On gully slopes: brown loams	IIe_2,d_2 A4/R_S VIIe_7 A4/R_S	Palm and pandan vegetation (*Gulubia–Pandanus*), mountain scrub and mountain low forest in gullies
3	5	Ridge crest: knife-edged to narrow (5–150 ft); stepped; crestal slope gentle to precipitous (2–50°)	Ash soils: on gentle slopes, brown loams with an ash pan On steeper slopes, brown loams On precipitous slopes, abundant weathered rock outcrop	IIe_2,d_2 A4/R_S III, VI, VII e_2, e_{6-7} A4/R_S VIIIe_8,r_8 R_S	As unit 1
4	3	Scarp: medium length (500–1000 ft); irregular; precipitous	Mainly stones and boulders Locally, rock outcrop	VIIIe_8,st_8 B+C VIIIe_8,r_8 R_H	Palm and pandan vegetation (*Gulubia–Pandanus*)
5	26	Erosional hill slope: short; straight; very steep (30–45°); slump alcoves at gully heads	Ash soils: brown loams	VIIIe_8 A4/R_S	Palm and pandan vegetation (*Gulubia–Pandanus*), mid-height forest (*Garcinia–Elaeocarpus*) and tall forest (*Neonauclea–Sloanea*)

Inclusions.—Balbi land system at Lake Loloru.

Population and Land Use.—100 people currently using 0·2 sq mile on the periphery of the land system.

Forest Potential.—25 sq miles high-altitude upland forest, low yield, on units 1 and 3; 8 sq miles mid-altitude upland forest, moderate yield, on units 1, 3, and 5; 1 sq mile low-altitude upland forest, moderate yield, on units 1, 3, and 5. Access category III.

Observations.—7, including 3 on unit 1, plus 2 aerial observations.

(16) Erava Land System (115 sq miles)

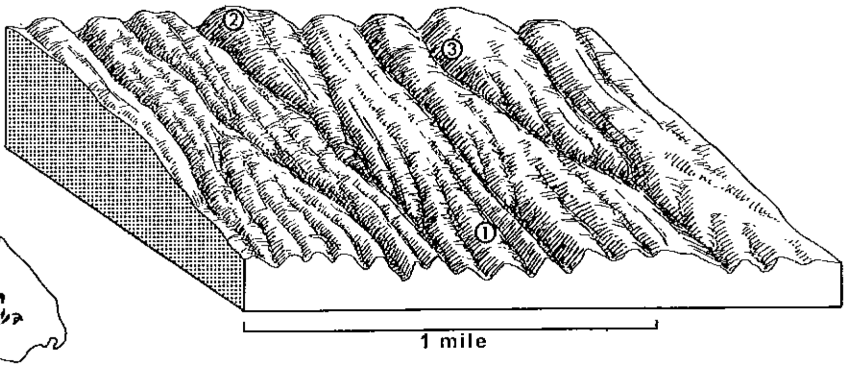
Dissected moderately steep volcanic debris slopes.

Geomorphology.—Debris slopes on Pleistocene or Recent volcanoes, largely dissected to form a very fine pattern of radiating bifurcating low ridges. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., V; min., 1200 ft; max., 6000 ft. Relief: low (250 ft). Characteristic slope: very steep. Grain: very fine (300 ft). Plan-profile: 4L//.

Geology.—Andesitic lava, ash, and agglomerate; Middle Pleistocene to Recent.

Distribution



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	9	Ridge crest: narrow or very narrow; uneven; crestal slope moderate	Ash soils: brown loams	III and VIe$_{8,6}$ A4/R_S	Palm and pandan vegetation (*Gulubia–Pandanus*) and mountain low forest; northern occurrence commonly with scrub (*Cyathea–Bambusa*); lower altitudes: mid-height forest (*Garcinia–Elaeocarpus*) and tall forest (*Neonauclea–Sloanea*)
2	16	Debris slope: up to 2 miles long and ½ mile wide; concave; moderate axial slope (6–17°); 10 ft irregular microrelief, forming steep local slopes	As unit 1 Locally on gentler slopes, brown loams with an ash pan	As unit 1 IIIe$_3$,d$_2$ A4/R_S	Palm and pandan vegetation (*Gulubia–Pandanus*), scrub (*Cyathea–Bambusa*), and mid-height forest (*Garcinia–Elaeocarpus*)
3	90	Hill slope: short; straight; very steep to precipitous	Ash soils: brown loams Minor rock outcrop	VIIIe$_8$ A4/R_S	As unit 1

Population and Land Use.—Nil.

Forest Potential.—17 sq miles mid-altitude upland forest, moderate yield, on units 1 and 3; 6 sq miles high-altitude upland forest, low yield, on units 1–3. Access category III.

Observations.—2, plus 3 aerial observations.

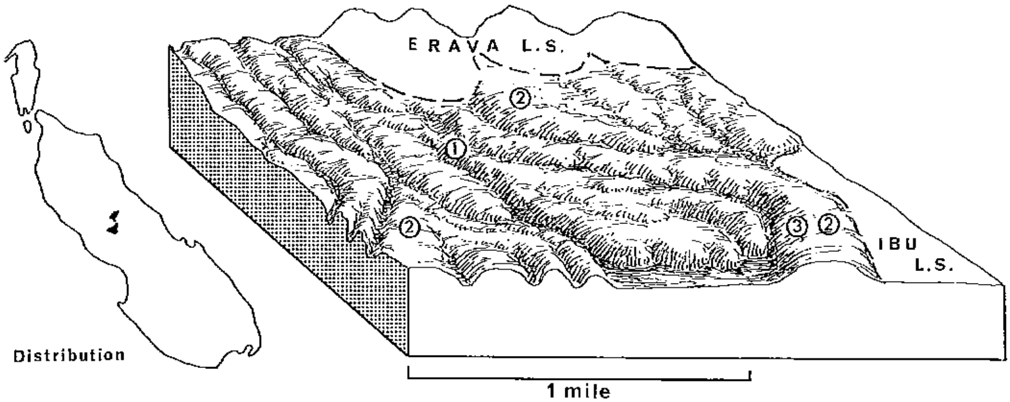
(17) Sisivi Land System (10 sq miles)

Moderately high very steep-sided lava ridges and plateaux.

Geomorphology.—Low or moderately high dendritic or radiating ridges and plateaux resulting from partial dissection of fields of gently sloping lava flows. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., IV; min., 1200 ft; max., 3000 ft. Relief: moderately high (400 ft). Characteristic slope: very steep. Grain: fine (600 ft). Plan-profile: 4L.

Geology.—Andesitic lava and agglomerate; Upper Pleistocene or Recent. Overlain by thick superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	**Ridge crest:** very narrow or narrow (20–150 ft); uneven; low-moderate crestal slope (6–10°)	Ash soils: brown loams with lapillitic horizons	$IIIe_3,n_2$ A4/A1/A4	Tall forest (*Neonauclea–Sloanea*) and secondary forest (*Artocarpus–Albizia*); minor mid-height forest (*Garcinia–Elaeocarpus*)
2	3½	**Plateau:** very gentle to low-moderate slope (1–8°); up to 1500 ft wide; up to 20 ft undulating microrelief, shallow gullies		$II–IIIe_{2–3},n_2$ A4/A1/A4	Extensively cultivated, regrowth up to secondary forest (*Artocarpus–Albizia*)
3	5½	**Hill slope:** short; straight or irregular; very steep (34–38°); steep spurs, and precipitous slump alcoves at heads of closely spaced gullies		$VIIIe_3,n_2$ A4/A1/A4	As unit 1

Population and Land Use.—450 people currently using 1·1 sq miles mostly on unit 2.

Forest Potential.—4 sq miles mid-altitude upland forest, moderate yield, on units 1 and 3; 2 sq miles low-altitude upland forest, moderate yield, on units 1 and 3. Access category III.

Observations.—9.

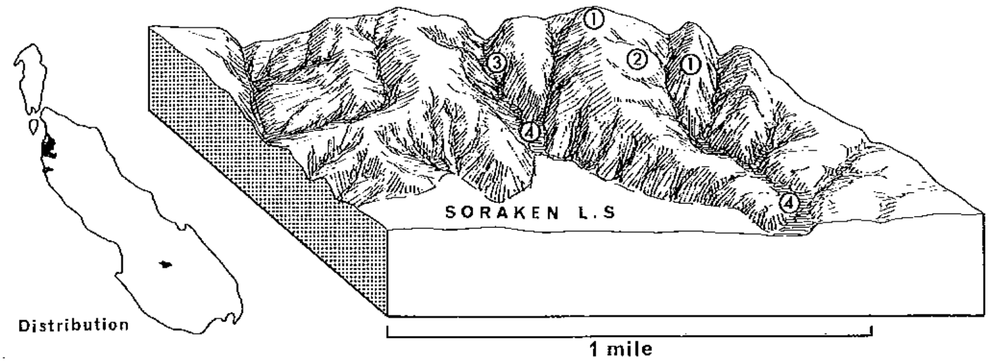
(18) Puto Land System (35 sq miles)

Moderately high steep lava ridges with red clay subsoils.

Geomorphology.—Low or moderately high dendritic or radiating ridges resulting from partial dissection of fields of gently sloping lava flows. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 2000 ft. Relief: moderately high (400 ft). Characteristic slope: steep. Grain: fine (800 ft). Plan-profile: 4L.

Geology.—Andesitic lava and agglomerate; Middle Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	3½	Ridge crest: knife-edged to narrow (10–150 ft); uneven; crestal slope gentle to low-moderate (2–10°)	Ash-covered soils: brown loams over reddish friable clays	$II–IIIe_{2-3}$ A4/A6	Tall forest (*Vitex–Pometia*); secondary forest (*Artocarpus–Albizia*)
2	9	Upper hill slope: short (300 ft); convex; moderate (8–15°); moderately sloping spurs and gullies		VIe_6 A4/A6	
3	20	Lower hill slope: short (300 ft); straight or concave; mainly steep (17–38°); moderately sloping inconspicuous spurs, and gullies	Ash-covered soils: brown loams over reddish friable clays Acid clay soils: red friable clays Locally on steeper slopes, ash soils: brown loams	$VIIe_7$ A4/A6 $VIIe_7$ A6 $VIIIe_8$ $A4/R_S$	
4	2½	Valley floor: ultra-high gradient: up to 500 ft wide; terraces up to 50 ft above stream level; undulating microrelief forming moderate local slopes	Ash soils: brown loams	II or VIe_2 or e_5 $A4/R_S$	

Population and Land Use.—600 people currently using 1·6 sq miles mostly on unit **4**, rarely on units 1–3.
Forest Potential.—3 sq miles low-altitude upland forest, moderate to high yield, on units 1–4. Access category IIa (steepest slopes, unit 3).
Observations.—9.

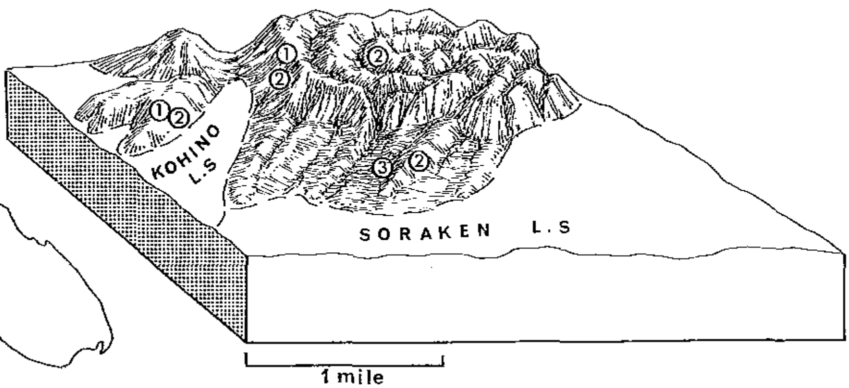
(19) Umum Land System (20 sq miles)

Moderately high steep lava ridges with brown clay subsoils.

Geomorphology.—Low or moderately high dendritic or radiating ridges resulting from partial dissection of lava flows and irregular mesa-like volcanic cumulo domes, and from dissection of bodies of diorite. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 500 ft. Relief: moderately high (400 ft). Characteristic slope: steep. Grain: fine (800 ft). Plan-profile: 4L.

Geology.—Andesitic lava; Middle Pleistocene. Diorite; age obscure.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1½	Ridge crest: very narrow or narrow (20–100 ft); uneven; gentle to low-moderate crestal slope	Ash-covered soils: brown loams over brown friable clays. Common bouldery outcrop	Ve$_{2-3}$,r$_5$ A4/A6	Tall forest (*Vitex–Pometia*), secondary forest (*Artocarpus–Albizia*); areas with outcrops; secondary scrub (*Macaranga–Bambusa*). Minor areas with mid-height grassland (*Imperata–Themeda*)
2	18	Hill slope: very short to medium length; straight; steep (20–25°)	Ash soils: brown loams Ash-covered soils: brown loams over brown friable clays. Common bouldery outcrop	VIIe$_7$,r$_5$ A4/R$_S$ VIIe$_7$,r$_5$ A4/A6	
3	½	Valley floor: ultra-high gradient; up to 500 ft wide; 3–10 ft of terraced microrelief	Ash-covered soils: brown loams over brown friable clays	IIe$_2$ A4/A6	Tall forest (*Vitex–Pometia*)

Population and Land Use.—No population; some minor gardening. 0·9 sq mile of non-indigenous plantations.

Forest Potential.—6 sq miles low-altitude upland forest, moderate to high yield, on units 1–3. Access category II.

Observations.—6.

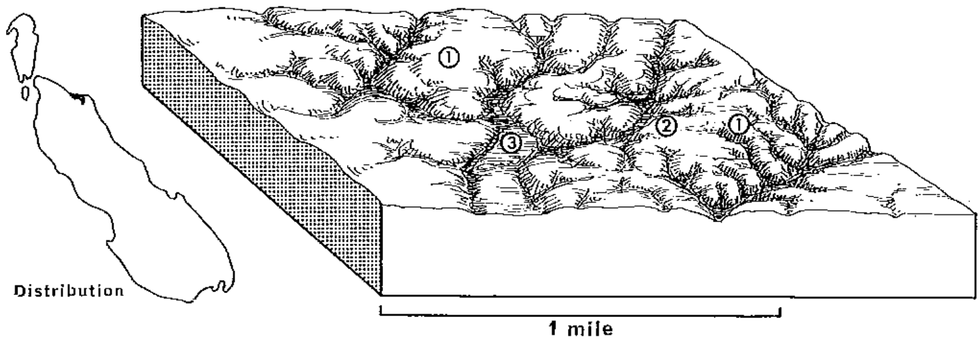
(20) Dios Land System (10 sq miles)

Lowland of very closely spaced ridges with occasional flood-plains.

Geomorphology.—Lowland situated between raised coral reef and old volcanic fan, in large part very finely dissected to form very low dendritic ridges. Gravelly small streams of ultra-high gradient normally less than 15 ft wide and 1 ft deep.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 100 ft. Relief: very low (100 ft). Characteristic slope: steep. Grain: very fine (300 ft). Plan-profile: 4L.

Geology.—Coral and volcanic debris; Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	3	Ridge crest: narrow or broad; uneven; gentle crestal slopes (3°)	Ash-covered soils: brown loams over brown friable clays	IIe_3 A4/A6	Tall forest (*Vitex–Pometia*), largely cleared for coconut–cacao plantations
2	6	Hill slope: very short (150 ft); steep (20–33°); steep spurs (20°)	As unit 1 On steeper slopes, lithosols	$VIIe_7$ A4/A6 $VIIIe_8$ R_S	
3	1	Flood-plain: high gradient; less than 1000 ft wide; locally up to 10 ft of terraced microrelief	Alluvial soils: stratified mottled loams and clays	$IIId_3,f_3$ A4 or A6	

Population and Land Use.—250 people currently using 0·6 sq mile mostly on unit 1. 4·3 sq miles of non-indigenous plantations.

Forest Potential.—1 sq mile low-altitude upland forest, moderate to high yield, on units 1 and 2. Access category IIa (steepest slopes, unit 2).

Observations.—5.

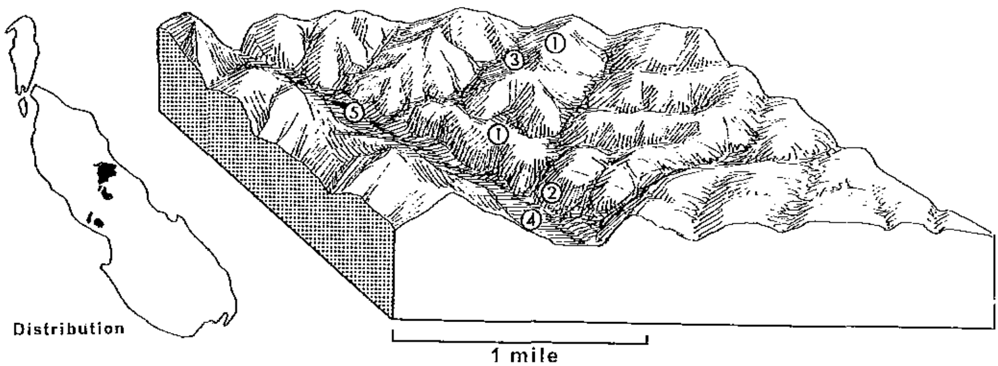
(21) Ibu Land System (45 sq miles)

Low dendritic ridges with both moderate and very steep slopes.

Geomorphology.—Low dendritic ridges formed of completely dissected laharic and volcano–alluvial deposits. Very steep slopes occur throughout the land system but moderate or gentle slopes are dominant, occurring either near ridge crests or near stream beds. Many incised bouldery torrents. Higher relief is associated with through-going rivers normally up to 15 ft wide and 6 in. deep.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 2500 ft. Relief: moderately high (300 ft). Characteristic slope: low-moderate. Grain: medium (1500 ft). Plan-profile: 4L.

Geology.—Probably andesitic lava, ash, and agglomerate; Middle Pleistocene. Overlain by thick superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	5	Ridge crest: very narrow (30–50 ft); even or uneven; gentle or low-moderate crestal slope (3–10°); locally bounded by breakaways	Ash soils: brown loams with lapillitic horizons	$II–IIIe_{2-3},n_2$ A4/A1/A4	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); much secondary forest (*Artocarpus–Albizia*)
2	14	Steeper slope: short; concave; very steep (35–45°), decreasing to steep (20°) at foot; prominent steep spurs (25°), and precipitous slump alcoves at gully heads	Ash soils. On steep slopes, brown loams with lapillitic horizons On very steep slopes, brown loams with minor rock outcrop	$VIIe_7,n_2$ A4/A1/A4 $VIIIe_8,r_3$ $A4/R_S$	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); much secondary forest (*Artocarpus–Bambusa*)
3	23	Gentler slope: short (400 ft); straight; gentle or moderate (2–14°); 10 ft undulating microrelief	Ash soils: brown loams with lapillitic horizons	II–III or VIe_{2-3} or e_6,n_2 A4/A1/A4	As unit 1
4	2	Flood-plain: "major bed" very high gradient; up to 800 ft wide; recessed; 20 ft channelled relief; locally with terrace remnant up to 50 ft above stream bed	Alluvial soils: brown mottled sands (stony phase). Water-table 0–10 ft	$VIIId_5,st_8$ A3+B	Tall forest (*Terminalia brassii*)
5	1	River bed: very high gradient; up to 200 ft wide and 6 ft deep; gravel bars and flood channels	Boulders	$VIIIst_8$ B+C	On high bars, mixed herbaceous vegetation (*Paspalum–Cassia*) and tall grass vegetation (*Saccharum robustum*)

Population and Land Use.—1200 people currently using 3·1 sq miles (10% for cash crops) mostly on units 1 and 3, and adjacent parts of Mafahia land system.

Forest Potential.—25 sq miles low-altitude upland forest, moderate to high yield, on units 1–3; small stands *Terminalia brassii* forest, high yield, on unit 4. Access category IIa (very steep slopes, unit 2).

Observations.—9.

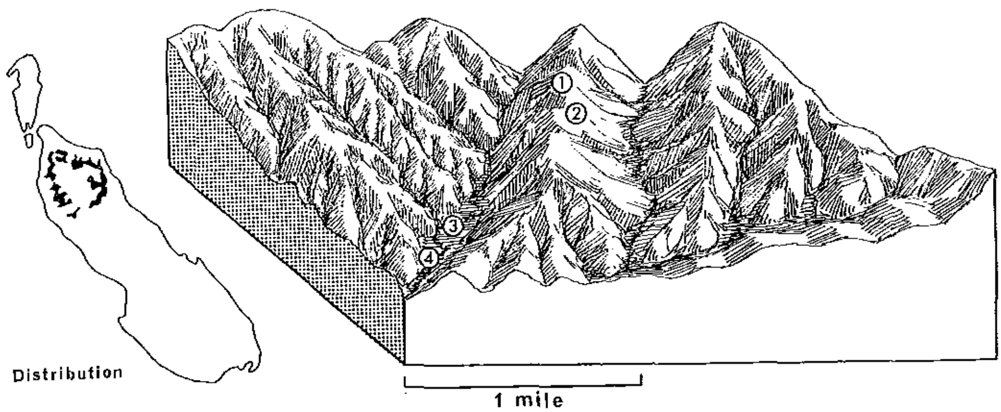
(22) Tumuri Land System (120 sq miles)

High ridges of eroded volcanoes, at low altitude.

Geomorphology.—High ridges eroded from laharic and nuée deposits of the moderate slopes of former volcanoes with radial or dendritic drainage pattern of incised bouldery torrents, and larger through-going rivers normally up to 30 ft wide and 6 in. deep, sometimes with multiple channels.

Terrain Parameters.—Altitude: H.I., III; min., 500 ft; max., 2500 ft. Relief: high (600 ft). Characteristic slope: very steep. Grain: mainly fine (900 ft). Plan-profile: 4*L*//.

Geology.—Volcanic debris; Middle Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	16	**Ridge crest**: very narrow; uneven; moderate or steep crestal slope (up to 21°)	Ash soils: brown loams	VIe_6 $A4/R_S$	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); some gardening and cash cropping
2	100	**Hill slope**: short or medium length; straight or convex; very steep to precipitous (44°); closely spaced steep spurs, and slump alcoves at gully heads		$VIIIe_8$ $A4/R_S$	
3	3	**Flood-plain**: ultra-high gradient; up to 300 ft wide; 10 ft channelled microrelief; recessed	Alluvial soils: brown mottled sands (stony phase)	VIf_4,st_6 A3+B	Tall forest (*Terminalia brassii*)
4	1	**River bed**: ultra-high gradient; up to 120 ft wide and 5 ft deep; with channel bars	Boulders	$VIIIst_8$ B	Nil

Population and Land Use.—850 people currently using 2·2 sq miles on units 1 and 2.

Forest Potential.—78 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 12 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 1 sq mile *Terminalia brassii* forest, high yield, on unit 3. Access category III.

Observations.—4.

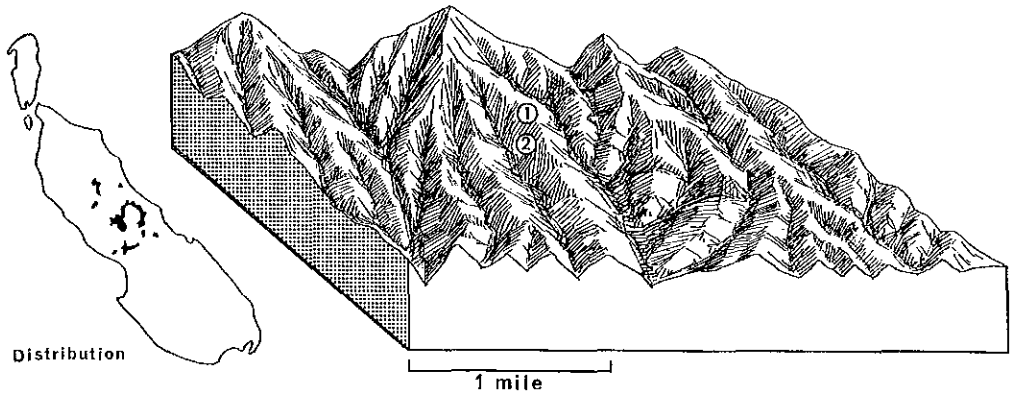
(23) Mafahia Land System (50 sq miles)

Moderately high ridges of eroded volcanoes, at low altitude.

Geomorphology.—Moderately high ridges eroded from laharic and nuée deposits of the moderate slopes of former volcanoes with radial or dendritic drainage pattern of incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., IV; min., 300 ft; max., 2000 ft. Relief: moderately high (500 ft). Characteristic slope: precipitous. Grain: fine (900 ft). Plan-profile: 4L//.

Geology.—Volcanic debris; Middle Pleistocene. Superficial ash with a lapilli layer; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	5	**Ridge crest:** very narrow; uneven; moderate crestal slope (5–15°)	Ash soils: brown loams with lapillitic horizons	III or VIc$_3$ or c$_6$,n$_2$ A4/A1/A4	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*)
2	45	**Hill slope:** short; straight or convex; very steep to precipitous (40–70°); closely spaced steep spurs (30°), and slump alcoves at gully heads	As unit 1 On steeper slopes, ash soils: brown loams, with local rock outcrop	VIIIc$_8$,n$_2$ A4/A1/A4 VIIIe$_8$,r$_3$ A4/R$_S$	As above; tall forest (*Terminalia brassii*) fringing incised torrents

Population and Land Use.—No population, but 0·6 sq mile currently used by population on Ibu land system.

Forest Potential.—19 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 6 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield, on unit 2. Access category III.

Observations.—2.

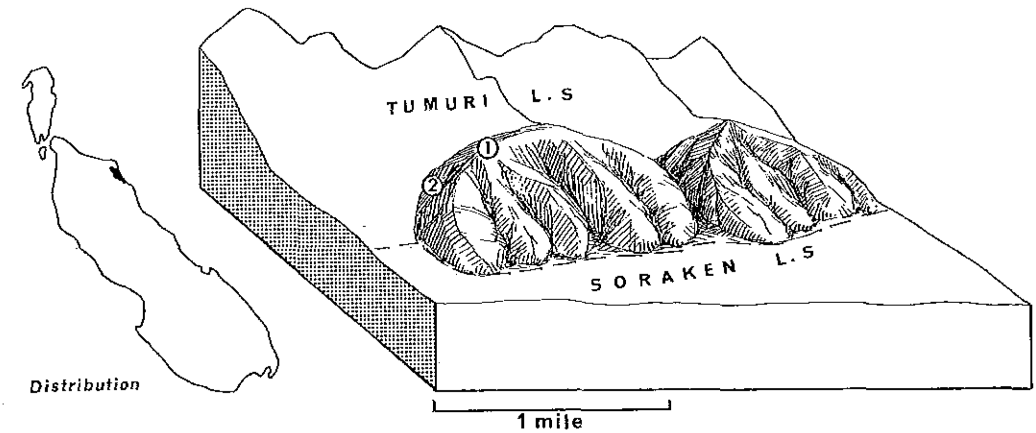
(24) Teopasino Land System (10 sq miles)

Moderately high subdued ridges.

Geomorphology.—Moderately high cuesta ridges of subdued aspect eroded from tilted volcanic rocks or greywacke. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., II; min., 0 ft; max., 800 ft. Relief: moderately high (300 ft). Characteristic slope: high-moderate. Grain: moderate (2000 ft). Plan-profile: 4L.

Geology.—Volcanic sandstone, andesitic lava and tuff, and dolerite; moderate eastward dip; (?)Oligocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	**Ridge crest**: narrow (100 ft); even; gentle or moderate crestal slope (2–17°)	Ash-covered soils: brown loams over reddish friable clays. Common rock outcrop	II–III or VIe_{2-3} or e_6,st_2 A4/A6	Regrowth in various stages; young secondary forest (*Kleinhovia–Hibiscus*) and secondary forest (*Artocarpus–Albizia*)
2	9	**Hill slope**: short (250–500 ft); straight; undulating microrelief; dip slopes moderate (12–17°), escarpments steep (23°)		$VI–VIIe_{6-7}$ A4/A6	As above; tall forest (*Terminalia brassii*) lining incised torrents

Population and Land Use.—No population. 0·9 sq mile of non-indigenous plantations.

Forest Potential.—5 sq miles low-altitude upland forest, moderate to high yield, on units 1 and 2; small stands *Terminalia brassii* forest high yield, on unit 2. Access category II.

Observations.—2.

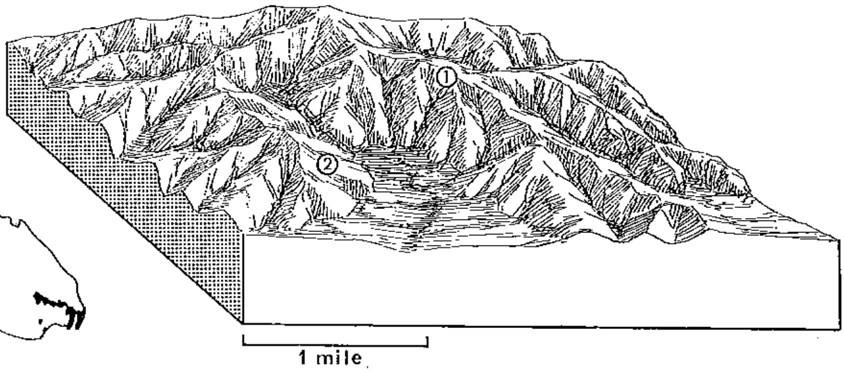
(25) Deuro Land System (100 sq miles)

Coarse-grained high dendritic ridges.

Geomorphology.—High dendritic ridges eroded from various folded volcanic rocks. Homoclinal ridges and fault-line scarps form structural lineaments. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 2500 ft. Relief: high (700 ft). Characteristic slope: steep. Grain: coarse (3000 ft). Plan-profile: 4L.

Geology.—Volcanic sandstone, andesitic lava and tuff, and dolerite; moderate dips, mainly to the west; (?)Oligocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	5	**Ridge crest**: very narrow or narrow (15–50 ft); very uneven; variable moderate crestal slope (5–25°)	On Deuro Range, acid clay soils: brown friable clays Locally lithosols, with frequent rock outcrop On Buka, Madehas, and Taiof Islands, ash-covered soils: brown loams over brown friable clays	IIIe$_3$ A6/R$_S$ VII–VIIIe$_7$,r$_{6-8}$ R$_S$ IIIe$_3$ A4/A6	Tall forest (*Vitex–Pometia*, *Neonauclea–Sloanea* at higher altitudes); moderate areas of gardens and regrowth, the latter in areas with rock outcrops, secondary scrub (*Macaranga–Bambusa*)
2	95	**Hill slope**: medium length (500–1000 ft); irregular; mainly steep (12–40°); with spurs of moderate crestal slope; slump microrelief of scarps and hummocks common, especially in re-entrants		VI–VIIIe$_{6-8}$,r$_6$ A4/A6	As above; tall forest (*Terminalia brassii*) lining incised torrents

Inclusions.—Kohina land system.

Population and Land Use.—175 people currently using 2·5 sq miles of lower sections of unit 2. Additionally, approx. 300 people living on adjacent parts of Soraken land system use this land system. 0·7 sq mile of non-indigenous plantation.

Forest Potential.—67 sq miles low-altitude upland forest, moderate to high yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield, on unit 2. Access category IIa (very steep slopes and slump alcoves, unit 2).

Observations.—13, including 7 on unit 2.

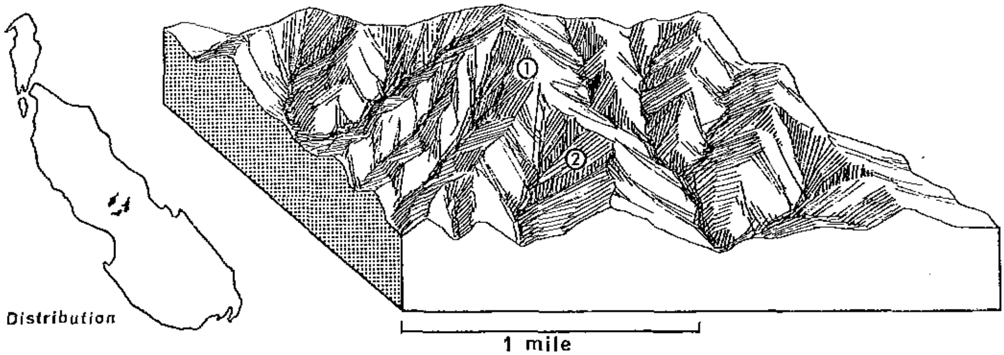
(26) Bagana Land System (15 sq miles)

Dendritic ridges subject to frequent ash showers.

Geomorphology.—Moderately high dendritic ridges with very fine-textured drainage pattern of incised streams, subject to frequent severe ash showers. *Incised bouldery torrents.*

Terrain Parameters.—Altitude: H.I., IV; min., 600 ft; max., 4000 ft. Relief: moderately high (400 ft). Characteristic slope: very steep. Grain: fine (800 ft). Plan-profile: 4L.

Geology.—Probably andesitic lava ash and agglomerate; Middle Pleistocene. Overlain by thick stony ash; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	Ridge crest: very narrow (15 ft); very uneven; moderate or steep crestal slope (10–25°)	Ash soils: grey fine sands (stony phase)	VIe$_6$,st$_6$,n$_2$ A3+C	Scrub (*Cyathea–Bambusa*); on ridges adjacent to Balbi land system, mixed herbaceous vegetation (*Lycopodium–Gleichenia*)
2	14	Hill slope: short or very short; straight; very steep (40°)		VIIIe$_8$,st$_8$,n$_2$ A3+C	

Population and Land Use.—Nil.
Forest Potential.—No forest. Access category III.
Observations.—2.

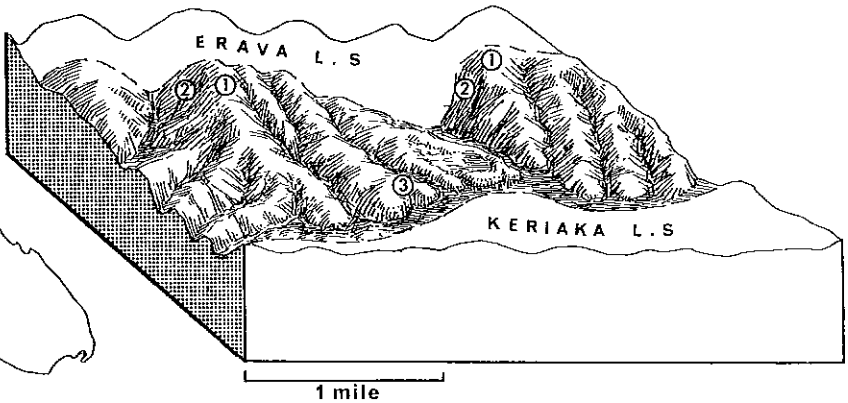
(27) Doiabi Land System (15 sq miles)

Moderately high ridges covered with bamboo scrub.

Geomorphology.—Moderately high dendritic ridges with steep upper slopes and finely dissected very steep lower slopes, eroded from older sedimentary rocks. Topographically recessive below Keriaka land system. Thick ash tends to choke the valleys, forming a lake at one point. Incised bouldery torrents, commonly with travertine dams.

Terrain Parameters.—Altitude: H.I., IV; min., 300 ft; max., 4500 ft. Relief: high (700 ft). Characteristic slope: steep. Grain: medium (2000 ft). Plan-profile: 4L.

Geology.—Fine-grained volcanic sandstone; Palaeogene–Mesozoic. Superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	1	Ridge crest: very narrow; uneven; moderate crestal slope	Ash soils: brown loams with lapillitic horizons	III or VIe$_3$ or e$_6$,n$_2$ A4/A1/A4	Scrub (*Cyathea–Bambusa*); locally tall forest (*Neonauclea–Sloanea*) or secondary forest (*Artocarpus–Bambusa*, *Artocarpus–Albizia*)
2	5	Upper hill slope: very short; straight; steep (25°)		VIIe$_7$, n$_2$ A4/A1/A4	
3	9	Lower hill slope: short; straight; very steep (40–45°); closely spaced steep spurs		VIIIe$_8$,n$_2$ A4/A1/A4	

Population and Land Use.—Nil.

Forest Potential.—2 sq miles mid-altitude upland forest, moderate yield, on units 1–3. Access category III.

Observations.—3.

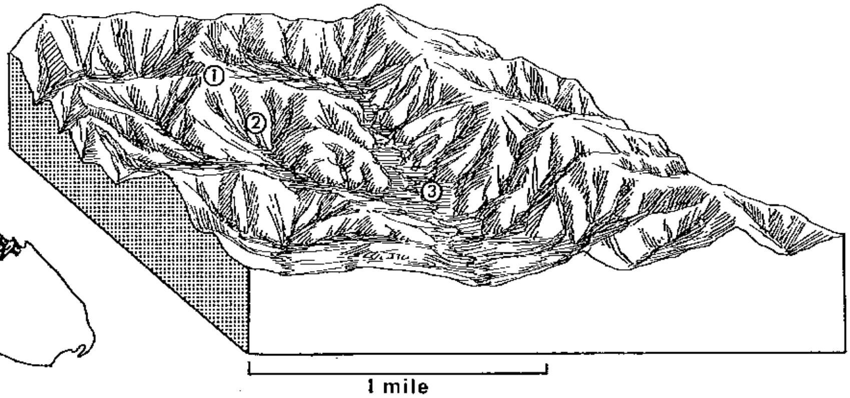
(28) Boira Land System (100 sq miles)

High ridges on older sedimentary rocks, with lapillitic ash soils.

Geomorphology.—High dendritic to subparallel ridges, eroded from a variety of steeply dipping rocks. Hogbacks and homoclinal ridges common. Bouldery torrents up to 20 ft wide and 6 in. deep, mainly incised.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 3500 ft. Relief: high (1000 ft). Characteristic slope: very steep. Grain: medium (1500 ft). Plan-profile: 4L.

Geology.—Volcanic sandstone, siltstone, and marl; strike N., dips near vertical; local minor intrusions; Palaeogene–Mesozoic. Superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	6	Ridge crest: very narrow (15–20 ft); uneven; gentle to moderate crestal slope (3–20°)	Ash soils: brown loams with lapillitic horizons	III or VIe$_3$ or e$_6$,n$_2$ A4/A1/A4	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*) and secondary forest (*Artocarpus–Albizia*); above 2500 ft, mid-height forest (*Garcinia–Elaeocarpus*)
2	90	Hill slope: very short (200 ft); straight; very steep (35°); closely spaced prominent steep spurs		VII–VIIIe$_{7-8}$,n$_2$ A4/A1/A4	
3	4	Valley floor: ultra-high gradient; up to 500 ft wide; 3–10 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase)	VIIIf$_8$,st$_8$ A3+B	Tall forest (as above or *Terminalia brassii*)

Population and Land Use.—1250 people currently using 3·4 sq miles of lower sections of units 1 and 3. 0·7 sq mile of non-indigenous plantations.

Forest Potential.—28 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 7 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield, on unit 3. Access category III.

Observations.—3.

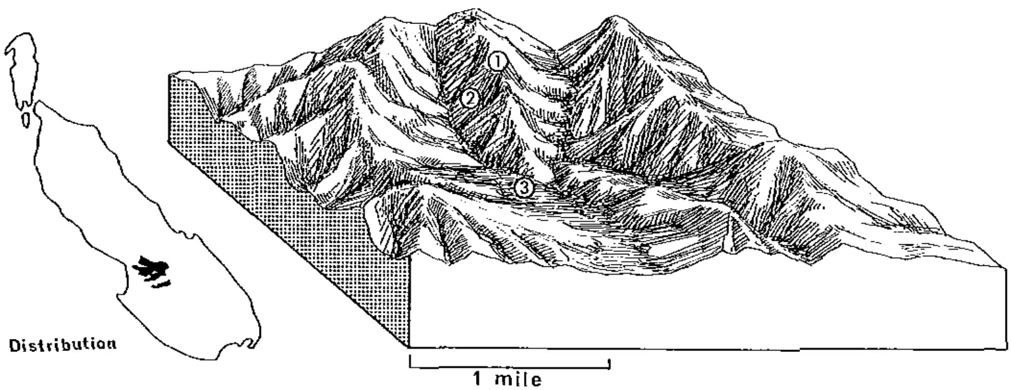
(29) MAINOKI LAND SYSTEM (50 SQ MILES)

High ridges on older sedimentary rocks.

Geomorphology.—High dendritic ridges eroded from a variety of steeply dipping rocks. Poorly developed karst land forms occur locally. Bouldery torrents up to 20 ft wide and 6 in. deep, mainly incised.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 2500 ft. Relief: high (900 ft). Characteristic slope: very steep. Grain: medium (2000 ft). Plan-profile: 4L.

Geology.—Limestone, volcanic sandstone, siltstone, and marl; strike N., dips near vertical; local minor intrusions; Palaeogene–Mesozoic.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	3	**Ridge crest:** very narrow (15–50 ft); uneven; gentle to moderate crestal slope (3–20°)	Ash soils: brown loams Lithosols, with minor rock outcrop	$IIIe_3$ $A4/R_S$ VIe_{6},r_2 R_S	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*) and secondary forest (*Artocarpus–Albizia*)
2	45	**Hill slope:** very short (200 ft); straight, very steep (35°); closely spaced prominent steep spurs; some precipitous faces	Ash soils: brown loams Locally lithosols, with variable rock outcrop	$VII–VIIIe_{7-8}$ $A4/R_S$ $VIIIe_{8},r_5$ R_S	
3	2	**Valley floor:** ultra-high gradient; up to 500 ft wide; 3–10 ft channelled microrelief	Alluvial soils: brown mottled sands (stony phase)	$VIIIf_{8},st_{8}$ A3+B	Tall forest (*Vitex–Pometia, Terminalia brassii*)

Population and Land Use.—500 people currently using 1·0 sq mile mostly on units 1 and 2.

Forest Potential.—8 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 7 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 1 sq mile *Terminalia brassii* forest, high yield, on unit 3. Access category III.

Observations.—3.

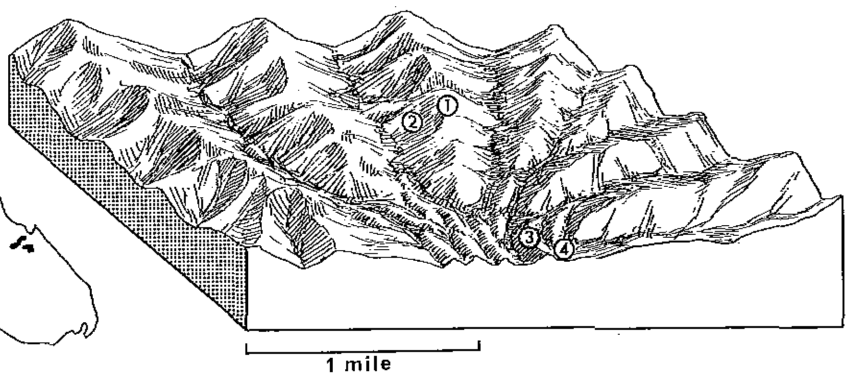
(30) POMAUA LAND SYSTEM (10 SQ MILES)

Structurally controlled high ridges.

Geomorphology.—High structurally controlled subparallel ridges eroded from a variety of steeply dipping rocks. Major ridges trend NNW.; secondary ridges and spurs trend WNW. Incised bouldery torrents normally up to 20 ft wide and 6 in. deep.

Terrain Parameters.—Altitude: H.I., IV; min., 500 ft; max., 2500 ft. Relief: high (700 ft). Characteristic slope: very steep. Grain: medium (1500 ft). Plan-profile: 4L//.

Geology.—Volcanic sandstone, siltstone, and marl with prominent fractures trending WNW.; Palaeogene–Mesozoic. Profuse surface debris of plateau volcanics; (?) Miocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	½	Ridge crest: very narrow (15–30 ft); *uneven; steep crestal slope* (15–25°)	Ash soils: brown loams	$VIIe_7$ A4/Rs	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*) and secondary forest (*Artocarpus–Bambusa, Artocarpus–Albizia*)
2	10	Hill slope: medium length (700 ft); straight; very steep (40–45°); closely spaced prominent steep spurs on lower parts, locally associated with short steep hill slopes (20°)		$VII–VIIIe_{7–8}$ A4/Rs	
3	<½	Valley floor ridge crest: broad (100 ft); even; gentle to moderate crestal slope (4–10°)		$IIIe_3,st_3$ A4/Rs	Tall forest (*Vitex–Pometia*); largely cultivated; locally secondary scrub (*Saurauja conferta*)
4	<½	Valley floor ridge slope: very short (50 ft); straight; moderate (10–17°)		VIe_6,st_5 A4/Rs	

Population and Land Use.—250 people currently using 0·6 sq mile of units 1, 3, and 4.
Forest Potential.—6 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2. Access category III.
Observations.—6.

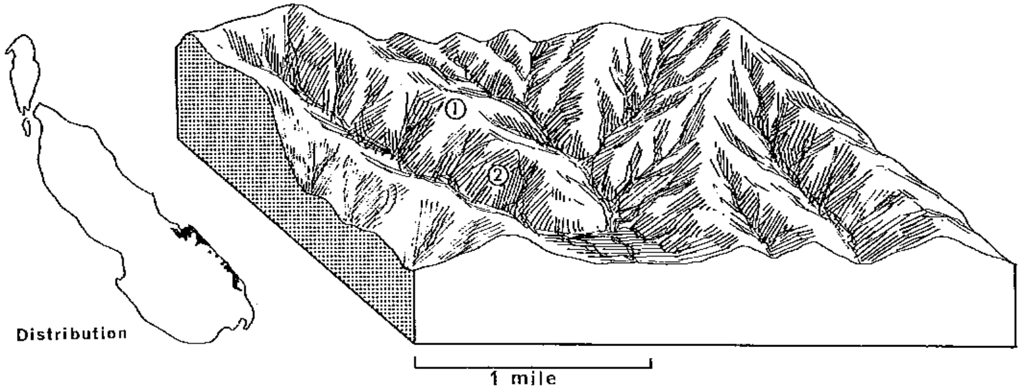
(31) Osirei Land System (60 sq miles)

Coarse-grained high subparallel ridges.

Geomorphology.—High subparallel ridges of coarse grain, eroded from deeply weathered volcanic rocks. Long steep slopes dominated by slumping are only shallowly dissected by a finely dendritic pattern of bouldery torrents.

Terrain Parameters.—Altitude: H.I., III; min., 0 ft; max., 2500 ft. Relief: high (700 ft). Characteristic slope: steep. Grain: coarse (3000 ft). Plan-profile: 4L//.

Geology.—(?)Andesitic agglomerate; Palaeogene–Mesozoic. Profuse surface debris of plateau volcanics; (?)Miocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	2	**Ridge crest:** narrow (50–100 ft); uneven; gentle or moderate crestal slope (5°, rarely 15°); some boulders	Ash-covered soils: brown loams over reddish friable clays Acid clay soils: red friable clays	$IIIe_3,st_2$ A4/A6 $IIIe_3,st_2$ A6	Gardens and plantations, regrowth in various stages, secondary forest (*Artocarpus–Bambusa*, *Artocarpus–Albizia*); at highest altitudes, tall forest (*Neonauclea Sloanea*)
2	58	**Hill slope:** very variable length (100–1500 ft); irregular, mainly steep (20°); 3 ft hummocky microrelief and inconspicuous steep spurs. Shallow slumping common; tunnelling occurs in re-entrants	Ash-covered soils: brown loams over reddish friable clays	$VIIe_7$ A4/A6	As above; tall forest (*Terminalia brassii*) along torrents

Inclusions.—Soraken land system.

Population and Land Use.—3050 people currently using 7 sq miles (<5% for cash crops) on units 1 and 2. 1·8 sq miles non-indigenous plantations on Soraken land system inclusions.

Forest Potential.—7 sq miles low-altitude upland forest, moderate to high yield, on units 1 and 2; 1 sq mile mid-altitude upland forest, moderate yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield, on unit 2. Access category II.

Observations.—5.

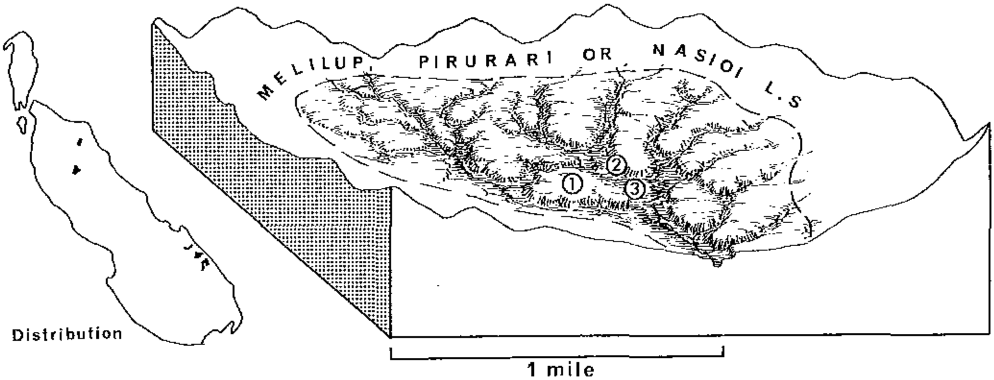
(32) TOROMBEI LAND SYSTEM (15 SQ MILES)

Sloping dissected basin floors.

Geomorphology.—Basin fills of mudflow debris now stabilized and subject to very shallow dissection by subparallel streams; superficial thin volcanic ash. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., IV; min., 100 ft; max., 2500 ft. Relief: low (150 ft). Characteristic slope: low-moderate. Grain: very fine (400 ft). Plan-profile: 1L//.

Geology.—*Mudflow debris, mainly volcanic; Upper Pleistocene.*



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	10	Terrace: of gentle or moderate slope (2–10°); 200–800 ft wide; 2 ft hummocky relief and fields of boulders and blocks	Ash soils: brown loams with an ash pan Local boulder fields	II–IIIe_{2-3},d_2 A4/R_S VIIIst_8 B	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); locally intensively gardened and planted to coconuts and cacao
2	4	Terrace-front slope: very short (30–200 ft); steep or very steep (20–45°)	On steep slopes: brown loams On very steep slopes: lithosols, with local rock outcrop	VIIe_7 A4/R_S VIIIe_8,r_5 R_S	
3	1	Valley floor: of gentle or moderate slope (8°); about 100 ft wide; 6 ft channelled relief	Alluvial soils: brown mottled sands (stony phase)	VIIIf_6,st_8 A3+B	Tall forest (*Terminalia brassii*); locally secondary scrub (*Saurauja conferta*)

Population and Land Use.—550 people currently using 3·1 sq miles (15% for cash crops) on units 1 and 2. Additionally, approx. 600 people living on surrounding land systems use this land system. *1·1 sq miles of non-indigenous plantations.*

Forest Potential.—4 sq miles low-altitude upland forest, high yield, on units 1 and 2; 3 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield, on unit 3. Access category I (occurrences in Aita and Aruai valleys inaccessible).

Observations.—7.

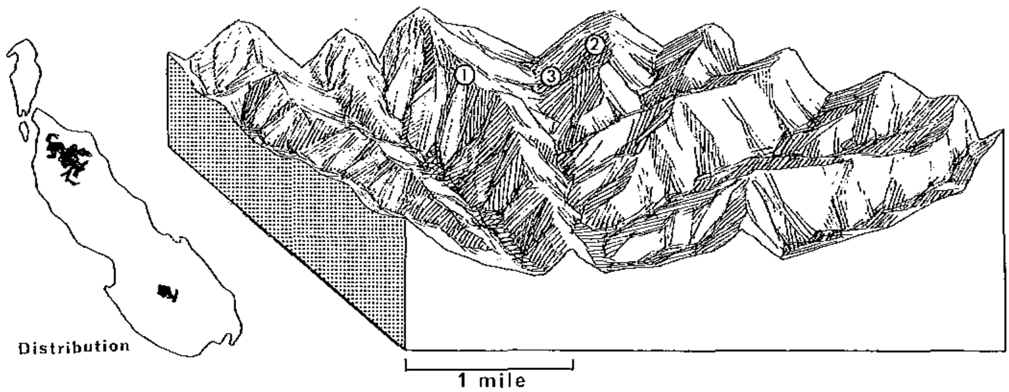
(33) Melilup Land System (190 sq miles)

High ridges of eroded volcanoes with lithosols.

Geomorphology.—High or very high radiating or dendritic ridges eroded from the central parts of former volcanoes. Some high-altitude areas have only moderately high ridges without precipitous lower slopes. Incised bouldery torrents with many waterfalls.

Terrain Parameters.—Altitude: H.I., IV; min., 2000 ft; max., 7000 ft. Relief: very high (1200 ft). Characteristic slope: precipitous. Grain: coarse (2000–3000 ft). Plan-profile: 4L.

Geology.—Andesitic lava, ash, and agglomerate; Middle Pleistocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	10	Ridge crest: knife-edged or very narrow (5–50 ft); stepped; variable steep crestal slope (5–45°)	Lithosols. Locally ash soils: brown loams	III or VI–VIIIe$_3$ or e$_{6-8}$,r$_2$ R_S or A4/R_S	Mid-height forest (*Garcinia–Elaeocarpus*); locally scrub (*Cyathea–Bambusa*); at high altitudes palm and pandan vegetation (*Gulubia–Pandanus*), and mountain scrub and low forest; below 2500 ft, tall forest (*Neonauclea–Sloanea*)
2	110	Upper hill slope: short; straight; very steep (42°); very steep spurs; terracettes		VIIIe$_8$,st$_3$ R_S or A4/R_S	
3	70	Lower hill slope: short or medium length; straight; precipitous (45–70°); debris slide scars	Lithosols, with local rock outcrops	VIIIe$_8$,r$_2$ R_S	

Population and Land Use.—1050 people currently using 3·8 sq miles of lower parts of units 1 and 2.

Forest Potential.—98 sq miles mid-altitude upland forest, moderate yield, on units 1–3; 9 sq miles high-altitude upland forest, low yield, on units 1–3. Access category III.

Observations.—3, plus 2 aerial observations.

(34) Chambers Land System (35 sq miles)

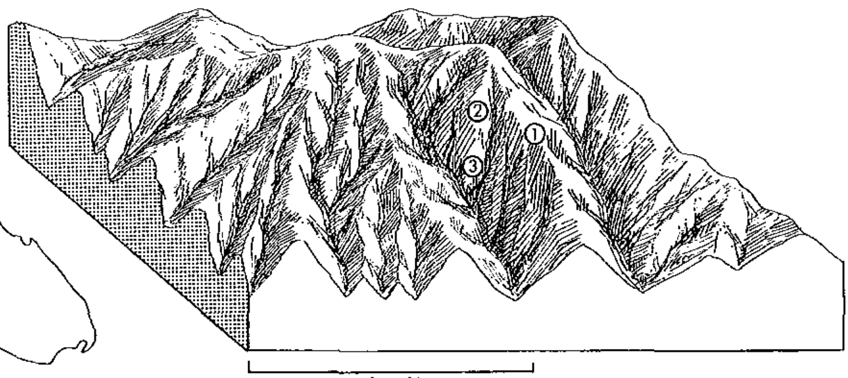
High ridges of eroded volcanoes with lapillitic ash soils.

Geomorphology.—High radiating or dendritic ridges eroded from the central parts of former volcanoes. Incised bouldery torrents with many waterfalls.

Terrain Parameters.—Altitude: H.I., V; min., 1500 ft; max., 5000 ft. Relief: high (750 ft). Characteristic slope: precipitous. Grain: medium (1000–2000 ft). Plan-profile: 4L.

Geology.—Andesitic lava, ash, and agglomerate; Middle Pleistocene. Superficial ash with layers of lapilli; Recent.

Distribution



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	2	Ridge crests: knife-edged or very narrow (5–50 ft); stepped; variable steep crestal slope (5–45°)	Ash soils: brown loams with lapillitic horizons	III or VI–VIIIe$_3$ or e$_{6-8}$,n$_2$ A4/A1/A4	Mid-height forest (*Garcinia–Elaeocarpus*); on exposed crests at high altitudes, palm and pandan vegetation (*Gulubia–Pandanus*)
2	17	Upper hill slope: short; straight; very steep (42°); very steep spurs; terracettes		VIIIe$_8$,n$_2$ A4/A1/A4	Mid-height forest (*Garcinia–Elaeocarpus*); tall forest (*Neonauclea–Sloanea*) below 2500 ft above sea level
3	16	Lower hill slope: short or medium length; straight; precipitous (45–70°); debris slide scars	Ash soils: brown loams, with local rock outcrops	VIIIe$_8$,r$_3$ A4/Rs	

Population and Land Use.—Nil.

Forest Potential.—19 sq miles high-altitude upland forest, low yield, on units 1–3; 16 sq miles mid-altitude upland forest, moderate yield, on units 2 and 3. Access category III.

Observations.—5.

(35) Emperor Land System (20 sq miles)

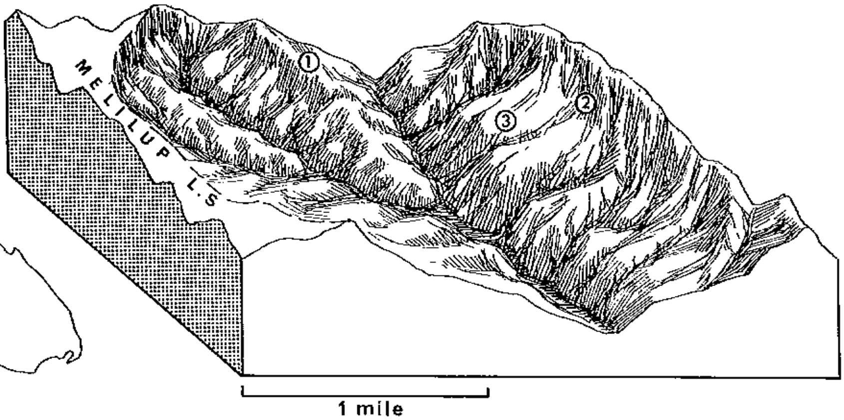
Broad steep-floored high-altitude basins.

Geomorphology.—Broad montane basins enclosed by precipitous ridges with irregular subplanar sloping floors largely destroyed by dissection. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., V; min., 2500 ft; max., 7000 ft. Relief: very high (1500 ft). Characteristic slope: very steep. Grain: coarse (3000 ft). Plan-profile: 4L.

Geology.—Andesitic lava, ash, and agglomerate; Middle Pleistocene.

Distribution



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	½	Ridge crest: knife-edged or very narrow; stepped; variable steep crestal slope	Lithosols Ash soils: brown loams	VIIe$_7$ R$_S$ VIIe$_7$ A4/R$_S$	Palm and pandan vegetation (*Gulubia–Pandanus*); some scrub (*Cyathea–Bambusa*) and mountain scrub and low forest
2	10	Steeper slope: short; straight; precipitous; very steep spurs; debris slides	Lithosols, with local rock outcrop	VIIIe$_8$,r$_3$ R$_S$	
3	10	Gentler slope: medium length; undulating; moderate to steep	Ash soils: brown loams Locally lithosols	VI–VIIe$_{6-7}$ A4/R$_S$ VIIe$_7$ R	Scrub (*Cyathea–Bambusa*)

Population and Land Use.—125 people currently using 0·2 sq mile of units 1 and 3 and adjacent parts of Melilup land system.
Forest Potential.—2 sq miles mid-altitude upland forest, moderate yield, on unit 2. Access category III.
Observations.—4 aerial observations.

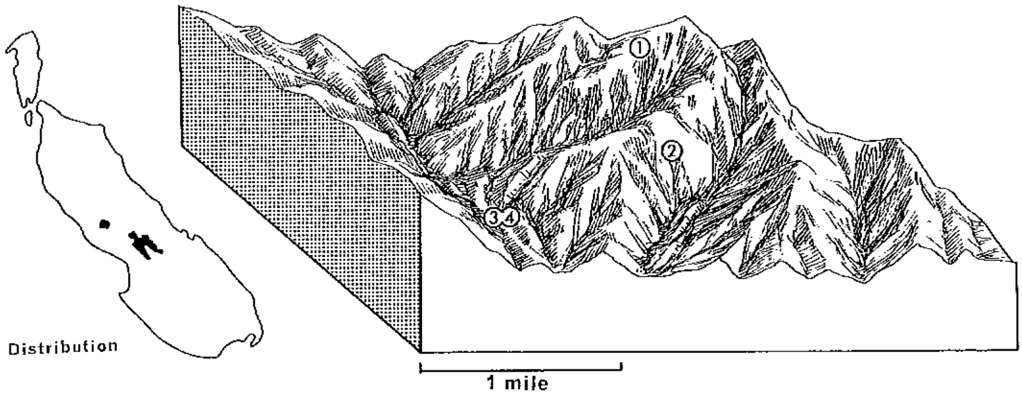
(36) Karato Land System (45 sq miles)

High dendritic ridges on older sedimentary rocks with lapillitic ash.

Geomorphology.—High dendritic ridges with very steep slopes and steep spurs leading down to moderately high dendritic ridges. Valley floors are dissected with very low ridges parallel to the valley axis. Bouldery torrents normally less than 50 ft wide, mainly incised.

Terrain Parameters.—Altitude: H.I., IV; min., 300 ft; max., 3800 ft. Relief: high (1000 ft). Characteristic slope: very steep. Grain: coarse (2500 ft). Plan-profile: 4L.

Geology.—Volcanic sandstone, tuff, and lava; Palaeogene–Mesozoic. Superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	3	Ridge crest: very narrow; very uneven; moderate to steep crestal slope	Ash soils: brown loams with lapillitic horizons	III or VI–VIIe$_3$ or e$_{6-7}$,n$_2$ A4/A1/A4	Mid-height forest (*Garcinia–Elaeocarpus*), tall forest (*Neonauclea–Sloanea*), secondary forest (*Artocarpus–Albizia*); on highest exposed crests, palm and pandan vegetation (*Gulubia–Pandanus*)
2	40	Hill slope: very short to medium length; straight or concave; very steep (35–45°), locally precipitous; closely spaced steep spurs; slump alcoves (50°) at gully heads	As unit 1 Locally brown loams (stony phase)	VIIIe$_8$,st$_5$ A4/A1/A4 VIIIe$_8$,st$_5$ A4/Rs+C	Forest as above; locally tall forest (*Terminalia brassii*) along torrents
3	1	Valley floor ridge crest: narrow or broad; even; gentle to moderate crestal slope (3–16°); grading to terrace	Ash soils: brown loams with lapillitic horizons	III or VIe$_3$ or e$_6$,n$_2$ A4/A1/A4	Largely cultivated and with regrowth; some secondary forest (*Artocarpus–Albizia*)
4	1	Valley floor ridge slope: very short (50 ft); straight; steep; some slump microrelief		VIIe$_7$,n$_2$ A4/A1/A4	

Population and Land Use: 125 people currently using 0·2 sq mile on units 3 and 4.

Forest Potential.—29 sq miles mid-altitude upland forest, moderate yield, on units 1–4; 4 sq miles low-altitude upland forest, moderate yield, on units 1–4; 1 sq mile high-altitude upland forest, low yield, on units 1 and 2; small stands *Terminalia brassii* forest, high yield on unit 2. Access category III.

Observations.—7.

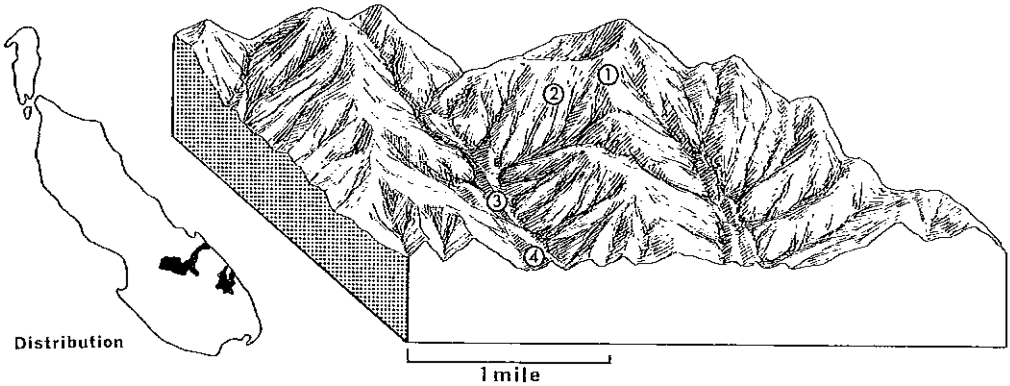
(37) Pirurari Land System (110 sq miles)

High dendritic ridges on older sedimentary rocks.

Geomorphology.—High dendritic ridges with very steep slopes and steep spurs leading down to moderately high dendritic ridges. Valley floors are dissected into very low ridges parallel to the valley axis. Bouldery torrents normally less than 50 ft wide, mainly incised.

Terrain Parameters.—Altitude: H.I., V; min., 50 ft; max., 5000 ft. Relief: high (800 ft). Characteristic slope: very steep. Grain: coarse (2500 ft). Plan-profile: 4L.

Geology.—Volcanic sandstone and tuff; Palaeogene–Mesozoic. Profuse surface debris of plateau volcanics; (?)Miocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	5	Ridge crest: very narrow; very uneven; moderate to steep crestal slope	Ash soils: brown loams	III or VI–VIIe$_3$ or e$_{6-7}$ A4/R$_S$	Mid-height forest (*Garcinia–Elaeocarpus*), tall forest (*Neonauclea–Sloanea, Vitex–Pometia*), secondary forest (*Artocarpus–Bambusa, Artocarpus–Albizia*); on exposed crests, palm and pandan vegetation (*Gulubia–Pandanus*)
2	100	Hill slope: very short to medium length; straight or concave; very steep (30–45°); closely spaced steep spurs; slump alcoves (50°) at gully heads		VIIIe$_3$ A4/R$_S$	Forest as above; locally tall forest (*Terminalia brassii*) along torrents
3	2½	Valley floor ridge crest: narrow or broad; even; gentle to low-moderate crestal slope (1½–10°); grading to terrace		II–IIIe$_{2-3}$ A4/R$_S$	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*) and secondary forest (*Artocarpus–Albizia*)
4	2½	Valley floor ridge slope: very short (50 ft); straight; steep; some slump microrelief		VIIe$_7$ A4/R$_S$	Forest as above; locally tall forest (*Terminalia brassii*) along torrents

Inclusions.—Kieta land system.

Population and Land Use.—2600 people currently using 5·0 sq miles of units 1 and 2. 0·4 sq mile of non-indigenous plantation.

Forest Potential.—41 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 14 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 2 sq miles high-altitude upland forest, low yield, on units 1 and 2; 1 sq mile *Terminalia brassii* forest, high yield, on units 2 and 4. Access category III.

Observations.—7.

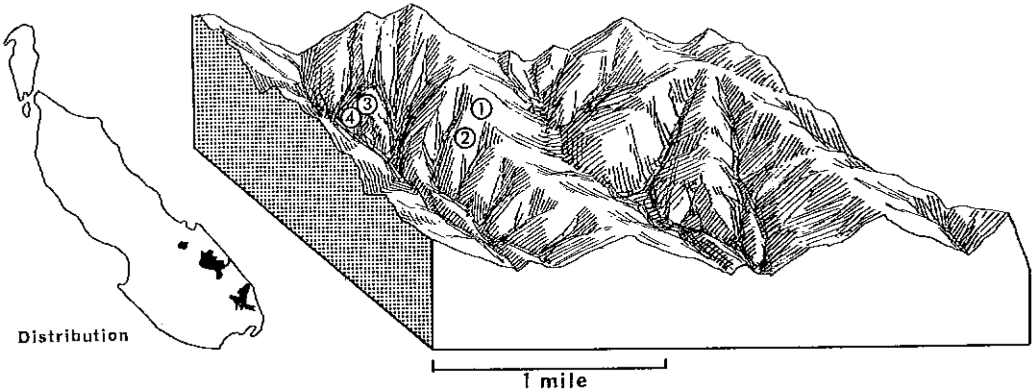
(38) NASIOI LAND SYSTEM (70 SQ MILES)

High dendritic ridges on largely intrusive rocks.

Geomorphology.—High or moderately high dendritic ridges with very steep slopes and steep spurs; valley floors commonly are dissected into very low ridges parallel to the valley axis. Bouldery torrents normally less than 50 ft wide, mainly incised.

Terrain Parameters.—Altitude: H.I., IV; min., 50 ft; max., 4000 ft. Relief: high (600 ft). Characteristic slope: very steep. Grain: coarse (2500 ft). Plan-profile: 4L.

Geology.—Microdiorite and volcanic sandstone; Palaeogene–Mesozoic. Profuse surface debris of plateau volcanics; (?)Miocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	4	Ridge crest: knife-edged or very narrow; very uneven; moderate to steep crestal slope	Ash soils: brown loams	III or VI–$VIIe_3$ or e_{6-7} $A4/R_S$	Mid-height forest (*Garcinia–Elaeocarpus*), tall forest (*Neonauclea–Sloanea*), secondary forest (*Artocarpus–Albizia*); on highest exposed crests, palm and pandan vegetation (*Gulubia–Pandanus*)
2	62	Hill slope: short or very short; straight; very steep (45°); closely spaced steep spurs		$VIIIe_8$ $A4/R_S$	Forest as above; locally tall forest (*Terminalia brassii*) along torrents
3	2	Valley floor ridge crest: narrow or broad; even; gentle to moderate crestal slope; grading to terrace		III or VIe_3 or e_6 $A4/R_S$	Cultivated and with regrowth; some secondary forest (*Artocarpus–Albizia*)
4	2	Valley floor ridge slope: very short (50 ft); straight; steep; some slump microrelief		$VIIe_7$ $A4/R_S$	

Inclusions.—Kieta land system.

Population and Land Use.—1000 people currently using 2·9 sq miles mostly on units 1, 3, and 4.

Forest Potential.—18 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 13 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 2 sq miles high-altitude upland forest, low yield, on units 1 and 2; 1 sq mile *Terminalia brassii* forest, high yield, on unit 2. Access category III.

Observations.—4.

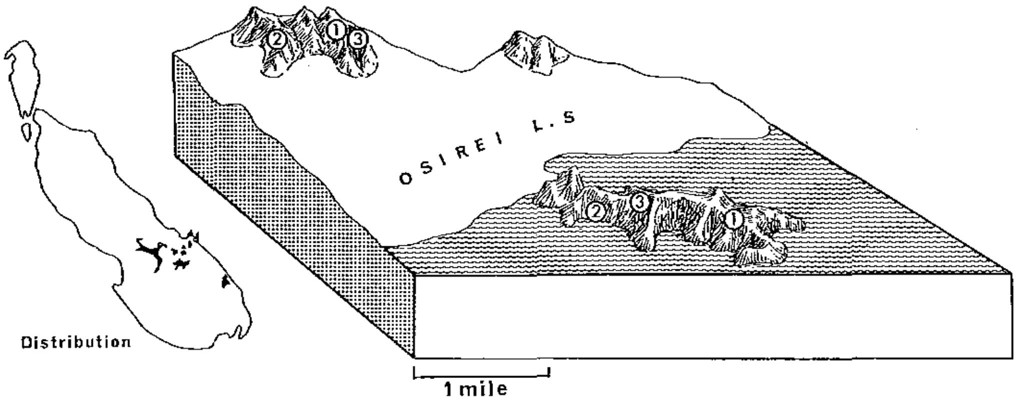
(39) KIETA LAND SYSTEM (60 SQ MILES)

Remnants of agglomerate plateau.

Geomorphology.—Remnants of plateau of resistant volcanic rocks forming buttes and cuestas with finely dissected upper surfaces and discontinuous marginal scarps. Incised bouldery torrents.

Terrain Parameters.—Altitude: H.I., IV; min., 0 ft; max., 5200 ft. Relief: high (800 ft). Characteristic slope: very steep. Grain: medium (1200 ft). Plan-profile: 4//.

Geology.—Andesitic agglomerate and conglomerate; (?)Miocene.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	5	**Ridge crest:** knife-edged; uneven; gentle to steep crestal slope	Lithosols, with rock outcrops	VI–VIIe$_{2-7}$,r$_6$ R$_S$+R$_H$	Tall forest (*Vitex–Pometia, Neonauclea–Sloanea*); much secondary forest (*Artocarpus–Albizia*); mid-height forest (*Garcinia–Elaeocarpus*); on exposed ridges, scrub (*Cyathea–Bambusa*) and palm and pandan vegetation (*Gulubia–Pandanus*)
2	44	**Hill slope:** very short or rarely long; straight; steep or very steep (25–40°); closely spaced steep spurs	Acid clay soils: brown friable clays Locally on steep slopes, ash-covered soils: brown loams over brown friable clays. Locally boulders	VII–VIIIe$_{7-8}$,r$_6$ A6/R$_S$ VII–VIIIe$_{7-8}$,r$_8$ A4/A6	Forest as above; locally tall forest (*Terminalia brassii*) along incised torrents
3	11	**Scarp:** short (up to 500 ft); straight; cliffed or precipitous; irregular	Rock outcrop	VIIIe$_8$,r$_8$ R$_H$	Scrub (*Cyathea–Bambusa*)

Inclusions.—Soraken land system.

Population and Land Use.—650 people currently using 0·8 sq mile (10% for cash crops) mostly on inclusions of Soraken land system. Fishing of considerable importance. 0·2 sq mile of non-indigenous plantations.

Forest Potential.—25 sq miles mid-altitude upland forest, moderate yield, on units 1 and 2; 13 sq miles high-altitude upland forest, low yield, on units 1 and 2; 6 sq miles low-altitude upland forest, moderate yield, on units 1 and 2; 1 sq mile *Terminalia brassii* forest, high yield, on unit 2. Access category III.

Observations.—4.

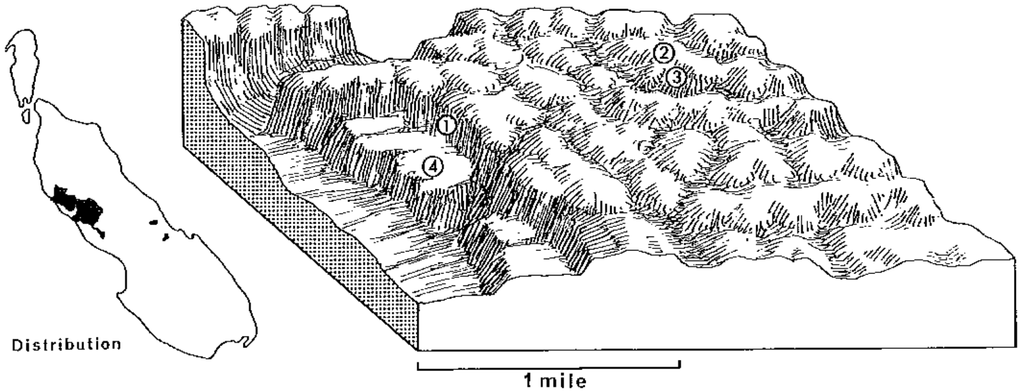
(40) Keriaka Land System (115 sq miles)

Very high dissected limestone plateau.

Geomorphology.—Very high tilted limestone plateau with upper surfaces completely dissected by karst erosion to form a fine-grained reticulate pattern of moderately high ridges separating large dolines or valleys of incised torrential streams. Scarps exceeding 2000 ft in height are common, locally bearing narrow benches. They occur either marginal to the land system or as pairs forming gorges. Structural lineations are prominent. The landscape is mantled with a thick ash cover.

Terrain Parameters.—Altitude: H.I., IV; min., 0 ft; max., 4200 ft. Relief: moderately high (400 ft); very high (4000 ft) at margins. Characteristic slope: steep. Grain: fine (900 ft). Plan-profile: 4L.

Geology.—Dense creamy white organic limestone dipping gently SW.; Lower Miocene. Superficial ash with layers of lapilli; Recent.



Land Unit	Area (sq miles)	Land Form	Soil	Land Class; AASHO Soil	Vegetation
1	6	Scarp: very long (4000 ft); concave precipitous or cliffed (45–80°); precipitous gullies and debris slide tracks	Rock outcrop Ash soils: brown loams with lapillitic horizons	$VIIIr_8$ RH $VIIIe_8,n_2$ A4/A1/A4	Scrub (*Cyathea–Bambusa*)
2	12	Ridge crest: very narrow (20–50 ft); saw-tooth; high-moderate or steep crestal slope (10–30°)	Ash soils: brown loams with lapillitic horizons. Variable rock outcrop	$VI–VIIe_{6–7},n_2,r_2$ A4/A1/A4	Scrub (*Cyathea–Bambusa*); localized areas with tall forest (*Neonauclea–Sloanea*, *Vitex–Pometia*) or with secondary forest (*Artocarpus–Bambusa*, *Artocarpus–Albizia*); outcrops with low forest (*Phyllanthus*)
3	90	Hill slope: short or very short (200–500 ft); concave; grading from very steep (30–45°) to steep (27°); inconspicuous steep spurs (20°); slumped microrelief		$VII–VIIIe_{7–8},n_2$ A4/A1/A4	
4	7	Bench: short (400 ft); concave; gentle to moderate slope (3–17°); undulating microrelief		III or VIe_3 or e_6,n_2 A4/A1/A4	

Population and Land Use.—125 people currently using 0·2 sq mile and adjacent parts of Silibai land system.

Forest Potential.—12 sq miles low-altitude upland forest, moderate yield, on units 2–4; 9 sq miles mid-altitude upland forest, moderate yield, on units 2–4. Access category III.

Observations.—9, including 4 on land unit 3.

II. References

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PART IV. CLIMATE OF BOUGAINVILLE AND BUKA ISLANDS

By J. R. McALPINE*

I. INTRODUCTION

(a) *Principal Climatic Features and Controls*

The climatic classification of Bougainville and Buka Islands is the tropical rain forest type (*Af*) of Köppen (1931) or the wet tropical type (*AA'r*) of Thornthwaite (1931).

The equatorial and oceanic position of these islands results in a markedly equable climate. Mean annual temperature is 80°F and the range of monthly means is only 30 degF. Diurnal temperature range is essentially constant at 13 degF, ranging from 74°F to 87°F. Spatially the greatest temperature variations are associated with increasing elevation. The marked seasonality of rainfall often found elsewhere in coastal Papua and New Guinea is not a feature of this area, noticeable rainfall seasonality occurring only in the north. Annual rainfall is, however, higher to the south (132 in.) than the north (105 in.) of Bougainville.

No reliable data relating to surface winds or upper air movements are available, but, in general, the major climatic controls of Papua and New Guinea, as discussed by Hounam (1951), also apply here. The major controls are the seasonal wind systems and the aspect of the terrain in relation to these systems. The north-west season occurs between December and April and the south-east (trade) wind season between May and November. The winds of the south-east season are stronger, more persistent, and less variable in direction than those of the north-west season.

These major controls are modified diurnally through the establishment of an orographic–convectional cell associated with land–sea breezes over the whole island as described by Malkus (1955).

To the south-east of Bougainville lies the favoured zone of tropical cyclone tracks. While these have no direct effects, the proximity to this zone produces at times short periods of heavy rains and strong winds.

Because the available climatic data are intermittent and sketchy, it has been impossible to select identical periods of record for all stations so as to allow the most reliable geographic comparison of average conditions. This must be kept in mind in the interpretation of the data presented here.

II. GENERAL CLIMATIC CHARACTERISTICS

(a) *Rainfall*

The regional rainfall seasonality pattern within which Bougainville and Buka Islands are situated is discussed by Fitzpatrick, Hart, and Brookfield (1966).

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TABLE 1

RAINFALL CHARACTERISTICS FOR 11 STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Highest Annual	Lowest Annual
Buka (10 yr of records)															
Mean rainfall (in.)	11·0	11·1	12·2	8·0	6·0	4·3	4·5	6·0	5·6	6·8	8·4	8·5	92·4	113·5	80·5
Mean no. of rain days	14	16	16	15	12	11	16	17	15	14	16	15	117		
Sohano (17 yr of records)															
Mean rainfall (in.)	13·4	10·6	13·3	11·3	6·5	5·4	5·1	6·1	5·9	7·0	9·7	11·1	105·3	113·3	91·8
Mean no. of rain days	18	16	19	18	15	15	17	17	17	16	17	18	203		
Kieta (26 yr of records)															
Mean rainfall (in.)	8·6	9·1	13·9	12·8	9·2	10·9	11·8	10·1	6·7	9·6	9·6	10·7	123·2	149·2	103·9
Mean no. of rain days	12	15	16	16	14	13	16	14	12	14	11	13	166		
Buin (5 yr of records)															
Mean rainfall (in.)	9·0	8·1	13·7	9·1	6·4	11·9	19·9	11·5	12·9	8·9	12·7	8·8	132·8	153·8	118·4
Mean no. of rain days	16	17	18	17	17	17	23	19	17	18	20	17	216		
Boku (9 yr of records)															
Mean rainfall (in.)	15·7	10·5	18·9	18·3	11·5	16·4	16·5	22·0	17·8	16·9	18·2	16·1	198·8	238·9	183·6
Mean no. of rain days	22	14	18	21	16	20	22	22	22	20	17	18	232		
Kunua (5 yr of records)															
Mean rainfall (in.)	9·3	7·0	12·2	6·8	6·6	6·4	8·5	10·0	9·5	9·2	10·5	7·4	103·5	140·7	80·9
Soraken (5 yr of records)															
Mean rainfall (in.)	11·3	8·1	11·7	8·6	6·4	5·2	5·8	6·8	6·6	9·0	9·8	7·3	96·7	125·0	83·0
Baniu (5 yr of records)															
Mean rainfall (in.)	8·4	8·9	10·4	8·9	4·4	5·4	4·0	2·8	3·7	5·8	6·7	5·6	75·2	81·2	69·8
Teopasino (5 yr of records)															
Mean rainfall (in.)	7·4	7·7	8·0	11·7	6·3	8·4	7·4	7·6	7·9	8·7	7·6	7·4	96·2	110·3	79·1
Arigua (5 yr of records)															
Mean rainfall (in.)	7·2	7·6	12·8	7·5	10·0	7·9	10·2	8·3	8·5	6·9	9·5	7·5	103·9	118·5	89·2
Toimonapu (5 yr of records)															
Mean rainfall (in.)	7·1	8·9	8·7	11·1	9·5	12·6	15·4	15·0	9·0	9·1	13·1	6·4	125·1	175·6	96·4

Rainfall data for 11 stations are shown in Table 1. All stations are situated on the coast and hence no clear picture of the overall rainfall pattern for inland areas can be gained. However, rainfall tends to increase in amount and frequency with ground elevation, particularly where there is a favourable aspect to prevailing winds.

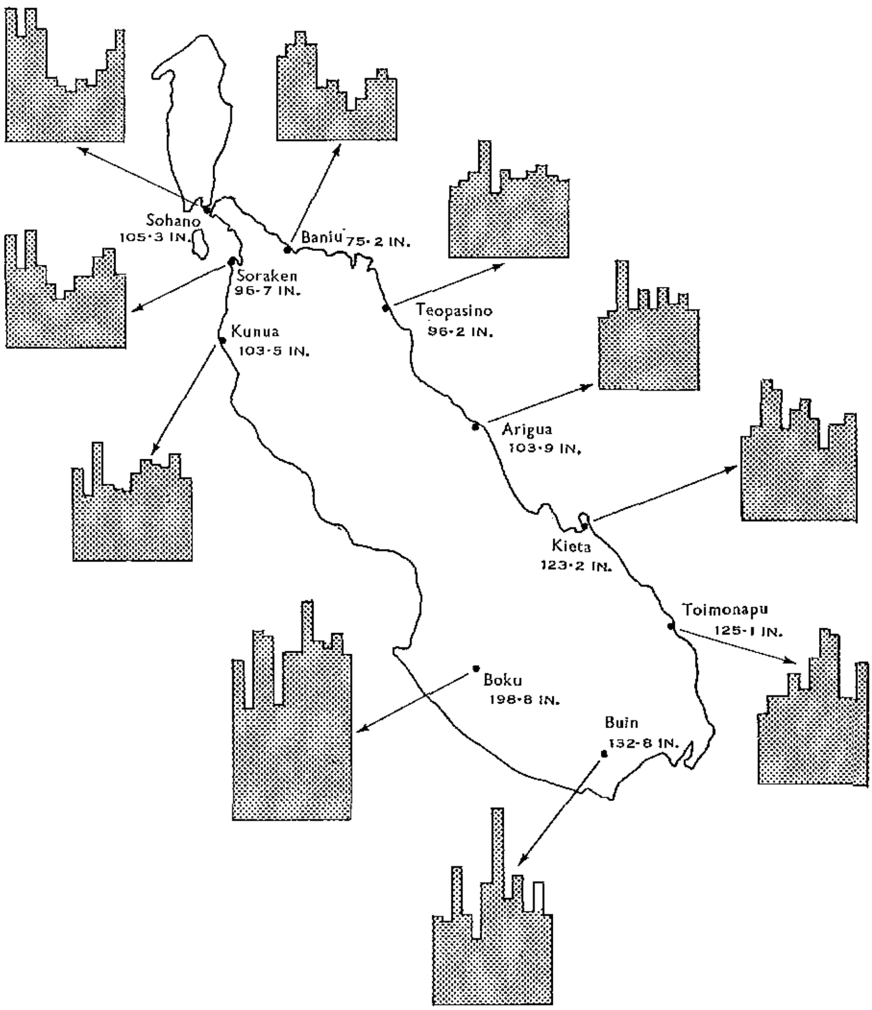

Fig. 4.—Annual distribution of rainfall (from January to December) at 10 recording stations. Values shown with station names are the mean annual rainfall for the station.

The chief feature of rainfall distribution on these islands (Fig. 4) is the difference in seasonal variation of rainfall between northern and southern Bougainville. The continuum of seasonal change from north-west to south-east is clearly seen and results from the combined effects of the dual system of climatic controls referred to previously. The north-west season produces approximately the same amount of rainfall throughout the islands between December and April. Thus variation in seasonal distribution of rainfall is due not to the north-west season, but to the varying effects over the islands of the south-east (trade) winds. The southern mountains of Bougainville induce instability in these warm and moist winds, which, in turn, results in heavy precipitation in southern Bougainville during this season between May and October. A sheltering lee effect causes rainfall from this source to diminish in a north-westerly direction, resulting in a considerable decline in rainfall at the north of the island. In fact, rainfall in the north is less than half that of the south during the south-east season and this gives the north its somewhat seasonal rainfall character.

Records are too short to give a measure of rainfall variability. Highest and lowest annual totals recorded for each station are given in Table 1. The coefficient of variation of annual rainfall (standard deviation as percentage of means) determined from 26 years of records for Kieta, the longest period available, is 18 %.

TABLE 2

MEAN DURATION OF RAINLESS PERIODS AND LONGEST RAINLESS PERIODS* OBSERVED (IN DAYS) FOR EACH MONTH AT THREE STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Sohano						
Mean duration	2·2	2·1	2·0	2·0	2·4	2·3	2·1	2·7	2·0	2·2	2·3	2·3
Longest observed	12	9	7	9	10	11	6	14	7	9	11	9
						Kieta						
Mean duration	1·9	1·9	1·9	2·3	2·1	2·1	2·2	2·2	2·2	2·2	2·4	2·3
Longest observed	11	7	9	13	9	10	9	16	12	13	10	11
						Buin						
Mean duration	2·3	2·1	3·0	2·0	2·2	2·1	1·5	2·1	2·1	2·1	2·0	2·1
Longest observed	8	6	10	4	5	9	5	9	7	7	6	5

* Sequence of days without any observed rainfall.

Table 2 indicates the mean and longest observed periods without rain. As the records for Kieta are much longer than those for Sohano and Buin, comparison of longest rainless periods between stations is not valid. Generally, there is little variation in this feature of rainfall over the year except at Sohano where longer rainless periods can occur during the south-east season. Rainless periods of over 10 days are uncommon throughout the area.

The frequency of daily rainfalls within specified limits is given in Table 3. These data give an indication of the occurrence of heavy falls. There appears to be no seasonal trend of very heavy falls at Kieta or Buin; those heavy falls that do occur are distributed relatively evenly throughout the year. Sohano, by contrast, does exhibit a seasonal pattern; daily falls exceeding 1 in. are not common in the south-east season between June and October, whereas falls in the north-west season are heavier and more frequent.

(*b*) *Elements other than Rainfall*

The only other climate element for which data are available is temperature. These data are given in Table 4, and indicate the marked uniformity through the year and for the region. Mean annual temperatures are therefore meaningful. Generally, the mean annual temperature is 80°F, with mean monthly maximum temperature rising only to 87°F and mean minimum temperature falling to 74°F. The only exception to this uniformity is in the lowest monthly minimum temperatures on record. Kieta and Buin have consistently lower temperatures than Sohano. This difference results from the proximity of Kieta and Buin to cold descending mountain

TABLE 3

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

Amount (in.)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Sohano						
0·01–0·24	44·1	42·5	43·2	47·7	57·7	57·7	68·3	57·2	60·3	54·9	44·0	43·6
0·25–0·99	32·8	32·3	35·2	31·7	31·3	34·4	25·3	31·4	29·9	30·9	33·5	36·2
1·00–1·99	10·4	16·8	12·3	12·8	8·5	5·8	5·4	8·9	7·4	9·9	16·1	13·3
2·00–3·99	10·4	7·0	7·2	7·0	2·0	1·6	0·5	2·5	2·4	3·8	5·0	6·4
4·00–5·99	1·4	1·5	2·1	0·4	0·5	0·5	0·5	—	—	0·5	1·4	—
≥6·00	0·9	—	—	0·4	—	—	—	—	—	—	—	0·5
						Kieta						
0·01–0·24	45·5	46·7	45·9	43·3	47·0	46·8	46·6	42·8	43·8	43·9	47·1	43·7
0·25–0·99	35·8	35·5	38·7	36·6	36·5	35·1	34·9	37·7	40·1	38·3	33·6	38·3
1·00–1·99	14·0	12·4	9·8	13·6	12·0	12·2	12·4	12·6	12·6	11·1	12·1	12·4
2·00–3·99	3·4	4·0	3·9	6·1	4·4	5·2	5·2	5·3	3·2	6·2	6·6	5·1
4·00–5·99	0·9	0·7	1·7	1·2	0·2	0·7	0·9	1·3	0·3	0·5	0·6	0·5
≥6·00	0·4	0·7	—	0·2	—	—	—	0·3	—	—	—	—
						Buin						
0·01–0·24	43·6	55·3	51·6	52·3	55·0	42·7	35·0	36·2	36·4	55·2	43·4	47·8
0·25–0·99	37·2	28·2	25·3	32·6	37·8	35·4	37·6	47·8	37·6	27·6	39·4	40·6
1·00–1·99	11·6	10·6	14·3	9·3	5·8	14·6	17·1	10·6	12·9	11·5	10·1	7·3
2·00–3·99	7·6	5·9	4·4	5·8	1·4	6·1	7·7	4·3	11·8	5·7	6·1	2·9
4·00–5·99	—	—	3·3	—	—	1·2	0·9	1·1	1·3	—	1·0	1·4
≥6·00	—	—	1·1	—	—	—	1·7	—	—	—	—	—

air masses (katabatic winds) as against the contrasting strong maritime influence affecting Sohano. Spatial temperature differences are mostly due to elevation and, although no records are available, it may be assumed that normal lapse rate conditions apply (i.e. 3·5 degF drop in mean temperature for every 1000-ft ascent). Under the prevailing strong maritime influence there is no frost risk at any elevation on these islands.

Table 5 illustrates similar uniformity with regard to relative humidity. The strong maritime influence on the island is clearly indicated in the slightness of differences between the 0900 and 1500 hr relative humidity conditions.

TABLE 4

TEMPERATURE CHARACTERISTICS FOR THREE STATIONS

Temperature (°F)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Sohano							
Mean maximum	87·7	87·7	87·2	86·8	87·3	86·7	85·8	86·1	86·9	87·4	87·4	87·7	87·0
Mean	81·8	81·8	81·6	81·2	81·6	80·9	80·0	80·2	80·7	81·2	81·3	81·6	81·2
Mean minimum	75·9	76·0	75·9	75·7	75·8	75·1	74·3	74·3	74·5	75·0	75·3	75·6	75·3
Highest maximum	93·0	92·2	91·0	90·5	92·8	91·0	90·0	89·3	91·0	91·3	93·0	93·0	93·0
Lowest minimum	71·5	71·0	69·0	71·9	71·5	71·6	70·3	68·7	69·8	68·0	72·0	72·0	68·0
						Kieta							
Mean maximum	88·4	85·8	88·0	87·5	86·6	84·4	85·4	85·8	86·6	87·0	87·9	88·8	86·8
Mean	82·1	80·0	81·9	81·4	80·9	79·5	79·8	80·0	80·6	81·0	81·4	82·0	80·9
Mean minimum	75·8	75·0	75·8	75·3	75·2	74·6	74·2	74·2	74·7	75·0	75·0	75·3	75·0
Highest maximum	98·0	95·4	96·0	95·0	93·0	92·0	93·0	92·0	93·0	94·4	93·2	94·0	98·0
Lowest minimum	64·0	65·5	70·0	61·2	60·2	60·2	58·6	59·8	69·0	69·2	68·0	66·0	58·6
						Buin							
Mean maximum	87·6	88·0	87·3	86·3	85·6	84·4	83·9	85·0	85·1	86·4	87·1	87·8	85·6
Mean	81·0	81·2	80·7	80·3	80·2	78·8	78·8	79·0	79·3	80·0	80·6	80·9	79·7
Mean minimum	74·4	74·5	74·1	74·4	74·9	73·7	73·7	73·0	73·6	73·7	74·2	74·0	73·9
Highest maximum	95·6	96·0	94·0	92·5	92·0	90·0	91·0	90·0	95·0	91·6	96·0	91·8	96·0
Lowest minimum	65·0	62·0	67·0	66·0	64·0	63·0	58·0	61·0	64·0	59·0	69·8	63·0	58·0

TABLE 5

MEAN MONTHLY RELATIVE HUMIDITY AND MEAN MONTHLY EVAPORATION AT THREE STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Sohano						
Relative humidity at 0900 hr (%)	78	80	79	80	77	77	80	75	75	76	76	78
Relative humidity at 1500 hr (%)	76	79	76	78	77	76	78	77	80	76	76	76
Evaporation* (in.)	5·1	4·9	4·6	4·4	4·8	4·9	4·7	4·9	4·5	4·7	4·8	4·7
						Kieta						
Relative humidity at 0900 hr (%)	77	80	81	82	81	84	82	81	79	77	78	78
Relative humidity at 1500 hr (%)	78	79	79	80	80	81	79	82	78	78	78	78
Evaporation* (in.)	5·1	4·3	4·9	4·6	4·6	4·2	4·4	4·7	4·6	4·9	5·4	4·7
						Buin						
Relative humidity at 0900 hr (%)	79	78	77	82	84	85	86	86	85	82	80	82
Relative humidity at 1500 hr (%)	79	79	80	82	82	83	83	84	84	84	81	83
Evaporation* (in.)	4·7	4·7	4·4	4·1	4·0	3·7	4·0	3·9	3·5	4·0	4·5	4·3

* Estimated by method of Fitzpatrick (1963).

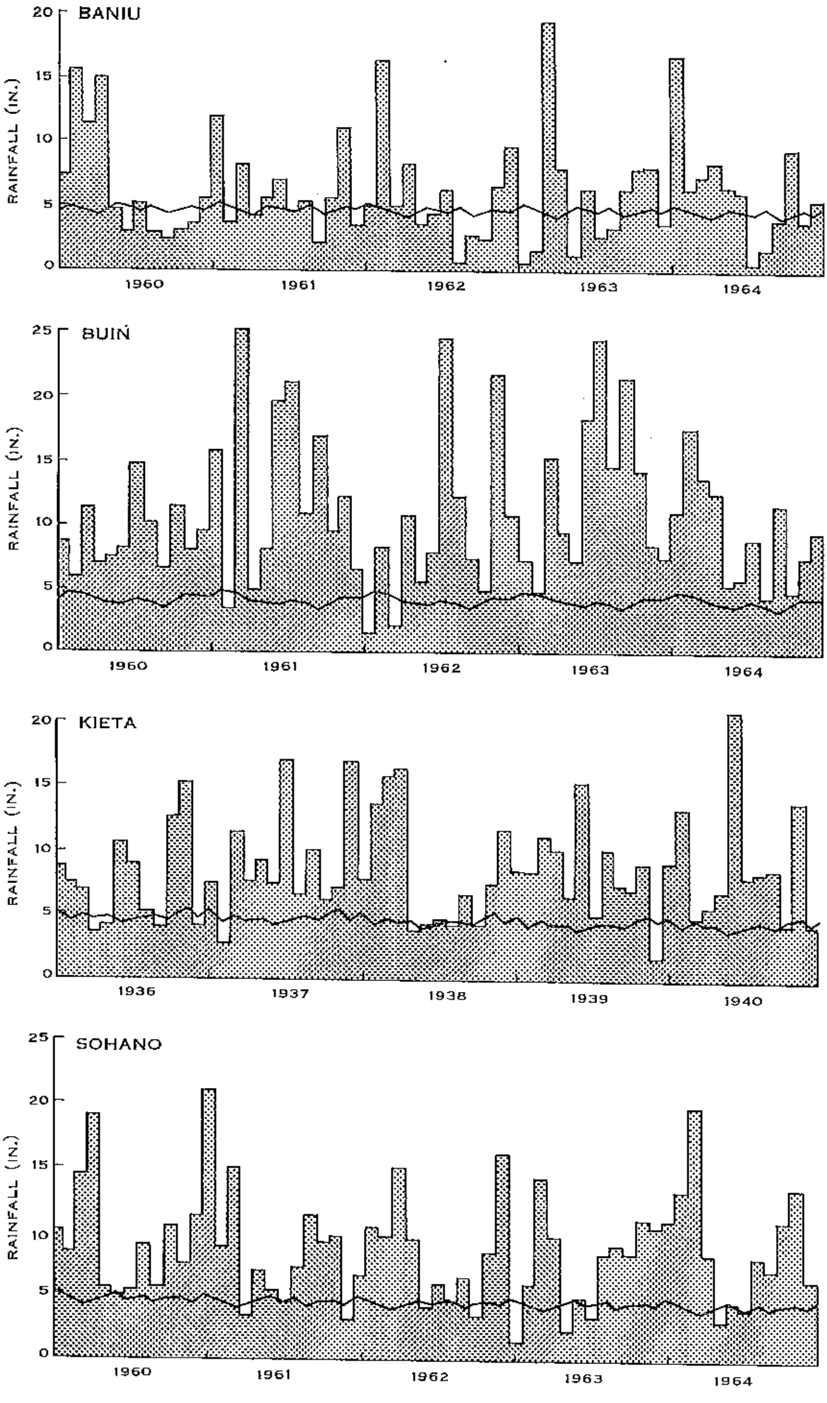

Fig. 5.—Monthly rainfall for five-year periods at four stations.

The greatest areal differences in cloudiness are related to elevation and the associated orographic and convectional processes. Day length varies only by about forty minutes through the year, and thus the low latitude in conjunction with uniform cloudiness results in little seasonal variation in insolation throughout the year.

III. Evaporation–Precipitation Relationships

It is clear from the preceding discussion that temperature and other conditions on the coastal and subcoastal regions are generally suitable for plant growth throughout the year. No evaporation data are available but estimates related empirically to the standard Australian tank have been obtained from monthly mean maximum temperature, vapour pressure, and day length (Fitzpatrick 1963) and are given in Table 5. Potential evapotranspiration requirements roughly equivalent to these estimates may be assumed under the prevailing conditions of frequent and copious rainfall and high temperature. As seen from Figure 5, only occasionally at Buin and Kieta has rainfall failed to satisfy these requirements. At Sohano, deficit periods are slightly more frequent. Baniu has the longest periods with rainfall below the estimated evapotranspiration requirement. However, considering the ability of plants to draw upon stored soil moisture, no major restriction in plant growth due to inadequate water supply appears likely throughout the islands. Specific mention of soil moisture–plant growth relationships is made in Part VIII.

IV. Acknowledgments

The help of Mr. J. Terrey, of Burns Philp and Co., in supplying rain data for Soraken, Baniu, Teopasino, Arigua, Kunua, and Toimonapu plantations is gratefully acknowledged.

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PART V. GEOLOGY OF BOUGAINVILLE AND BUKA ISLANDS

By J. G. Speight*

I. Introduction

Of the total area (3475 sq miles) of the Bougainville–Buka land mass, 650 sq miles consists of Recent surficial deposits and more than half of the remainder comprises Pleistocene volcanic products. There is, however, a substantial area underlain by older lavas, volcanic sediments, and limestone, notably the Miocene organic limestone of the Keriaka Plateau.

Up to 1964, reports on geological exploration of the islands had been concerned mainly with mineral prospects,† active volcanoes (Fisher 1939, 1957; Taylor 1956), and the age of limestone samples (Mawson and Chapman 1935; Kicinski 1956).‡ The visit by the author in 1964 was followed by a geological reconnaissance in 1965 by a party led by Dr. D. H. Blake, of the Australian Bureau of Mineral Resources, Geology, and Geophysics, with whom the author has had valuable discussions. Their work is embodied in a report (Blake and Miezitis 1967) in which the definitions of stratigraphic names employed here will be found. This report should also be consulted for information on economic geology. Regional geological relationships have been discussed by Glaessner (1950).

Both the stratigraphy (Table 6) and the geological mapping depend heavily on interpretation of air photos, as palaeontological dating fixes the age of only the Keriaka Limestone (Lower Miocene), and field sampling and traversing have been rather restricted.

II. Stratigraphy

(a) *Pre-Miocene Rocks*

It is clear from air-photo patterns that rocks with dips much greater than that of the Miocene limestone underlie the major part of the Crown Prince Range, as well as the Deuro Range in the far south and the Parkinson Range of Buka Island. These rocks consist mainly of volcanic sandstone, siltstone, and conglomerate, but also include agglomerate and tuff, andesite and basalt lava, pillow lava, and welded tuff. Air-photo lineaments, formed mostly of slightly curved ridge crests, are abundant

* Division of Land Research, CSIRO, Canberra.

† Fisher, N. H.—Geological report Kupei goldfield, Bougainville, T.N.G. Territory New Guinea Report (1936) (unpublished).

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‡ Crespin, I.—Micropalaeontological examination of a limestone from Numa-Numa–Balbi Track, Bougainville, Solomon Islands Group. Bur. Min. Resour. Aust. Rec. 1951/18 (unpublished).

TABLE 6

STRATIGRAPHY AND LAND SYSTEMS

Age	Stratigraphic Unit	Lithology	Land System
Recent	Alluvium	Peat, alluvial and littoral sand Volcanic alluvium Volcanic and coralline littoral sand, coral Coral, coralline and volcanic littoral sand	Moila Silibai, Saua Jaba Soraken
Upper Pleistocene–Recent	Part of Bougainville Group	Volcanic alluvium Agglomerate, volcanic conglomerate, tuff, and alluvium Andesite lava and agglomerate Mud-flow deposit	Siwai Buin, Numa (minor part), Leikaia (minor part), Pauroka Balbi, Takuan, Sisivi, Erava (part) Torombei
Middle Pleistocene	Sohano Limestone	Massive coralline and shelly limestone	Lonahan, Kohino
?Middle Pleistocene	Part of Bougainville Group	Agglomerate, volcanic conglomerate, tuff, and alluvium	Dios
Lower or Middle Pleistocene		Agglomerate, volcanic conglomerate, tuff, and alluvium	Numa (major pt.), Leikaia (major pt.), Erava (pt.)
Lower Pleistocene		Agglomerate, volcanic conglomerate, and tuff Andesite lava Andesite lava, agglomerate, conglomerate, and tuff	Rugen, Tumuri (major part), Mafahia, Bagana Umum (part), Puto, Ibu Melilup (major part), Chambers, Emperor
Lower or Middle Miocene	Keriaka Limestone	Foraminiferal, shelly, and coralline limestone	Keriaka
?Miocene	Part of Kieta Volcanics	Andesitic agglomerate and lava	Kieta
?Oligocene	Buka Volcanics, part of Kieta Volcanics (Deuro Range)	Volcanic sandstone and siltstone; tuff and agglomerate; basalt lava	Deuro, Teopasino
?Pre-Oligocene	Kieta Volcanics	Volcanic sandstone, siltstone, and conglomerate; agglomerate and tuff; andesite and basalt lava; pillow lava; welded tuff Andesitic agglomerate and andesite lava	Doiabi, Boira, Mainoki, Pomaua, Karato, Pirurari Osirei
?Oligocene–?Pleistocene	Diorite	Microdiorite, diorite, monzonite, granodiorite, syenite, granophyre	Nasioi, Umum (part), Melilup (minor part), Tumuri (minor part)

except on the Deuro Range. Their trend is generally about 160° (true bearing). They represent bedding planes dipping at steep angles to the west on Buka Island and at moderate angles to the east at Teopasino, but elsewhere one cannot tell whether they express bedding, jointing, or perhaps the result of subparallel consequent drainage. A wide spacing of linear ridges is the basis for distinguishing Osirei land system, near Kieta, an area considered to be underlain largely by agglomerate.

(*b*) *Miocene Rocks*

The Keriaka Limestone, a foraminiferal, shelly, and coralline limestone, forms the Keriaka Plateau, a spectacular massif on the west coast of Bougainville, as well as a number of smaller bodies towards the east. Micropalaeontological dating* has established that this formation falls within the Lower Miocene 'e' stage of the Indonesian classification. The planar summit surface of the plateau and the form of its marginal escarpments suggest that it is an ancient reef complex, elevated over 4000 ft and tilted through 3° towards the west (240°) about an axis at 150°. A tendency to summit slopes in the opposite sense on bodies on the eastern side of the island suggests an overall anticlinal structure.

TABLE 7

APPROXIMATE RELATION OF MAPPING UNITS TO FORMATIONS OF THE BOUGAINVILLE GROUP

This Report		Blake and Miezitis (1967)	
Upper Pleistocene to Recent	Volcanic alluvium Lava and pyroclastics	Taroka Volcanics Takuan Volcanics Billy Mitchell Volcanics Balbi Volcanics Tore Volcanics Bagana Volcanics Reini Volcanics	Bougainville Group
Lower to Middle Pleistocene	Lava and pyroclastics	Bakanovi Volcanics Numa Numa Volcanics Emperor Range Volcanic Beds	

Towards the south-east many of the summits of the Crown Prince Range are capped by bodies of resistant fanglomerate, agglomerate, and lava forming the plateaux and escarpments of Kieta land system. Their distribution suggests that they may have formed an extensive sheet overlying the pre-Miocene rocks, although Blake and Miezitis (1967) have not distinguished them from the remainder of the Kieta Volcanics. The prominent joints in the Pomaua area extend upward through this agglomerate capping.

(*c*) *Lower or Middle Pleistocene Volcanics*

From the lithological point of view all post-Miocene volcanic rocks may be considered to comprise a single group, the Bougainville Group (Table 7) of Blake and

* Terpstra, G. R. J.—Micropalaeontological examinations of outcrop samples from Bougainville, T.P.N.G. Bur. Min. Resour. Aust. Rec. 1966/66 (unpublished).

Miezitis, since they are characterized by a monotony of lava type within the range siliceous andesite to basaltic andesite and a dominance of ash-flow and mud-flow deposits. The land forms associated with the rocks, however, make it possible to differentiate between older and younger volcanoes. Volcanoes that are older than Upper Pleistocene are unlikely to show more than a few remnants of the original cone form (cf. Kear 1957, 1959), while younger volcanoes are better preserved.

Older volcanoes, thought to be of Lower or Middle Pleistocene age, but possibly even older, form the mountains of northern Bougainville and the mountain called Chambers Hill south of Wakunai. These are mainly "residual mountains" in the terminology of Kear (1957), though surrounded by readily recognizable former volcano–alluvial fans. The land forms are discussed in Part VI.

(*d*) *Pleistocene Raised Coral Reef*

A former barrier reef, upwarped without faulting to nearly 300 ft above sea level at one point, extends from Cape Laverdy to the northern end of Buka Island. The radiocarbon age of a giant clam shell embedded in the former reef flat is greater than 33,000 years B.P., but the very slight degree of dissection and corrosion of the land surface suggests an age no greater than Upper Pleistocene. The rock, the Sohano Limestone, is massive, coralline, and shelly, containing fossils indistinguishable from Recent species. The axis of uplift lies off the east coast of Buka Island and strikes at 165°, while the line of zero uplift skirts the western and southern margins of limestone outcrop, passing out to sea at Cape Laverdy.

(*e*) *Upper Pleistocene and Recent Volcanoes*

Younger volcanoes, similar lithologically to the older volcanoes mentioned above, form three complexes associated with Mounts Balbi, Bagana, and Takuan respectively. Volcanic phenomena and land forms are discussed at length as an aspect of geomorphology in Part VI.

(*f*) *Recent Alluvium and Coral*

Fluvial and littoral deposits and Recent coral reefs are discussed in Part VI. Recent mantles of volcanic ash are also considered there.

(*g*) *Intrusive Rocks*

Both the pre-Oligocene rocks and the Lower or Middle Pleistocene volcanic rocks are apparently intruded by stocks of microdiorite and other plutonics including diorite, monzonite, granodiorite, syenite, and granophyre (D. H. Blake, personal communication). The extent of these bodies is only tentatively mapped as yet, and their relationship to the Pleistocene volcanics is problematical, as an Upper Pleistocene age is unlikely. Copper–gold mineralization occurs near the divide 10 miles south-west of Kieta. The regional significance of this mineralization has been considered by Thompson and Fisher (1967).

III. Structure

The most prominent large-scale topographic lineament of the Solomon Islands region is the sigmoidal chain of islands stretching from Guadalcanal in the south-east, through New Georgia and Bougainville to the Tabar Islands in the north-west (Fig. 6). The alignment of the islands is paralleled by submarine contours including those defining the walls of the Planet Deep, a trench 28,600 ft deep. In the British Solomon Islands this lineament marks the axis of the "volcanic province" of Coleman (1965) characterized by the abundance of Quaternary volcanoes. Similarly, on Bougainville the Quaternary volcanic vents are associated with the lineament, all vents lying within 5 miles of a line striking at 140°, parallel with it.

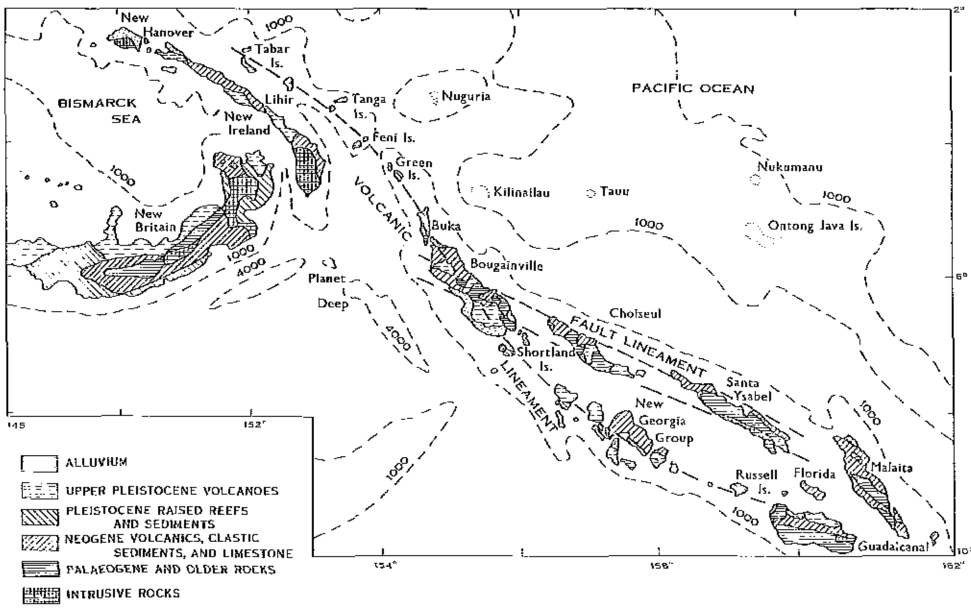

Fig. 6.—Regional geological trends in the Solomon Islands–New Britain area. Geology of New Britain after Noakes (1942), New Ireland after Montgomery, Glaessner, and Osborne (1950), and the Solomon Islands after Coleman *et al.* (1965). Bathymetric contours at 1000 and 4000 fathoms interpreted on Admiralty charts 3860 and 214, or copied from U.S. Navy Hydrography Office map of the world, 1 : 12,233,000 (1961).

The alignment of volcanic vents is, however, the only structural feature on Bougainville that has this trend. Both the well-marked regional strike and the preferred fault orientation diverge appreciably from it.

Wherever the strike of warped or tilted rocks is apparent, as in some pre-Miocene rocks (160°), the Keriaka Limestone (150°), and the Sohano Limestone (165°), it is more southerly in trend than the volcanic axis. Most of the air-photo lineaments that have not been definitely identified as bedding planes have a similar orientation, averaging 160°.

Certain persistent air-photo lineaments that mark abrupt changes in topography and have been interpreted as faults are indicated on the geological map. Their trend is consistently between 110° and 120°, and they tend to delineate a zone, oblique to the axis of the island, that contains the bulk of the Miocene and pre-Miocene outcrop. It is significant that this zone is in line with the island of Choiseul (Coleman 1962) and the southern part of Santa Ysabel, which have similar faulted structure and comparable stratigraphy. It may thus be linked to Coleman's Central Province of the British Solomons (Coleman 1965).

Further data for the study of the structure of the Bougainville region are provided by a recent summary of seismic activity (Brooks 1965) and by a gravity survey (V. P. St. John, personal communication). Epicentres of strong earthquakes are extremely abundant beneath the southern half of Bougainville and beneath the sea to the west and south. To be precise, within an area of 12,000 sq miles there have been 46 earthquakes of magnitude 6 or greater in the last 55 years. This zone of activity is cut off abruptly at the Kieta coast, and at a line parallel to the major faults which passes north of the Keriaka Plateau. The area to the east and north, including northern Bougainville and Buka Island, is practically aseismic by comparison. The Upper Pleistocene or Recent uplift of Buka Island is therefore not associated with any noteworthy present seismicity.

The gravimetric survey has indicated positive anomalies typically between +100 and +150 milligals at sea level stations around the Bougainville–Buka area, with an extreme positive anomaly of more than +240 milligals near Mt. Bei, on Buka Island, indicating that this uplifted area is a load on the Earth's crust supported only by horizontal compression.

IV. Geology and Land Systems

While geological factors are frequently the primary cause of land system differences, their geomorphic expression is more important in practice. In Table 10 (in Part VI) it can be seen that a distinction has been made between erosional landscapes underlain by Pleistocene and by pre-Pleistocene rocks. The significance of this is structural, the attitude of the Pleistocene rocks being practically undisturbed by tectonism. Many of the diagnostic land forms on pre-Pleistocene rocks, such as cuestas, homoclinal ridges, and ridges with parallel or rhomboidal arrangement, are structurally determined.

Lithology sets the limestone landscapes apart from the rest, but elsewhere monotonous andesite–tuff–volcanic sandstone rocks are virtually ubiquitous, leading to a lack of lithologic contrast between land systems except in two cases, Osirei and Nasioi land systems. Osirei has a land form pattern of very broadly spaced parallel ridges that appears to be correlated with a body of deeply weathered agglomerate and lava. In Nasioi land system a pattern of dendritic ridges of rather uniform height is thought to be an expression of diorite outcrop.

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PART VI. GEOMORPHOLOGY OF BOUGAINVILLE AND BUKA ISLANDS

By J. G. SPEIGHT*

I. INTRODUCTION

Bougainville and Buka Islands, separated only by a narrow tidal channel, form a high-standing land mass 150 miles long and up to 40 miles wide. Their major physical features are shown on the accompanying map. The remarkable north-west to south-east elongation conforms to a regional trend evident throughout the Solomon Islands chain and beyond it.

The mountains forming the main watershed of Bougainville are divided into the Emperor Range in the north-west and the Crown Prince Range in the south-east, each with a number of peaks between 4000 ft and 5000 ft high. Active and dormant volcanoes in clusters down the axis of the island include numerous peaks over 5000 ft high, culminating in the 8500 ft Mt. Balbi. North-west of Mt. Balbi there is an unnamed volcano 7000 ft high, and in the centre of the island Mt. Bagana rises to 5700 ft. To the south lies a spectacular volcanic complex that includes Mt. Taroka (7200 ft) and Mt. Takuan (7400 ft). The Bluff (4200 ft), near Mt. Balbi, is the most elevated corner of an ancient coral atoll.

The lowlands of Bougainville consist mainly of sloping plains and fans of volcanic debris. The Buin Plain on the south coast is the most extensive, having an area of more than 350 sq miles. Large tracts of swamp are also common, particularly near the coast. On Buka Island and the adjacent parts of northern Bougainville, the lowlands are formed on a raised coral reef standing 290 ft above sea level at the highest point.

The configuration of Bougainville inhibits the development of very large stream catchments, the largest being that of the Luluai River, 185 sq miles, which is only 5% of the total land area. The 15 rivers whose upland catchments exceed 30 sq miles are listed in Table 8.

II. GEOMORPHIC PROCESSES

Bougainville, being situated on a particularly active part of the tectonically unstable margin of the Pacific Ocean basin, is subject to volcanism and tectonism to a high degree. Certain exogenous processes, such as weathering, landsliding, and stream transport, promoted by the high temperature and precipitation of the prevailing tropical rain-forest climate, act with comparable intensity so that the landscapes are in a state of incessant rapid change.

While land forms rather than land-forming processes provide the major criteria for differentiation and definition of land systems, the distribution and severity of the

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processes discussed below are closely correlated with land system boundaries and significant differences occur between every pair of land systems. These relations are set out in Table 9.

(*a*) *Tectonism*

In the southern part of the area severe earthquakes are as frequent as anywhere else in the world, but direct effects are difficult to identify because scarplets are obscured by the dense vegetation and landslides are a normal feature on precipitous slopes of the area, whether triggered by earthquakes or not. Several prominent lineaments across the landscape are almost certainly traces of faults, probably with an important strike–slip component, but no recent movement can be detected.

Table 8

PRINCIPAL STREAM CATCHMENTS OF BOUGAINVILLE

River	Area of Catchment (sq miles)		
	Silibai and Moila Land Systems	Other Land Systems	Total
Luluai	15	170	185
Jaba	40	135	175
Tagessi	45	85	130
Wakunai	0	100	100
Laruma	10	75	85
Mivo	15	70	85
Puriata	10	70	80
Aita	0	75	75
Silibai	15	55	70
Uruai	0	60	60
Aitara	20	35	55
Sarime	10	35	45
Red	0	45	45
Ramazon	0	45	45
Bakanovi	0	35	35

The most significant aspect of tectonism appears to be the warping of the land surface, most clearly displayed where a former intertidal reef flat has been uplifted, as in both the Pleistocene and the Miocene coral reefs. On the Pleistocene raised reef of Buka Island the maximum height of the reef flat, 290 ft, attained near Cape Kotopan, is considered to represent the uplift accomplished since the last interglacial high sea level, representing a rate of movement of 3 or 4 ft per 1000 years. Forty miles to the north-north-west, Nissan Island and Pinipel Island of the Green Islands group are raised atolls of an associated uplift zone. None of the atolls to the north-east of Bougainville (Kilinailau, Tauu, Nukumanu, Ontong Java) is significantly uplifted, a fact supporting the delineation of the Pacific Basin margin between the two. South of Bougainville, raised reefs on Shortland Island form a series of terraces tilted towards the north; the topography of the floor of Empress Augusta Bay, on the other hand, appears to be a sunken coral platform at a depth of about 350 ft.

TABLE 9

DISTRIBUTION AND SEVERITY* OF GEOMORPHIC PROCESSES RELATIVE TO LAND SYSTEMS ON BOUGAINVILLE AND BUKA ISLANDS

Land System	Tectonism	Volcanic Processes				Weathering		Slope Processes						Fluvial Processes			Littoral Processes	
	Uplift	Lava Flow	Ash Flow	Ash† Fall	Mud Flow	Maturity	Rate	Rock Fall	Avalanche	Flow	Creep	Wash	Gullying	Erosion	Overbank Deposits	Channel Deposits	Longshore Drift	Coral Growth
Raised coral reef																		
Lonahan	●●● ××			○○ ××		●●● ×××××	●●●	● ××			● ×	●●● ×××						○○○
Kohino	●●● ××			○○ ××		●●● ×××××	●●●				● ×	●●● ×××		● ×				○○○
Coasts																		
Jaba						●●● ×	●●● ×××				● ×	●●● ×		● ×		● ×	●○○ ××××	● ×
Soraken						●●● ×	●●● ×××					●●● ×		● ×	● ××	● ×	● ×	●● ×××
Swamps																		
Moila						●●● ×	●●● ×					●● ×		● ×	●●● ×××	● ××		
Plains																		
Saua			● ××	●● ×××	● ××	●●● ×	●●● ×××					●● ×		●● ×××	● ××××	●● ××××		
Silibai						●●● ×	●●● ×					●●● ×		●● ×××	●●● ×××	●● ×××		
Siwai				○○○ ×	○	●●● ×	●●● ×××					●●● ×	● ××	● ××	●○○ ×	●○○ ×		

Volcano–alluvial fans														
Buin			○	○○○ ×××	○○○	●●● ××	●●● ×××				●●● ×	● ××	● ×××	● ×
Rugen			○	○○○ ××	○○○	●●● ××××	●●● ××			●●● ×	●●● ××	●● ××	●● ×××	● ×
Numa			○	○○○ ×××	○○○	●●● ×	●●● ×××			●●● ×	●●● ×	●● ××	●● ×××	● ×
Leikaia			○○	○○ ×××	○○○	●●● ×	●●● ×××	● ××		●●● ××	●●● ×	●● ××	●● ×××	
Pauroka			○○	○○ ×××	○○○	●●● ××	●●● ×××	● ××	● ×	●●● ×	●●● ×	●● ××	●● ×××	
Volcanic landscapes														
Balbi		●○ ×××	●○ ××	●●● ××××	●○ ××	●●● ×	●●● ×××	● ××		●●● ××	●●● ×	●● ××	●● ×××	
Takuan		○○	○○	○○○ ×××	○○	●●● ××	●●● ×××	● ××		●●● ×	●●● ×	●● ××	●● ×××	
Erava		○	○○	○○○ ×××	○○	●●● ××	●●● ×××	● ××		●●● ××	●●● ×	●● ××	●● ×××	
Sisivi		○○○		○○○ ×××		●●● ×	●●● ×××		●● ×	●●● ××	●●● ×	●● ××	●● ×××	
Puto		○○○		○○○ ××		●● ××××	●●● ××			●●● ×	●●● ××	●● ××	●● ××	
Umum		○○		○○○ ××		● ×××	●●● ×			●●● ×	●●● ×××	●● ××	●● ×××	
Erosional hills														
Dios	●●● ××			○○○ ××		●●● ×××	●●● ××			●●● ×	●●● ××	●● ××	●● ×××	
Ibu				○○○ ×××	○○○	(●●) ××××	●●● ×××		● ×	●●● ×	●●● ×	●● ××	●● ××	● ×

TABLE 9 (*Continued*)

Land System	Tectonism	Volcanic Processes				Weathering		Slope Processes						Fluvial Processes			Littoral Processes	
	Uplift	Lava Flow	Ash Flow	Ash† Fall	Mud Flow	Maturity	Rate	Rock Fall	Avalanche	Flow	Creep	Wash	Gullying	Erosion	Overbank Deposits	Channel Deposits	Longshore Drift	Coral Growth
Tumuri				○○○ ×××		••• ×	••• ×××		• ××		••• ××	••• ×	•• ××	•• ××××	• ×			
Mafahia				○○○ ×××		••• ×	••• ×××		• ××	• ×	••• ××	••• ×	•• ××	•• ××××				
Teopasino	(○○○)			○○○ ××		••• ××××	••• ××				••• ×	••• ××	•• ××	•• ×××				
Deuro	(○○○)			○○ ×		••• ×××	••• ×			•• ×××	••• ×	••• ×××	•• ××	•• ××				
Bagana			•○ ××	••• ××××		(••) ××××	••• ×××				••• ××	••• ×	•• ××	•• ×××				
Doiabi	(○○○)			○○○ ×××		(••) ××××	••• ×××				••• ×	••• ×	•• ××	•• ×××				
Boira	(○○○)			○○○ ×××		(••) ××××	••• ×××				••• ××	••• ×	•• ××	•• ××				
Mainoki	(○○○)			○○○ ×××		(•••) ××	••• ×××				••• ××	••• ×	•• ××	•• ×××				
Pomaua	(○○○)			○○○ ×××		• ××××	••• ×××				••• ××	••• ×	•• ××	•• ×××				
Osirei	(○○○)			○○○ ××		••• ××××	••• ××			•• ×××	••• ×	••• ××	•• ××	•• ×××				
Basin floors Torombei				○○○ ×××	○○○	• ××××	••• ×××				••• ×	••• ×	•• ××	•• ××				

Erosional mountains													
Melilup				••• ×	••• ×		•• ×××		••• ××	••• ×××	•• ××	•• ××××	
Chambers			○○ ×××	••• ×	••• ×××		•• ×××		••• ××	••• ××	•• ××	•• ××××	
Emperor				••• ×	••• ×	• ××	• ×××		••• ××	••• ×××	•• ××	•• ×××	
Karato	(○○○)		○○○ ×××	(•••) ×××	••• ×××			• ×	••• ××	••• ×	•• ××	•• ×××	
Pirurari	(○○○)		○○○ ×××	•• ××××	••• ×××				••• ××	••• ×	•• ××	•• ×××	
Nasioi	(○○○)		○○○ ×××	••• ××	••• ×××				••• ××	••• ×	•• ××	•• ×××	
Kieta	(○○○)	○○○		••• ×××	••• ×	• ××			••• ××	••• ××	•• ××	•• ×××	
Karst plateau													
Keriaka	○○○		○○○ ×××	(•••) ××××	••• ×××	• ××		• ×	••• ×	••• ×	•• ××	• ×	○○○

* Distribution — Present activity — Former activity

Distribution	Present activity	Former activity
Ubiquitous	•••	○○○
Widespread	••	○○
Localized	•	○

Distribution dubious or inferred: ( )

Severity	
Extreme	××××
Severe	×××
Moderate	××
Mild	×

† "Severity" index for former ash fall indicates ash thickness.

The Keriaka Plateau is also considered to be an ancient coral reef (see Part V), and here the westward tilting since Lower Miocene times about 20 million years ago has amounted to nearly 3°, the maximum uplift being 4400 ft.

(*b*) *Volcanism*

Volcanism is a major landscape-forming factor at present on Bougainville, and the evidence of the rocks shows that it has had comparable importance through geological time. The main phenomena may be considered under the headings of lava flow, ash flow, ash fall, mud flow, and fumarole activity.

(i) *Lava Flow.*—Lava flows, though generally subordinate to other volcanic deposits, are a significant feature in many areas, forming sinuous, parallel-sided accumulations with moderate or steep axial slopes. Present-day lava flows on Mt. Bagana are viscous and slow-moving, and display a surface composed entirely of angular blocks and rubble. The form of well-preserved Pleistocene flows is similar to that of present-day flows, each flow being glacier-like, concave in cross-section at the upper end, and convex, with transverse pressure ridges, near the steep terminal face. Steep marginal ridges resembling stranded lateral moraines are characteristic (Plate 2, Fig. 1).

(ii) *Ash Flow.*—Hot ash flows, or nuées ardentes, involving the very rapid transport of gas-emitting particles across the ground surface and resulting in devastation of vegetation and even local erosion of the soil mantle, are a characteristic feature of Bougainville volcanism. Nuées ardentes were produced by Mt. Bagana in 1950 and 1952, one of them destroying forest up to 2 miles from the base of the mountain (Taylor 1956). Mt. Balbi is reputed to have produced a very destructive nuée ardente during the first half of the nineteenth century.* Their action in a similar environment in Papua has been graphically described by Taylor (1958). Depending on the nature of the ash flow, its deposits may consist either of a rather widely distributed ash mantle or of a valley-choking, bedded mass of unsorted debris. Enormous deposits of these types underlie the flanks of Bougainville volcanoes.

(iii) *Ash Fall.*—Volcanic ash has been distributed over practically the whole of the Bougainville–Buka area in Recent times, the northern and southern extremities being least affected (Fig. 7). Ash-free areas are limited to those dominated by fluvial or littoral deposition, or by extreme fluvial erosion, as in the northern mountains. The ash mantle is more than 3 ft thick only in central Bougainville, where it frequently contains layers of lapilli. These exceed 1 ft in aggregate thickness in a belt extending eastwards from Mt. Balbi. Areas affected by significant ash fall since European occupation are localized near Mounts Balbi and Bagana.

Early Recent or Pleistocene ash, now immaturely weathered, is found on gentle and moderate slopes within 20 miles of Mt. Takuan and in an area to the west of Mt. Balbi. It forms an impermeable pan in the soil profile that is discussed in Part VIII.

* Branch, C. D.—The Mt. Balbi volcano complex, Bougainville, T.P.N.G. Bur. Min. Resour. Aust. Rec. 1965/21 (unpublished).

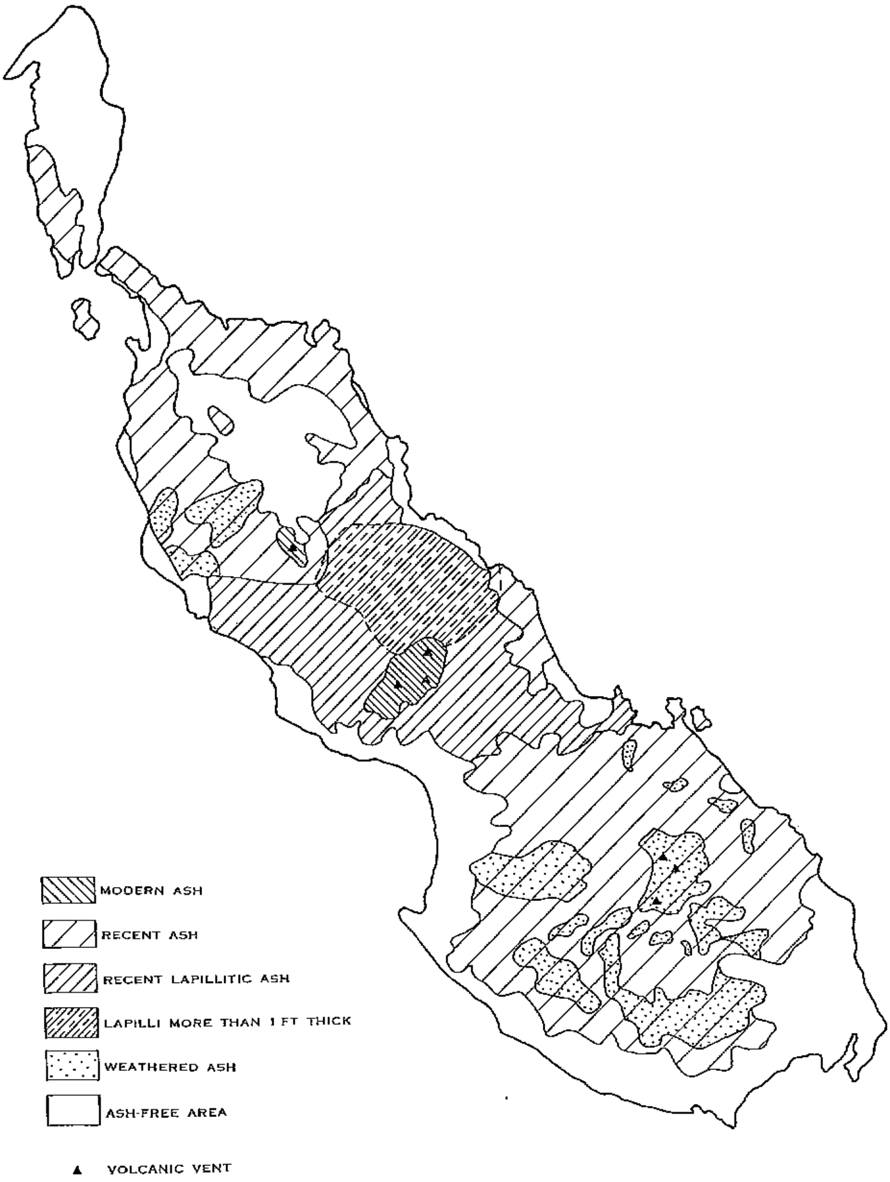

Fig. 7.—Distribution of volcanic ash.

(iv) *Mud Flow.*—Volcanic mud flows, or lahars, result whenever volcanic deposits are mobilized by the addition of water. They are particularly effective in humid climates such as that of Bougainville, where frequent heavy rain showers and occasionally the overflowing of a volcanic lake are to be expected during a period of eruption, at a time when there is no vegetation to protect the landscape. Their action has resulted in the redistribution of debris from the volcanic slopes down the stream valleys and out onto the surface of the peripheral fans and plains.

(v) *Fumarole Activity.*—Sulphurous steam vents are active at present on Mounts Bagana and Balbi (Plate 1) and on the dome at Lake Loloru in southern Bougainville.

(c) *Weathering and Solution*

The exposure of dominantly andesitic rocks rich in volcanic glass to a humid tropical climate might be expected to result in deep, mature profiles of chemical weathering, but such profiles are not common. This is a result of the rapidity of erosion and deposition: alluvial soils, lithosols, and deep deposits of Recent ash make up the bulk of the superficial materials, and weathering of these must be described as skeletal at most. This is not to say that the *rate* of weathering is low: it is probably very high, particularly in the least weathered of the granular materials where no clayey weathering products impede the movement of water. The rate of loss of material from the landscape in solution may be as great as the rate of removal of solid material (cf. Fig. 3–21 of Leopold, Wolman, and Miller 1964). It will vary from place to place with the relative rate of weathering, as crudely estimated in Table 9.

On the few landscapes where weathering has proceeded far enough to produce clay soils there is a correlation between slope and clay colour. Red clays are generally associated with slopes that are (or were originally) either gentle or moderate, while brown clays are related to rather steeper slopes. The maturity of development of the red clay soils (weathering maturity × × × × in Table 9) is considered to be greater than that of the brown clay soils (× × ×) in this context, so this correlation shows how profile development depends, in this case, on environment rather than time or lithology.

(d) *Slope Processes*

The major processes active on hill slopes in the area, in order of increasing role of water, are discussed below. It must be borne in mind that the widespread mantle of permeable Recent ash has radically altered the effectiveness of these processes, and there is little evidence in most landscapes to indicate the nature of the mantle material prevailing during the period of evolution of the present land forms.

(i) *Rock Fall.*—Portions of cliffed and precipitous slopes occasionally break away as they are weakened by weathering or undermining, and great blocks fall freely to the base of the slope. Limestone cliffs appear to be much less affected than those of agglomerate, which are generally underlain by weak rock and have yielded large numbers of fallen blocks.

(ii) *Debris Avalanche.*—Precipitous erosional slopes exceeding 45° show widespread evidence of the action of debris avalanches, slides of rock and soil material lubricated by water. The vegetation and regolith have been removed along narrow avalanche trails that generally begin near the top of the precipitous slope and end in the stream bed, where the stream rapidly disposes of the deposited material. Earthquakes may trigger off some debris avalanches, but heavy rain storms alone are probably the major cause. Wentworth (1943) has discussed similar "soil avalanches" on Oahu, Hawaii.

(iii) *Earth Flow.*—Earth flow, initiated by a rotational slip or slump of the regolith and characterized by a slow movement of the material downslope to form a hummocky deposit, occurs on steep and very steep slopes in favourable situations, particularly in gully heads. The activity of springs helps to saturate the regolith, which slips away leaving a slump alcove with a precipitous or cliffed head wall a few feet high. The hummocky deposit in the gully below does not survive long under the effects of other slope processes.

(iv) *Soil Creep.*—Of the conditions listed by Sharpe (1938) as influencing the development of soil creep, the unconsolidated ash mantle and prevailing steep or very steep slope on Bougainville are very favourable, but are balanced by the virtual absence of climatic alternations such as wetting and drying, heating and cooling, or freezing and thawing. Consistently high moisture contents must encourage creep, however, by reducing the shear strength of the soil.

Hummocky microrelief with an amplitude of about one foot, found under the forest, results primarily from the decay and occasional fall of trees and indicates the relative insignificance of slope processes as compared with vegetative effects on the micromorphology, although such disturbance must result in net downslope movement of the soil particles. Evidence of rapid creep, such as curving tree trunks or movement in artificial cuttings, is lacking.

(v) *Slope Wash.*—The relative importance of slope wash as a slope process in the tropical rain-forest environment is the subject of long-standing debate. Ruxton (1967) has expressed the opinion that "slope wash is an important, if not major, process of erosion on slopes of over 5° in northern Papua under rainfalls varying from 1750 mm to over 5000 mm". In Bougainville, 500 miles away, with over 2500 mm rainfall it seems to be less important, although still significant.

The erosional efficiency of slope wash is increased if the subsoil is impermeable at shallow depth. This is the main basis for the severity indices shown in Table 9. Where ash has been deposited over clay, thin ash layers have been rapidly removed while thicker ash layers have been allowed to remain and to accumulate. This applies particularly to the Buka raised reef. Rocky surfaces are also highly susceptible to slope wash but permeable deep ash mantles are practically unaffected. Where the ash overlies either an impermeable substratum due to former weathering or a highly permeable lapillitic layer the water may actually flow out to the streams quite rapidly by lateral movement through the soil, but any suspended particles will tend to be filtered out in its passage and effective erosion of solids will be accomplished only in the zone adjacent to the point of outflow. This is probably, however, a major mechanism for the transport of dissolved material.

(vi) *Gullying.*—Gullies, consisting of narrow channels between convergent straight slopes, begin within 200 ft of the ridge crests in most landscapes. The confluence of a small number of first-order gullies is sufficient to form one of the perennial stream channels that alternate with ridges in the typical elementary landscape of the islands. Where the soil consists of a layer of ash over clay the phenomenon of tunnelling occurs, the uppermost gullies consisting of a series of holes connected by tunnels at the base of the ash layer.

(*e*) *Fluvial Processes*

Fluvial erosion is probably the most rapid of all exogenetic processes operating on the Bougainville landscape. Furnished with abundant abrasive sand and coarser detritus from both young pyroclastic deposits and little-weathered bed-rock, it has carved gorges up to 1500 ft deep in the flanks of volcanoes of probable Pleistocene age. Talus supplied from the mountain and hill slopes is immediately removed by the streams, preventing the formation of talus cones or of basal concavities in the slope profiles.

On attaining a certain size, the streams begin to erode laterally. In steeper reaches where they are still incised and are encumbered by barely transportable blocks and boulders such erosion is limited and irregular, but further downstream the streams migrate cyclically back and forth across their flood-plains by concurrent bank erosion and point-bar or channel-bar deposition of sand and gravel. Deposition of silt on the flood-plain surfaces occurs commonly, but the development by this means of natural levees along the channels is limited to certain reaches of very low gradient where channel migration is slow.

At times of heavy rainfall, landsliding in the upland areas, particularly on very recent ash deposits, may contribute so much solid material to a river that its flow becomes a mud flow whose velocity and morphological effects may be as great as in a lahar related directly to volcanic activity. Bedded deposits of unsorted debris in valley floors are commonly produced in this way.

In the absence of river flow records or inland rainfall records little can be said of the hydrology of Bougainville streams. Their relative sizes may be assessed approximately from the catchment areas presented in Table 8. A distinction has been made between those parts of the catchments (Silibai and Moila land systems) that contribute only to low flows and other parts that form the effective catchment during high flows. Rivers with a high proportion of low-lying catchment, such as the Tagessi, may be expected to be the least variable in flow. Variability of daily flows is probably quite low in nearly all streams as a result of the frequency and reliability of orographic rainfall and the suppression of storm run-off by forest vegetation and permeable soils. Only streams flowing from the rocky slopes of the active volcano Mt. Balbi are highly variable. They are also the most susceptible to mud flows.

(*f*) *Littoral Processes*

The two dominant agencies determining the coastal morphology of Bougainville and Buka Islands are longshore drifting of sand and growth of coral. Calcareous sand, common on northern and eastern coasts, is much less abundant than sand derived from volcanic ash. The environment is not one of great energy as most beaches are protected to some degree by barrier reefs and typhoons do not occur. The tidal range is also small, being of the order of 3 ft. Longshore drifting is, however, effective enough to prevent the formation of river deltas and to supply material for the building of cuspate forelands in favourable situations. The action of the winds is apparently insufficient to form dunes on any part of the Bougainville coast (cf. Jennings 1965).

Vigorous coral growth is occurring on fringing or barrier reefs, or both, on most coasts. In Buka Passage an alternating tidal current of up to 4 knots (Anon. 1956) inhibits this growth so as to maintain a parallel-sided open channel 2 miles long, 1000 ft wide, and 50 to 80 ft deep (Plate 12, Fig. 1).

Coastal erosion is limited in extent by the dominance of coral growth and littoral sedimentation. Certain headlands, particularly between Moila Point and Kieta, are under attack but have not receded very far. There is characteristically a nick and abrasion platform at, or possibly above, high tide level with a short precipitous or overhanging rock face above. Solution appears to be the dominant process.

III. Landscapes

A comprehensive view of the types of landscape present on Bougainville and Buka Islands may be obtained from Table 10. The land system sequence of this table has been used for the tabular descriptions of land systems in Part III and for the reference to the land system map. The headings in the following discussion represent a further grouping of the geomorphic categories of Table 10.

(*a*) *Volcanic Landscapes and Volcano–Alluvial Fans*

Although dissected to varying degrees, the landscapes described in this section are all formed on the products of Upper Pleistocene or Recent volcanism. Two types of volcano, lava cones and strato-volcanoes, are characteristic, but this is not the basis of any land system division. Volcanic cones, upper slopes, and summits have been placed in Balbi or Takuan land system depending on whether or not their activity has been recent enough to prevent forest growth. No volcano in either of these land systems can be classified as extinct.

Lava cones, represented by Mt. Bagana, Mt. Takuan, and several unnamed mountains (Plate 2, Figs. 1 and 2), are symmetrical cones with slopes that in gross form are straight and steep, of the order of 25°, although local slopes average 35° and may be much steeper. If Mt. Bagana may be considered typical, the greater part of the surface of each cone is made up of blocky lava flows. Most of these originate near the apex of the cone, but some have breached the flanks without greatly modifying the straight profile of the mountain. Some areas between the lava flows, designated debris slopes, appear to have been built mainly by alluvial outwash from the lava flows rather than by direct accumulation of ejected material. The unnamed 7000-ft peak at the head of the Tore River, 8 miles NNW. of Mt. Balbi, also consists of sinuous lava flows, but in this case the lava was less viscous and the flows extend as far as 6 miles from the volcanic centre with an average slope of about 10°.

TABLE 10

DIAGNOSTIC GEOMORPHIC CRITERIA FOR LAND SYSTEM CLASSIFICATION ON BOUGAINVILLE AND BUKA ISLANDS

Geomorphic Category	Diagnostic Rock	Diagnostic Land Form	Diagnostic Mantle Material	Land System
Raised coral reef		Reef platforms		Lonahan
		Lagoon floor		Kohino
Coast		Beach ridges		Jaba
		Coral reef		Soraken
Swamp				Moila
Alluvial plain		Bar plain and ash plain		Saua
		Active alluvial plain		Silibai
		Relict alluvial plain		Siwai
Volcano–alluvial fan		Partly dissected fan	Recent ash over immaturely weathered ash	Buin
		Fan dissected to low ridges	Recent ash over red clay	Rugen
			Recent lapillitic ash	Numa
		Fan dissected to moderately	Recent lapillitic ash	Leikaia
		high ridges	Recent ash over immaturely weathered ash	Pauroka
Volcanic landscape		Volcanoes	Modern ash	Balbi
			Recent ash over immaturely weathered ash	Takuan
		Volcanic debris slopes		Erava
		Lava flows	Deep Recent lapillitic ash	Sisivi
			Recent ash over red clay	Puto
		Lava flows and cumulo forms	Recent ash over brown clay	Umum
Erosional hills	Pleistocene volcanics	Very fine dendritic ridges		Dios
		Former volcano–alluvial fan		Ibu
		Former volcanic debris slope	Recent ash	Tumuri
			Recent lapillitic ash	Mafahia

	Pre-Pleistocene rocks	Cuestas Common homoclinal ridges Structureless Common parallel structural ridges, closely spaced Rhomboidal structure Common parallel structural ridges, widely spaced	Deep modern and Recent ash Deep Recent lapillitic ash Recent lapillitic ash Recent ash	Teopasino Deuro Bagana Doiabi Boira Mainoki Pomaua Osirei
Basin floor				Torombei
Erosional mountains	Pleistocene volcanics	Precipitous lower slopes Precipitous-walled basins	Lithosol Recent lapillitic ash	Melilup Chambers Emperor
	Pre-Pleistocene rocks	With subsidiary ridges Without subsidiary ridges Buttes, cuestas	Recent lapillitic ash Recent ash	Karato Pirurari Nasioi Kieta
Karst plateau				Keriaka

In the formation of the strato-volcanoes, such as Mt. Balbi and the Lake Loloru volcano, lava flows played a subordinate role. There is typically a rugged summit area diversified by craters and tholoids included in Takuan and Balbi land systems (Plate 1; Plate 2, Fig. 2), below which extensive debris slopes (Erava land system) form a concave outline with an inclination decreasing from 20° at the top to 6° at the base, where there is a transition to broad peripheral volcano–alluvial fans (Plate 3, Fig. 1).

The very fine-textured, radiating ridge and ravine topography of Erava land system is probably of complex origin, having been built up by debris thrown out of the volcanic vents or avalanched down from disintegrating tholoids or flows, and subsequently largely eroded away by the action of streams, mud flows, and nuées ardentes.

The caldera of Billy Mitchell crater lake, 4 miles north-east of Mt. Bagana, is included in Balbi land system. It is $1\frac{1}{2}$ miles in diameter and has a rim between 3000 ft and 5000 ft in altitude. This caldera, from which over half a cubic mile of rock appears to have been removed, probably resulted from a catastrophic vulcanian eruption (cf. Cotton 1952, pp. 302–12) with subsequent collapse of the summit area. It suggests itself as a possible source of the layers of lapilli indicated in Figure 7, whose volume may be crudely estimated as about 0·2 cu mile.

At the foot of each Bougainville volcano, whether lava cone or strato-volcano, there is a volcano–alluvial fan with slope diminishing from 6° to 0·5° with distance, formed through deposition by running water, mud flow, and ash flow in varying proportions. The initial form of such fans is exemplified by the major surface of Buin land system, which is somewhat undulating, with ultra-low ridges formed by deposition and erosion during the period when vegetation was absent. Although volcano–alluvial fans are durable features, to the extent that they may still be recognizable when their parent volcanoes are not, those surrounding dormant or extinct volcanoes have become incised by the streams that traverse them in the time since the supply of fresh debris from upstream was cut off. The depth of insicion depends on the difference between the profile of volcanic equilibrium (Schmidt 1934, p. 118) and that of fluviatile equilibrium. A radial section of the Lake Loloru volcano, shown in Figure 8, illustrates how there is a zone of maximum incision midway down the slope, the valleys being cut as much as 800 ft below the original surface. Degree and depth of dissection have been made the major criteria for differentiating between land systems of the volcano–alluvial fans. Buin land system is only partially dissected, Numa and Rugen are dissected to valleys of low relief (200 ft), and Leikaia and Pauroka to valleys of moderate relief (400 ft). Further land system differentiation is on the basis of mantle characteristics. An impermeable weathered ash underlies a thin layer of Recent ash on Buin and Pauroka land systems, whereas deep Recent ash with lapillitic layers is found in Numa and Leikaia land systems. In Rugen land system a thin layer of Recent ash overlies a residual red clay.

As well as the major volcanoes, and mainly independent of them, there are a number of fields of subhorizontal lava flows dissected to form moderately high accordant ridges. Three land systems are distinguished on the basis of mantle characteristics. Sisivi has a deep lapillitic ash cover, while Puto and Umum have a shallow ash layer over residual red clay and brown clay respectively. Umum also includes a large mesa-like land form that appears to be a cumulo-dome (Cotton 1952, p. 158), as well as less regular hills eroded from intrusive diorite.

(*b*) *Erosional Landscapes*

This section is concerned with mountain, hill, and basin landscapes whose land forms have been sculptured by degradational processes to the point where their original constructional form is not readily recognizable. Karst landscapes are considered separately. Erosional hill slopes of the island are characteristically straight and very steep (30–45°), such slopes being common to landscapes of widely varying relief and geomorphic history. The main departures from this rule are found on eroded Pleistocene volcanoes, where the lower slopes are precipitous (45–72°) (Plate 5, Figs. 1 and 2), and in certain landscapes with clay soils, where the slopes are merely steep (17–30°) or high-moderate (10–17°).

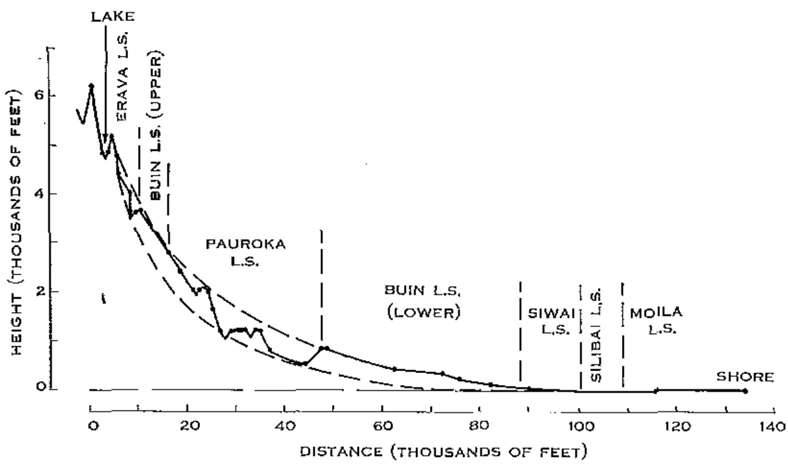

Fig. 8.—Topographic profile from the Lake Loloru volcano to the coast at Moila Point. Vertical exaggeration ×10.

(i) *Erosional Mountains.*—Mountains are distinguished from hills on the basis of terrain parameters, mountains being landscapes with relief greater than 500 ft satisfying at least two of the following three criteria:

(1) a maximum altitude greater than 3000 ft;

(2) a hypsometric index greater than III, so that the average altitude of the land surface is greater than 1200 ft; and

(3) characteristic slope greater than 30°.

Mountain landscapes that have suffered a long period of evolution occur on the Crown Prince Range. The landscape type most extensively developed here, classified in Karato and Pirurari land systems, consists of very steep-sided dendritic mountain ridges characterized by a large difference between the heights of the largest and the smallest ridges, major ridges being flanked by several orders of subsidiary ridges.

Karato differs from Pirurari only in the presence of lapillitic layers in the ash mantle. The landscape of Nasioi land system is similar to these in most respects, including terrain parameters, but subsidiary ridges are, by contrast, little developed. This land-form pattern has been correlated with the outcrop of diorite rock deeply but immaturely weathered to an incoherent granular texture.

The Emperor Range and other ranges of northern Bougainville, as well as Mt. Taroka and the mountain mass south of Wakunai, are ancient volcanoes that have been very deeply dissected to form "residual mountains" in the classification of Kear (1957, 1959). Melilup and Chambers land systems, differentiated because of the absence of ash from the former, consist of very high, widely spaced ridges with very steep side slopes that tend to become precipitous at the base. Even the stream beds have steep slopes, with many waterfalls. Within these mountain masses there are a number of large basins with precipitous walls standing above steep floors that are themselves quite deeply dissected. These basins comprise Emperor land system.

Kieta land system (Plate 6, Fig. 1), consisting largely of buttes at higher altitudes and cuestas at lower altitudes, comprises the dissected remnants of a structural plain or plains formed largely of andesitic agglomerate and fanglomerate. The agglomerate has strongly resisted weathering and the floors and sides of valleys adjacent to areas of Kieta land system are littered with large blocks of it.

(ii) *Erosional Hills*.—Most of the land systems of the erosional hills are formed on pre-Pleistocene rocks, whose structural expression is the main criterion for differentiation. Subparallel hogback ridges trending NNW. are common in Boira, Mainoki, Osirei, and Pomaua land systems. In Osirei these ridges are very widely spaced, with long steep flanks dissected by shallow gullies; in Pomaua the NNW. trend of the major ridges is not as conspicuous as a fine pattern of straight parallel lineaments trending WNW., expressed in the orientation of spurs, minor ridges, and valleys. Mainoki land system, with its rather closely spaced ridges, differs from Boira in lacking lapilli in the ash mantle.

A number of the ridges of Deuro land system are homoclinal ridges formed by moderately inclined strata, which also give rise locally to chevron spurs. More gently dipping beds form the cuestas of Teopasino land system. Expressions of structure are absent from Bagana and Doiabi land systems, which are both mantled by very great thicknesses of ash. The mantle of Bagana land system has been significantly added to by modern ash falls and ash flows.

The flanks of the Pleistocene volcanic "residual mountains" are dissected to very steep and precipitous ridges similar to those of Melilup land system except that they have lower relief. They are assigned to Tumuri land system, or to Mafahia land system when their ash mantle is lapillitic. Of the two remaining hilly land systems Dios is an area of very fine dissection and very low relief consequent on the uplift of a cliffed coast, and Ibu, comprising low, accordant, dendritic ridges, may be the remnant of an ancient volcano–alluvial fan in an advanced stage of dissection.

(iii) *Basin Floors*.—Many of the larger streams flow through upland basins, the floors of which are areas of low relief and low-moderate slopes. Such areas (Torombei land system) consist of irregular hummocky terraces grading into low accordant ridges. Fields of erratic blocks are common, suggesting deposition from mud flows during an epoch of slope instability. A similar morphology is found forming tracts too narrow to map in the upper valleys of a number of large streams, particularly in the Crown Prince Range where there are ultra-low ridges with steep side slopes showing evidence of slumping. Tributary streams on reaching the valley-floor tract tend to run down-valley, forming a local subparallel drainage pattern.

(*c*) *Alluvial and Swamp Landscapes*

In land systems of the erosional hills and dissected alluvial fans the major rivers are deeply entrenched. Their irregular bouldery channels are, however, commonly bounded by narrow-channelled flood-plains up to 1000 ft wide.

Such flood-plains persist as the rivers traverse Siwai land system, the major plains of which now stand up to 80 ft above water level. These major plains of very high gradient are nearly all of volcano–alluvial origin, being relict from the phase of rapid alluviation following the latest episode of eruption; they are "piedmont–banjir plains" (Paterson 1964). Terraces characteristically occur between the plain and the flood-plain. The river channels are gravelly rather than bouldery in this land system and, although the channel pattern is generally angular, there are some active meanders and also some alluvial islands.

Silibai land system is the main locus of alluvial activity at the present time. The river channels have actively migrating meanders (Plate 9, Fig. 1) and the main land surfaces are flood-plains built of point-bar and channel-bar deposits of sand and gravel with a veneer of fine sandy over-bank deposits. The high water-table of these plains makes them liable to surface flooding from local rains as well as from river overflow.

Rivers traversing Moila land system, which includes all the major swamps of the area, tend to have very low gradients and deep channels with either stable or migrating meanders. Natural levees are common and serve to delineate abandoned flood-plain scrolls. Little of the surface of this land system is normally above the water-table (Plate 10, Figs. 1 and 2). Nearly all Bougainville swamps result from coastal progradation and are impounded by beach ridges in the embayments between alluvial tracts or at the foot of hills.

At the base of the active volcano, Mt. Bagana, lie the plains of Saua land system (Plate 9, Fig. 2), built of the gravelly and sandy products of present-day volcanicity. Streams here have a high variability of flow as there is little vegetation to suppress storm run-off, and their channels are multiple or braided. There is no distinct boundary between the channel and the flood-plain, but zones up to ½ mile wide are kept free from woody vegetation by flooding and sediment movement. Towards the coast stream braiding is less conspicuous, but unstable distributary channels disperse the flow over the surface of the plain. The land system also includes ash plains that stand above the flood-plains and meet them at cliffs up to 50 ft high.

(*d*) *Coastal Landscapes*

Two land systems have been distinguished according to whether longshore drifting or coral growth is the dominant process. The curving, prograding sandy beach ridges of Jaba land system, rising 5 or 10 ft above high-water mark, form extensive beach ridge barrier systems, especially in the south (Plate 11, Fig. 1). Two large promontories, Motupena Point and Moila Point (Jennings 1955), have been constructed in this way. Coral coasts on which sandy beaches are relatively insignificant form Soraken land system. Submerged coral reefs extending up to 10 miles from the shore are found everywhere except on the northern coast between Queen Carola Harbour and Cape Laverdy. Emergent barrier reefs bearing occasional islands or sand cays (Plate 11, Fig. 2) are characteristic of the outer margin of the submerged reef, especially along the east coast of Bougainville.

Fringing reefs are ubiquitous on the shores of Soraken land system, but also occur near low-water mark at the foot of many prograding beaches of Jaba land system, so that some of the beach-ridge complexes may be partly or wholly underlain by coral. The dry-land part of Soraken land system consists largely of very flat coral platforms from 5 to 15 ft above sea level with very youthful (rendzina) soils. It is probable that these platforms were developed at sea level during a Recent relatively higher stand of the sea.

(*e*) *Limestone Landscapes*

The raised reef of Buka Island and northern Bougainville is an almost perfectly preserved barrier reef, the northern part of which was almost an atoll (Plate 12, Fig. 2). One may distinguish a former reef flat of very little relief, patch reefs, and islands, with associated precipitous or cliffed reef front and gentle to moderate lagoon slope (Lonahan land system) and a former lagoon floor (Kohino land system) that has an uneven surface formerly about 100 ft below sea level. Former islands on the reef flat stand as a ridge up to 40 ft high. In the southern part of Buka Island there are several examples of raised tidal channels completely analogous to Buka Passage.

The karst erosion of Lonahan and Kohino land systems is little developed as yet, consisting mainly of scattered dolines. Dolines tend to be smaller, shallower, and more numerous to the south, where the superficial volcanic ash layer is thick enough to prevent water from travelling so far over the ground surface. Such conditions may also have occurred after earlier ash showers, contributing to the contrast in development between south and north. A long deep trough cut in the former reef flat about 1000 ft from the reef front where the uplift has been greatest may be a solutional feature, but it is much better developed than the dolines. Some caves occur at the foot of the reef-front cliff, extending inland for a few hundred feet.

In the case of the Miocene limestone of Keriaka land system (Plate 4, Fig. 1), the gross form of an ancient coral atoll is well preserved but the detail of the land surface is entirely erosional. The typical landscape is a karst of very closely spaced dolines, grading into valleys of integrated drainage and separated by a reticulate system of saw-tooth ridges about 400 ft high. The slopes tend to be concave and very steep. In some areas on the periphery of the former atoll pyramidal hills are more conspicuous than conical dolines, resulting in a fine-textured type of kegel karst perhaps approaching the pyramid-and-doline karst of Jennings and Bik (1962). The landscape is at present mantled with many feet of ash and the development must have been influenced by this to some extent.

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PART VII. TERRAIN OF BOUGAINVILLE AND BUKA ISLANDS

By J. G. SPEIGHT*

The physical landscapes of Bougainville and Buka Islands have been discussed in Part VI in terms of their genesis and relationships. They may also be considered from the purely descriptive point of view and may be classified on the basis of the morphological parameters altitude, relief, slope, grain, and plan-profile. Definitions of terms and schemes of categorization are set out in Appendix I, and values for the parameters have been assigned to each land system, as recorded in the tabular land system descriptions in Part III. A summary of these terrain data is presented in Table 11, the categories employed being those defined in Appendix I, abbreviated to initial letters in the case of relief, characteristic slope, and grain.

As a rule, land systems are areas of homogeneous terrain, and their boundaries tend to represent more or less abrupt discontinuities in terrain parameters. Mapping of the distribution of the several categories of a particular parameter for the area as a whole as in Figures 9–12 may thus be based on land system boundaries, except in the case of altitude. Land systems, as delineated in this survey in particular, commonly cover a considerable altitude range, so that the hypsometry is best represented by a conventional contour map such as the accompanying map of physical features, the hypsometric zones of which have boundary values based on a mathematical function chosen to even out the horizontal contour spacing. Measurement of the areas within the several zones shows that, although very little of the land stands above 7000 ft, fully half of it stands above 300 ft. Altitude, particularly as it affects climate, is therefore a significant terrain factor over much of the area.

From the map of relief (Fig. 9) it will be seen that areas of very high relief are confined to the volcanoes, the northern mountains, and the Keriaka Plateau, but

TABLE 11

TERRAIN PARAMETERS OF LAND SYSTEMS

Land System	Area (sq miles)	Altitude			Relief	Characteristic Slope	Grain	Plan-profile
		H.I.	Min. (ft)	Max. (ft)				
Raised coral reef								
Lonahan	70	II	0	300	MH	HG	—	1L
Kohino	140	II	0	180	UL	G	—	1
Coasts								
Jaba	60	I	0	15	—	G	UF	5L//
Soraken	85	I	0	15	—	LG	—	6L
Swamps								
Moila	250	I	0	50	—	LG	—	7

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TABLE 11 (*Continued*)

Land System	Area (sq miles)	Altitude H.I.	Altitude Min. (ft)	Altitude Max. (ft)	Relief	Characteristic Slope	Grain	Plan-profile
Plains								
Saua	25	II	0	800	UL	VHG	C	2//
Silibai	240	I	0	50	—	HG	VC	7
Siwai	355	I	0	200	VL	VHG	VC	1L//
Volcano–alluvial fans								
Buin	270	II	100	3000	L	VHG	M	1L//
Rugen	75	II	0	1000	L	LM	M	4L//
Numa	115	II	0	1000	L	LM	M	4L//
Leikaia	60	III	200	1500	MH	VS	F	4L//
Pauroka	195	III	200	3000	MH	S	F	4L//
Volcanic landscapes								
Balbi	30	V	1000	8500	VH	VS	VC	4
Bagana	15	IV	600	4000	MH	VS	F	4L
Takuan	75	V	1000	7500	VH	S	C	4
Erava	115	V	1200	6000	L	VS	VF	4L//
Sisivi	10	IV	1200	3000	MH	VS	F	4L
Umum	20	III	0	500	MH	S	F	4L
Puto	35	II	0	2000	MH	S	F	4L
Erosional hills								
Dios	10	II	0	100	VL	S	VF	4L
Ibu	45	III	0	2500	MH	LM	M	4L
Tumuri	120	III	500	2500	H	VS	F	4L//
Mafahia	50	IV	300	2000	MH	P	F	4L//
Teopasino	10	II	0	800	MH	HM	M	4L
Deuro	100	III	0	2500	H	S	C	4L
Doiabi	15	IV	300	4500	H	S	M	4L
Boira	100	III	0	3500	H	VS	M	4L
Mainoki	50	III	0	2500	H	VS	M	4L
Pomaua	10	IV	500	2500	H	VS	M	4L//
Osirei	60	III	0	2500	H	S	C	4L//
Basin floors								
Torombei	15	IV	100	2500	L	LM	VF	1L//
Erosional mountains								
Melilup	190	IV	2000	7000	VH	P	C	4L
Chambers	35	V	1500	5000	H	P	M	4L
Emperor	20	V	3000	7000	VH	VS	C	4L//
Karato	45	IV	300	3800	H	VS	C	4L
Pirurari	110	V	50	5000	H	VS	C	4L
Nasioi	70	IV	50	4000	H	VS	C	4L
Kieta	60	IV	0	5200	H	VS	M	4//
Karst plateau								
Keriaka	115	IV	0	4200	VH	S	F	4L

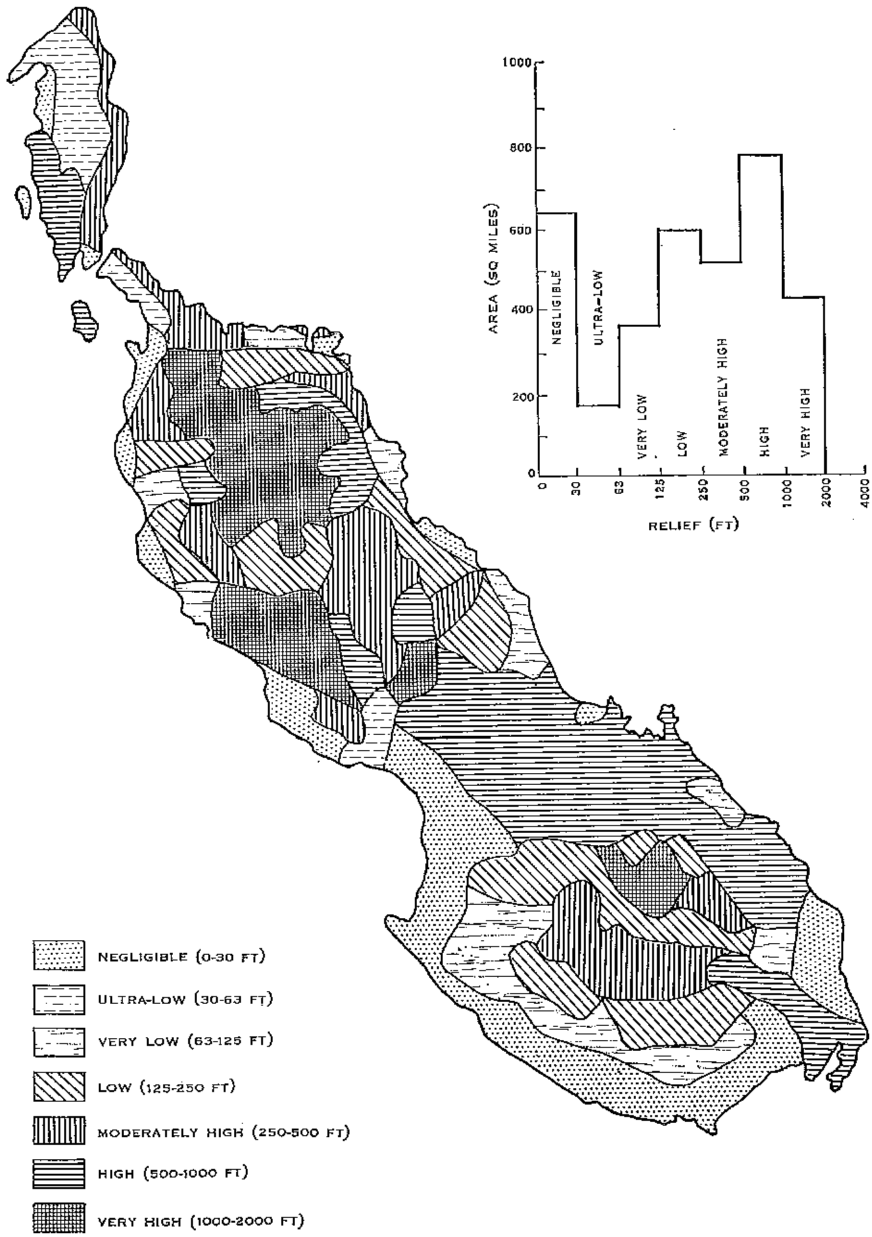

Fig. 9.—Distribution of relief.

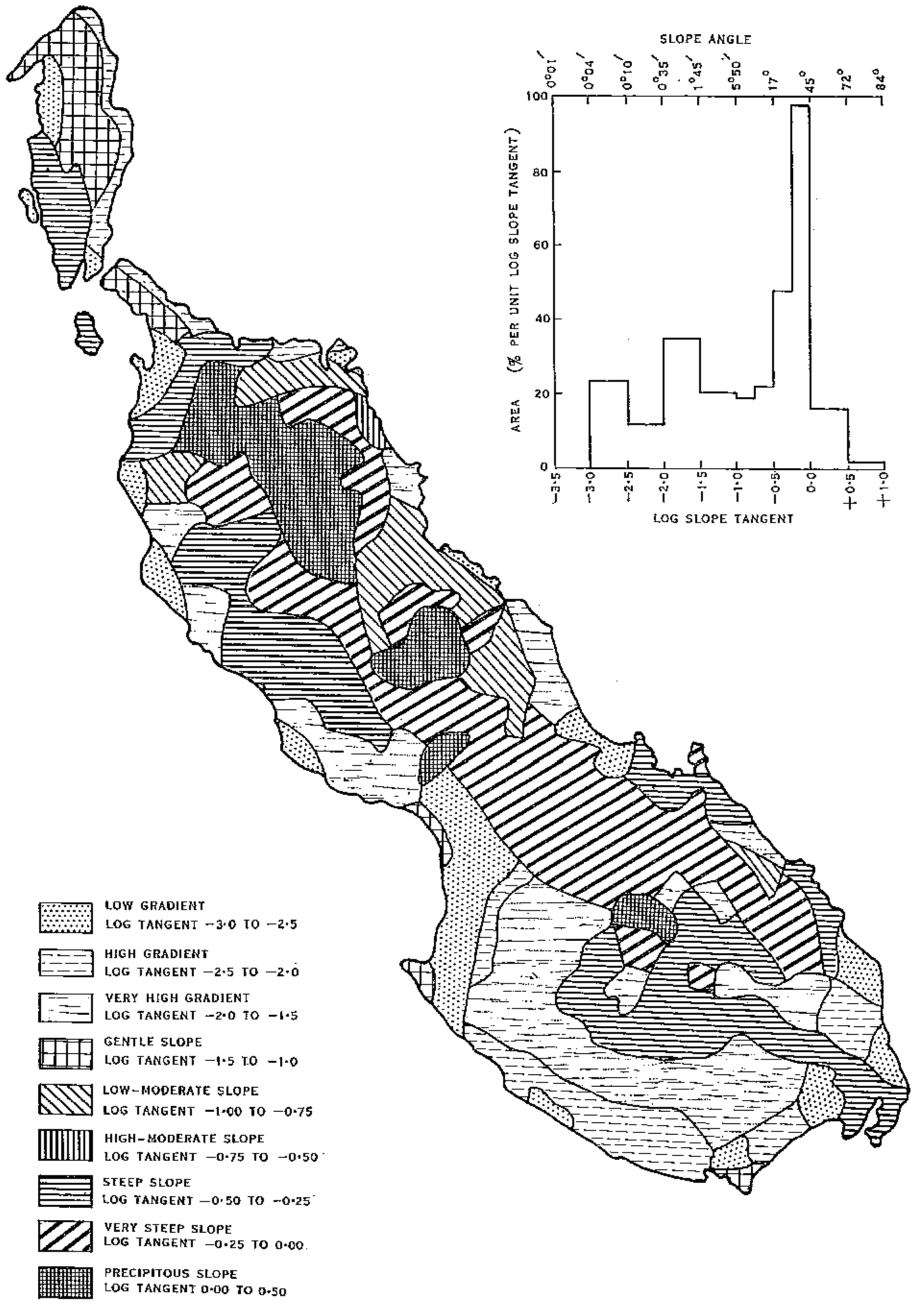

Fig. 10.—Distribution of characteristic slope categories.

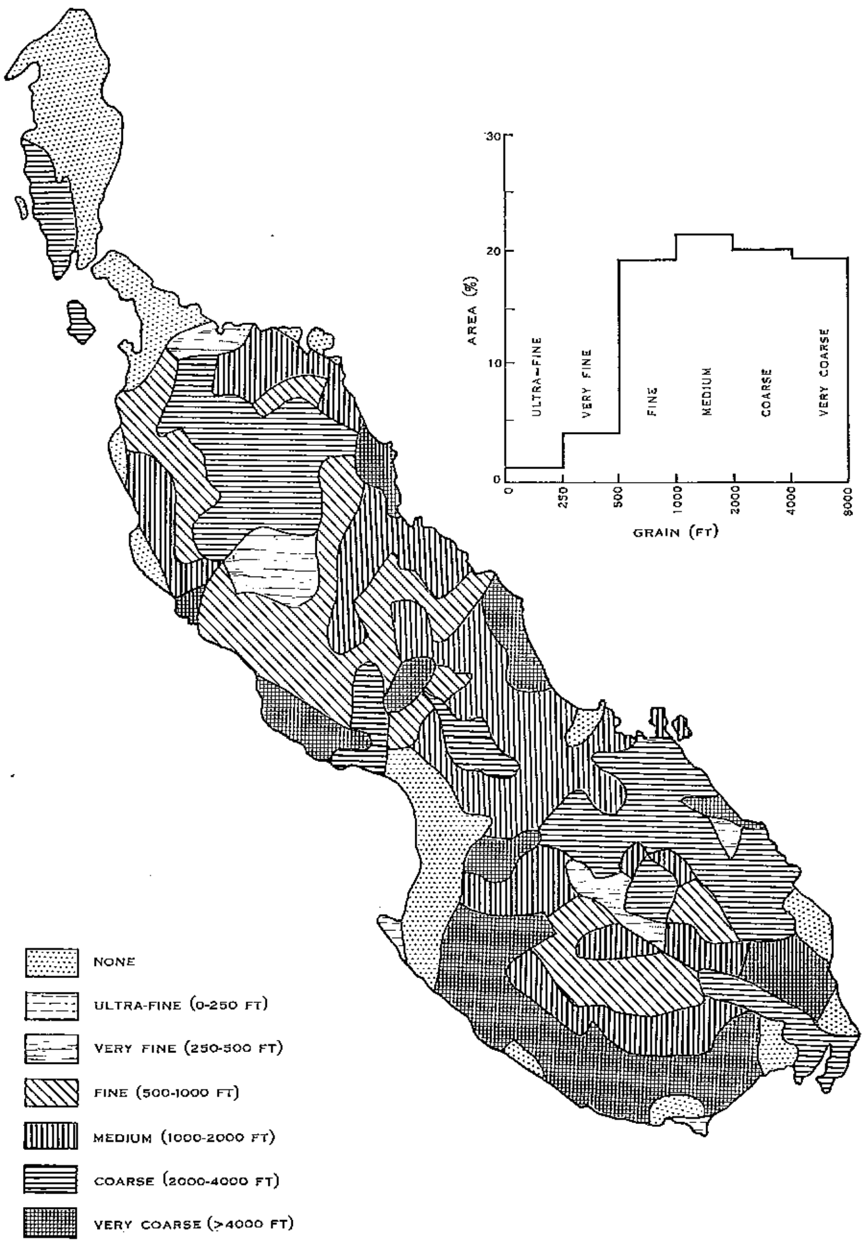

Fig. 11.—Distribution of categories of grain size.

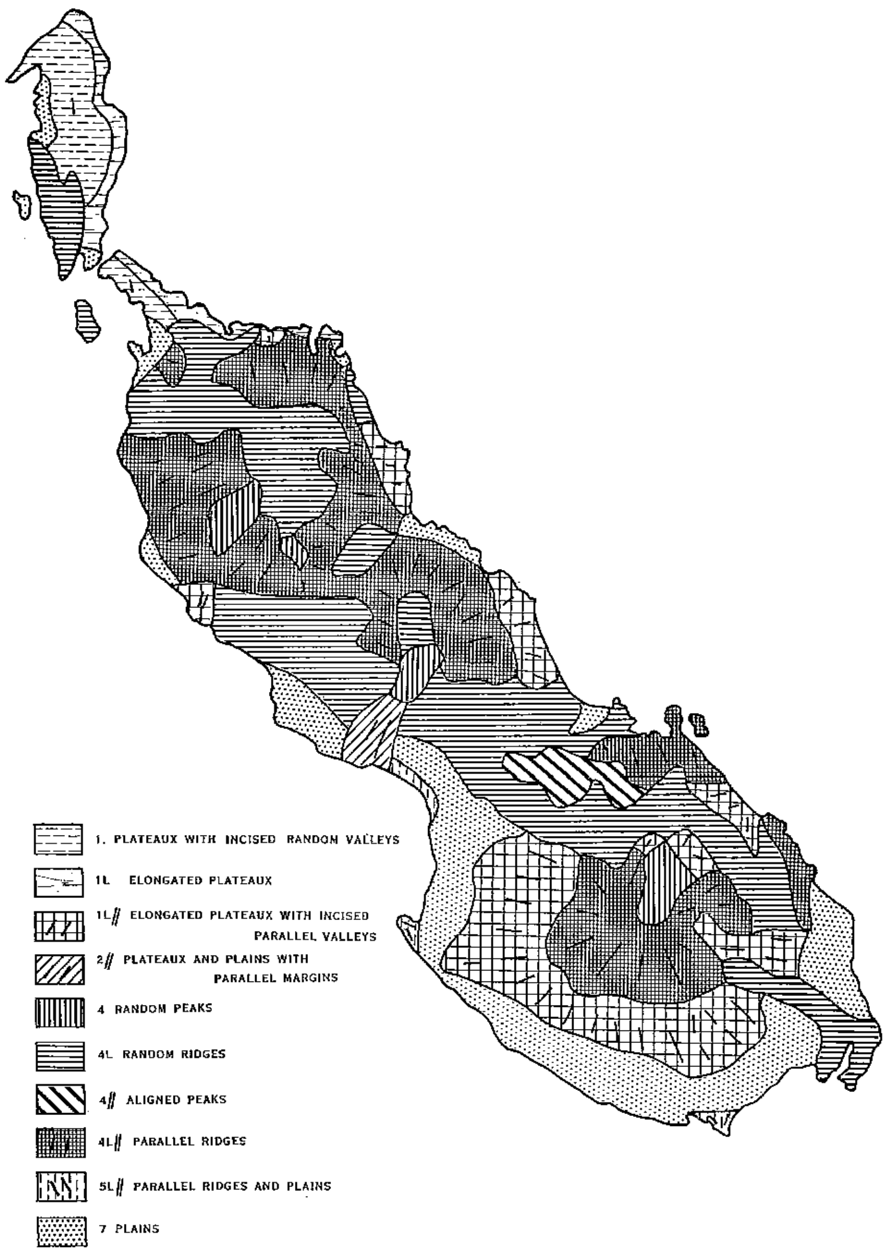

Fig. 12.—Distribution of categories of plan-profile.

areas of high and moderately high relief are very extensive along the axis of the islands and reach to the coast in the north and at Kieta, Toimonapu, and Tonolei. Low and very low relief is characteristic of volcano–alluvial fans and dissected plains, while negligible relief is found on flood-plains and sedimentary coasts. The histogram (Fig. 9) shows how relief is fairly evenly distributed through the categories, except that high relief (500–1000 ft) is particularly abundant and may be said to be the characteristic relief category of the area, and ultra-low relief (30–63 ft) is rare, being less than the relief of the lowest hills and greater than that of the deepest alluvial stream channels.

Figure 10 illustrates the distribution and relative extent of the various slope categories. The histogram, based on land unit rather than land system data, shows clearly how slopes are concentrated in the categories of "very steep" and "steep", the former prevailing over 25% of the planimetric area of the islands. Slopes of "very high gradient" (0°35′–1°45′) are also prominent, being characteristic of undissected volcano–alluvial fans and plains. Apart from these two modes, the histogram shows a practically uniform distribution of slope from "precipitous" through to "low gradient". Little significance can be attached to the relative frequencies of "high-gradient" and "low-gradient" slopes as the data are insufficiently precise.

Figure 11 shows the distribution of grain, a textural parameter indicating the spacing of streams or ridges. Raised reefs, coral coasts, and swamps cannot be said to have a characteristic grain, but the beach-ridge spacing of Jaba land system places it in the category of ultra-fine grain. Very fine grain of land surface is found only in three land systems which have an unusual genesis: Erava land system consists of former volcanic avalanche slopes, Torombei of finely dissected basin floors, and Dios of a coastal area dissected after an uplift of about 100 ft. Very coarse grain is found in two environments: the alluvial plains of Silibai and Siwai land systems where there is little local surface drainage and the landscape is compartmented only by through-going rivers, and the undissected volcanic cones of Balbi land system. Among the purely erosional land systems grain tends to be related to relief by a ratio from 2 : 1 to 4 : 1. Keriaka land system has relief comparable with the grain but here the grain has been measured on the dissected plateau surface while the relief is that of the escarpment. The histogram in Figure 11 shows how grain is evenly distributed through the categories from fine to very coarse, each category covering about 20% of the area. Very fine, ultra-fine, and "none" together make up the remaining 20%.

In the plan-profile map (Fig. 12) it is apparent that only 10 of the 25 possible categories are represented, and of these only 4 are of general occurrence: 1L//, 4L, 4L//, and 7. The simple erosional landscapes consist of randomly oriented sharp-crested ridges falling in category 4L. Where there is a preferred orientation of ridges, as a result either of geological structure or of radial drainage from a volcano, the plan-profile becomes 4L//. Alluvial plains, littoral plains, and swamps fall in category 7, and plains traversed by subparallel incised rivers and streams in category 1L//.

Categories 1 and 1L occur on the raised coral reef, category 1 being related to the random incised drainage of the former lagoon floor, and category 1L to the subparallel zonation across the former reef front, reef flat, and lagoon slope. Saua land system, having plains at two levels, falls in category 2//. The volcanic cones of Balbi and Takuan land systems fall in category 4, while the alignment of the pinnacles of Kieta land system along geological fractures places them in category 4//. The beach ridges of Jaba land system, though of negligible relief, have been classed as 5L//.

PART VIII. SOILS OF BOUGAINVILLE AND BUKA ISLANDS

By R. M. Scott*

I. Introduction

Over two-thirds of the survey area is covered by recent volcanic ash of varying depth, and the distribution of this ash mantle suggests that at one time it was much more extensive. The variation in thickness of the ash mantle has given rise to ash and ash-covered soils. In areas where the ash is absent there are mature developed soils of a former land surface as well as juvenile sedentary, depositional, and organic soils.

Unlike many areas in Papua and New Guinea, Bougainville had already been the subject of a soil survey before the CSIRO survey was carried out. C. L. van Wijk's (1963) study of the distribution and main characteristics of the soils of Bougainville Island, together with some of his field notes, has proved most helpful in the compilation of this part of the report.

II. Soil Formation

Soils differ according to the influence of climate, organisms, topography, parent material, and time (Jenny 1941). Thus soils will differ according to which soil-forming factor or factors exert the greatest influence. Should one or more factors be dominant over an area, then the soils will be uniform in spite of variations in the other soil-forming factors.

The variations in the soils of Bougainville and Buka Islands are mainly a result of the time the climate factor has had to operate on various parent materials. The influence of time must be considered in conjunction with topography, since topography will influence the stability of the land surface. The processes of aggradation and degradation are active or have been recently active; aggradation tends to be episodic whereas degradation is more sustained and the rate is largely controlled by slope. These processes have caused the majority of the soils to be youthful, and it is only where the old land surface is exposed or lies near the surface that mature developed soils occur.

In Bougainville and Buka Islands the influences of both climate and organisms appear to have little effect on soil differentiation. Although there are variations in both rainfall and temperature accompanied by changes in vegetation types, these variations do not appear to be sufficient to produce marked differences in the soils. Changes in soils by human interference are negligible since population is low and the regrowth of vegetation rapid.

There is a variety of parent materials in the area, but they can be considered as two kinds. There are those of volcanic origin, which may vary in texture but are all similar in mineralogical composition, and uniform coral limestone material. In some

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TABLE 12

SOIL CLASSIFICATION

Classification Used		Classification according to 7th Approximation				Soils of van Wijk (1963)
Soil Group	Family	Order	Suborder	Great Group	Subgroup	
Permanently inundated soils						
(1) Swamp peats	(1*a*) Submerged peats (1*b*) Surface peats	Histosols				Alluvia
(2) Swamp soils	(2*a*) Neutral peaty sands (2*b*) Neutral peaty clays	Entisols	Aquents	Hydraquents		
Tidally inundated soils						
(3) Mangrove soils	(3*a*) Shallow alkaline peaty sands					
	(3*b*) Alkaline sands			Psammaquents	Orthic Psammaquents	
Periodically inundated soils						
(4) Alluvial soils	(4*a*) Shallow grey mottled sands					
	(4*b*) Brown mottled sands		Psamments	Orthopsamments	Aquic Orthopsamments	Coarse sand ash soils
	(4*c*) Stratified mottled loams and clays		Udents	Hapludents	Aquic Hapludents	Alluvia
Dry-land soils						
(5) Lithosols					Lithic Hapludents	
(6) Littoral soils	(6*a*) White sands (6*b*) Brown sands		Psamments	Orthopsamments	Orthic Orthopsamments	
(7) Ash soils	(7*a*) Grey fine sands					

	(7*b*) Brown loams with an ash pan	Inceptisols	Andepts	Durandepts	Orthic Durandepts	Brown-yellow andesitic tuff loams/clay loams. Silt ash-covered andesitic tuff loams. Andesitic tuff-covered coarse sand
	(7*c*) Brown loams			Umbrandepts	Orthic Umbrandepts	
	(7*d*) Brown loams with lapillitic horizons				Entic Umbrandepts	Pumice ash-covered andesitic tuff loams. Pumice ash soils
(8) Ash-covered soils	(8*a*) Brown loams over sands				Thapto psammentic entic Umbradepts	Silt ash soils. Gravel soil. Silt ash covered coarse sand
	(8*b*) Brown loams over brown friable clays (8*c*) Brown loams over reddish friable clays				Thapto ochrultic entic Umbrandepts	Fine sand ash-covered red-brown clays Coarse sand ash-covered red, yellow-brown clays
	(8*d*) Black loams over reddish plastic clays				Thapto ustalfic entic Umbrandepts	Coral limestone soils
(9) Acid clay soils	(9*a*) Brown friable clays (9*b*) Red friable clays	Ultisols	Ochrupts	Typochrults	Orthic Typochrults	Red-brown and yellow clays
(10) Rendzinas	(10*a*) Shallow greyish brown loams (10*b*) Shallow black clays	Mollisols	Rendolls			Coral limestone soils
(11) Terra rossa soils	(11*a*) Shallow reddish plastic clays	Alfisols	Ustalfs	Rhodustalfs	Ruptive lithic Rhodustalfs	
	(11*b*) Reddish plastic clays (11*c*) Brown plastic clays				Orthic Rhodustalfs	

areas the parent material of volcanic origin lies on coral limestone and both materials influence the soil formation.

III. Soil Classification

Many of the soils of Bougainville are polygenetic in origin and this gives rise to problems in classification. For the purpose of the survey, an ash-covered soil has a recognizable volcanic ash mantle less than 3 ft deep overlying a buried soil. An ash soil, on the other hand, has a recognizable volcanic ash mantle to a depth greater than 3 ft, or overlies weathered or fresh rock. The separation of ash and non-ash-covered soils is based on field observations and therefore many of the non-ash-covered soils may be ash-contaminated.

The soil classification is shown in Table 12. The soils have been placed into 11 soil groups according to profile morphology and parent material, and each soil group, with the exception of lithosols, has been further subdivided in soil families on the basis of colour and texture. The soil groups have been arranged in order of environmental "wetness", from permanently inundated to dry-land soils.

Alongside this classification is that of the 7th Approximation of the United States Soil Conservation Service (1960) and the equivalent soils recognized by van Wijk. The 7th Approximation classification of the soils must be regarded as very tentative since not all the data required to classify soils into this system were available.

IV. Descriptions of the 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, hence the information on structure of the subsurface horizons is not reliable.

(1) *Swamp Peats*.—These organic soils are composed of a poorly decomposed vegetative layer more than 1 ft thick, and occur in swampy areas that are permanently inundated to depths generally greater than 4 ft. The soils have been separated into two families, based on environment and the depth of occurrence of a peat layer relative to the surface of the water.

(1*a*) *Submerged Peats*.—These occur under at least 2 ft of flowing water. They consist of a very dark brown, mottled, poorly decomposed organic layer, consisting mainly of a fibrous root mass, overlying alluvial sands at depth. They are associated with open tall forest (*Terminalia brassii–Campnosperma*).

(1*b*) *Surface Peats*.—These consist of a fibrous root mat overlying a poorly decomposed organic layer. Surface peats are found floating at or near the surface of stagnant water and support a mixed herbaceous vegetation.

(2) *Swamp Soils*.—The soils show no profile development apart from peaty surface horizons. They occur in swampy situations and are permanently inundated by at least 6 in. of water. Two families have been distinguished on the basis of soil texture, which reflects mode of deposition of the parent material.

(2*a*) *Neutral Peaty Sands.*—A dark greyish brown, fine sandy peat up to 12 in. thick overlies a very dark grey, peaty fine sand, which merges into a dark grey sand between 24 and 36 in. The sand fraction has been sorted by both wave and tidal action. These sands occur in swales of beach ridge complexes that are normally inundated by more than 6 in. of fresh water, but near tidal inlets the water may be brackish.

(2*b*) *Neutral Peaty Clays.*—A brown to dark greyish brown, poorly decomposed peaty clay not more than 6 in. thick overlies a grey, gleyed, silty to fine sandy clay. These soils, which are derived from water-laid fine-textured material, have a neutral reaction throughout and occur on swamp margins away from the beach ridge complexes. The peaty layer may be absent on the outermost margins where fluctuations in water-table lead to partial drying out of the surface horizon.

(3) *Mangrove Soils.*—Mangrove soils show no profile development apart from a thin peaty or organic surface horizon. They are tidally inundated and the land surface commonly has a hummocky microrelief, not more than 1 ft high, due to the presence of crab mounds. These soils are found only on tidal flats. Separation into families is based on depth and the presence or absence of a peaty surface horizon.

(3*a*) *Shallow Alkaline Peaty Sands.*—A dark brown, strongly alkaline, sandy peat, poorly decomposed, overlies coral at between 6 and 12 in. depth.

(3*b*) *Alkaline Sands.*—A very dark greyish brown, neutral, loose sand with some pebbles merges at 12–18 in. into a dark greyish brown, moderately alkaline, loose sand containing some mangrove peat and pebbles.

(4) *Alluvial Soils.*—The soil group includes relatively unstable soils, which have no profile development apart from the presence in nearly all cases of an organic surface soil. These soils are derived from waterborne sediments and are all at some period inundated by river flooding, during which deposition takes place. Three families have been recognized on the bases of depth, colour, and texture.

(4*a*) *Shallow Grey Mottled Sands.*—A greyish brown to very dark grey, neutral, loose sand merges at 2–4 in. into a dark grey, slightly acid, mottled, loose sand, in which gravel and stones may be present. Gravel, stones, and boulders become very frequent below 6 in. depth. Such soils occur on point bars of large rivers and also on debris slopes of active volcanoes. Normally the point bars are devoid of plants or have an open vegetation, but where there is a dense grass vegetation a thin, brown, massive, silty loam surface layer is formed by the vegetation trapping finer sediments during floods. Where these soils occur on debris slopes or are associated with rivers with sources near active volcanoes, a high content of soluble salts may be present. Shallow grey mottled sands are subject to frequent and irregular flooding and when not inundated they have a very high water-table.

(4*b*) *Brown Mottled Sands.*—A dark brown, humic, weak crumbly, very strongly acid, fine sandy loam to loamy fine sand merges at 3–6 in. into a greyish brown to brown, mottled, strongly acid, massive, loamy fine sand to single-grain fine sand. Between 12 and 24 in. the latter horizon merges into a grey, mottled, strongly acid, loose fine sand to loamy fine sand that passes into a dark grey fine sand below the water-table. At greater depth a mixture of black and white fine sand grains (mainly hornblende and plagioclase crystals) may occur. Gravel and stones are occasionally encountered below depths of 18 in. In wetter sites the grey, mottled horizon may be very close to the surface. These soils have a rapid permeability but are poorly drained owing to a high water-table, which, when sampled after a relatively long dry spell, was generally within 4 ft of the surface. Brown, mottled sands occur on broad plains or terraces that are subject to only irregular and infrequent floods. However, a stony phase of this family has been distinguished, occurring on narrow flood-plains and valley flats associated with large rivers where flooding is more frequent. This phase, being less stable, has a less pronounced humic surface horizon.

(4*c*) *Stratified Mottled Loams and Clays.*—These soils, which are slightly acid throughout, are stratified, each layer being homogeneous and usually showing an abrupt change to the adjacent layer. The textures of the layers range mainly from fine sandy loams to fine sandy clays, although occasionally a fine sandy layer may be present. This stratification occurs in no apparent order and is presumably due to variations in river regime and sediment load.

They have a dark brown to brown, humic, weak crumbly surface horizon up to 6 in. thick overlying a mottled, massive subsurface horizon that is brown in the upper part, becoming grey with depth. The permeability of these soils is slow and the drainage is poor owing to a high water-table.

They occur on alluvial plains and are subject to irregular flooding for short periods.

(5) *Lithosols.*—Lithosols are shallow and show no profile development apart from a thin, humic, loamy surface horizon. In many cases they are associated with rock outcrops. No differentiation into families has been made in this soil group.

They consist of a thin (3–6-in.), brown to dark brown, humic, weak crumbly, sandy loam to sandy clay loam overlying weathered rock of variable thickness, colour, and texture that passes into hard rock within 20 in. Soil reaction is variable, ranging from very strongly acid to neutral. Lithosols occur on very narrow to knife-edge ridge crests and steep slopes where erosion does not allow sufficient time for the soils to develop.

(6) *Littoral Soils.*—Such soils have a sandy texture and are derived from both wave- and tidal-sorted sands. A subdivision into two families has been based on the degree of profile development, which varies from no profile development to the presence of a thin humic surface soil. This development reflects the stability and age of the families.

(6*a*) *White Sands.*—They consist of deep, loose, medium to fine, white sand grains with appreciable amounts of black mineral grains (ilmenite and magnetite crystals). Locally there may be a concentration of the black minerals by tidal sorting to form distinctive layers. This family has no A horizon and is very unstable, sand being continually added to or removed from it. They have a neutral surface reaction, become alkaline with depth, and occur on the outermost beach ridge.

(6*b*) *Brown Sands.*—A thin, very dark brown, humic, loose, fine sand 1–2 in. thick overlies a dark brown, loose, fine sand. This merges at 10–15 in. into a very dark greyish brown, loose, fine sand. In the vicinity of the water-table, which occurs between depths of 3 to 10 ft, the sand becomes dark grey and mottling is apparent.

The soil reaction is medium acid throughout. This family represents an older and more stable soil than the white sands, as shown by the development of an A horizon and by the browner colours in the C horizon, which become more marked with distance inland. Brown sands occur on beach ridges.

(7) *Ash Soils.*—The soils include all recent volcanic ash soils more than 3 ft deep or that overlie rock at a lesser depth. Four families have been recognized on the basis of profile development, which indicates differences in age and in source as shown by variations of texture. Many of these soils have buried humic horizons, pointing to intermittent volcanic activity.

(7*a*) *Grey Fine Sands.*—A dark grey, loose, structureless, fine sand, 1–2 ft deep, passes abruptly into a slightly humic, dark brown to brown, massive, loamy fine sand to fine sandy loam. Below 30 in. the latter horizon passes into a dark greyish brown to dark grey sand with ejected blocks. They have very rapid permeability and are strongly acid throughout.

The surface 1–2 ft represents very recent volcanic ash from the volcanoes of Balbi and Bagana. In fact, a thin cover of ash is at present being laid down with each slight explosion of Bagana. The colour, texture, and higher organic matter content in the second horizon indicate that this was once a surface horizon of an older ash shower.

A stony phase of this family occurs in the vicinity of Balbi and Bagana volcanoes, the stones consisting of blocks ejected during eruptions.

(7*b*) *Brown Loams with an Ash Pan.*—A very dark brown, humic, weak crumbly, fine sandy loam merges at 3–6 in. into a dark brown, humic, massive, fine sandy loam, which in turn merges into a thin, dark yellowish brown, slightly mottled, massive, loamy fine sand between 12 and 18 in. Between 15 and 24 in. there is an abrupt change to a dark brown to brown, humic, massive, sandy loam up to 12 in. thick, representing a buried humic horizon which in turn merges into a yellowish brown, compact, loamy sand to sandy loam that may contain large boulders. These soils are strongly acid at the surface, become medium acid with depth, and occur on level to gently sloping land.

The buried horizon indicates that the upper 15–18 in. are derived from a more recent volcanic ash shower. In some areas this horizon is absent, and thus the compact horizon is nearer the surface. The compact horizon or ash pan reduces the permeability of the soil, leading to temporary waterlogging after heavy rainfall. At high altitudes the effects of this impedance and lower temperatures have resulted in a peaty surface horizon. The compact layer has the appearance of a tuffaceous material, and varies from a few inches to over 30 ft thick. It overlies alluvial sands at lower altitudes and andesitic rock or buried acid clay soils at higher altitudes. Its origin may be associated with nuées ardentes.

(7*c*) *Brown Loams.*—A very dark brown to black, humic, weak crumbly, fine sandy loam between 3 and 12 in. thick overlies a dark brown to brown, massive, fine sandy loam. This in turn merges at 12–18 in. into a dark yellowish brown to dark greyish brown, massive, fine sandy loam. At depths varying from 18 to 30 in., there is a sharp break from the above ash-derived soils to rock at varying stages of weathering.

These soils are medium acid throughout, are well drained, and occur mainly on steep slopes.

(*7d*) *Brown Loams with Lapillitic Horizons.*—A dark brown to very dark brown, humic, weak crumbly, fine sandy loam 3–6 in. thick merges into a brown to dark greyish brown, less humic, massive, loamy fine sand. Between 18 and 24 in. there is an abrupt change to a lapillitic horizon about 6 in. thick, consisting of black and white loose fine sand (mainly hornblende and plagioclase crystals) with varying amounts of lapilli. Below the lapillitic horizon there is a dark grey to brown, massive, loamy sand that passes abruptly into a dark brown, humic, massive, fine sandy loam at depths varying from 30 to 46 in. This represents a buried humic horizon that overlies another lapillitic horizon up to 24 in. thick and similar to that which occurred above, and this in turn overlies a dark greyish brown, massive, loamy fine sand. At depths greater than 3 ft, buried acid clay soils were occasionally encountered but normally there was a great thickness of ash. These soils are medium acid throughout and have a rapid permeability leading to good drainage.

The lapillitic ash is likely to have originated from Billy Mitchell crater, although Bagana or the cone east of it, or even Balbi, are other possible sources.

One of the outstanding features of these soils is their resistance to erosion, since they cover all but precipitous slopes. However, on some of the steep slopes the buried humic horizon and its associated lapillitic horizon may be absent and rock is encountered in its place, indicating that erosion did take place before the latest volcanic activity.

(8) *Ash-covered Soils.*—This group of soils has an ash cover less than 3 ft deep over buried soils. They have been separated into four families according to the nature of the buried soils, which include the acid clay soils, and some of the alluvial and terra rossa soils.

(*8a*) *Brown Loams over Sands.*—A very dark brown, humic, weak crumbly, fine sandy loam, from 4 to 6 in. thick, overlies a dark brown to dark yellowish brown, less humic, massive, loamy fine sand. Below 12–18 in. there is an abrupt change to a dark greyish brown, fine sand of alluvial origin in which rounded gravel and stones may be present. A buried humic horizon of the alluvial soils was occasionally present below the ash soils. The soils are medium to slightly acid throughout, have rapid permeability, and are confined to stable alluvial plains.

(*8b*) *Brown Loams over Brown Friable Clays.*—A very dark brown to black, humic, weak crumbly, fine sandy loam, 3–12 in. thick, merges into a dark greyish brown to brown, fine sandy loam to loamy fine sand. Between 14 and 30 in. there is an abrupt change to a brown or dark yellowish brown, friable clay that may be slightly mottled. Rock or weathered rock is frequently encountered between depths of 30 and 48 in. The soils are slightly acid, have moderate permeability, and occur on ridge crests and moderate to steep slopes.

(*8c*) *Brown Loams over Reddish Friable Clays.*—A very dark brown, humic, weak crumbly, fine sandy loam merges at 3–6 in. into a dark greyish brown to dark yellowish brown, massive, fine sandy loam. This in turn merges between 12 and 18 in. into an olive-brown, loamy fine sand to fine sand. Between 18 and 36 in. there is an abrupt change to a dark brown, humic, massive, fine sandy clay loam, representing a buried humic horizon 6–12 in. thick. Below this horizon there is a reddish brown, subangular blocky, friable clay which merges into a yellow-red to red, friable clay between 30 and 48 in. The buried humic horizon is not always present. The soils are slightly acid in reaction and are moderately permeable. They occur on ridge crests and on moderate to steep hill slopes.

(8*d*) *Black Loams over Reddish Plastic Clays.*—A black, humic, weak crumbly, fine sandy loam merges at 8–15 in. into a very dark brown to dark greyish brown, humic, fine sandy loam. At depths varying from 12 to 30 in. there is a sharp boundary to a reddish brown, massive, sticky, plastic clay with faint mottling. This horizon in turn merges into coral at variable depth. These soils are medium to slightly acid in reaction and permeability is slow due to the underlying plastic clays. This soil family occurs on level to gently sloping lands.

(9) *Acid Clay Soils.*—The soils of this group were formerly covered by volcanic ash. They have well-developed A and B horizons and are considered to be soils of a former land surface. They generally occur on steeper slopes in areas more removed from volcanic centres where the ash cover would have been thinner and therefore more susceptible to erosion.

They have been separated into two families on the basis of colour and depth. There is no evidence that parent rock is responsible for the differences in colour or depth of these soils since each family overlies a variety of rocks, some of which are common to both. However, the red soils are always much deeper than the brown soils on similar sites, indicating that greater weathering has taken place and suggesting that the red are older than the brown soils.

(9*a*) *Brown Friable Clays.*—A dark brown to dark greyish brown, humic, crumbly, friable clay to clay loam between 3 and 6 in. thick merges into a brown to dark yellowish brown, friable clay. This in turn merges at depths between 20 and 30 in. into a strong brown, mottled clay that passes into weathered volcanic rock or tuffaceous sediments between 24 and 40 in. A stony phase of this family has been recognized, usually associated with rock outcrops. The soils are slightly acid in reaction, have moderate permeability, and occur on ridge crests and slopes.

(9*b*) *Red Friable Clays.*—A very dark brown to dark brown, humic, crumbly, friable clay to clay loam, 6–12 in. thick, merges into a reddish brown, subangular blocky, friable clay, which in turn merges between 12 and 24 in. into a yellow-red to red friable clay. Weathered volcanic rock or tuffaceous sediments were encountered at depths varying from 40 to 72 in.

These soils are slightly acid, have moderate permeability, and occur on steeper slopes in association with the brown loams over reddish friable clays.

(10) *Rendzinas.*—They consist of coral-derived soils that may be contaminated by wind-blown sands and volcanic ash, occurring on youthful coral platforms 5–15 ft above high-water mark. The lack of mantle-ash soil may be due to the youthfulness of the platform or to its removal by erosion. Rendzinas have been divided into two families, based on differences in colour and texture, the loamy family being considered a more youthful variant of the clayey family. Both are shallow, with coral at various stages of weathering occurring at depths between 12 and 15 in.

(10*a*) *Shallow Greyish Brown Loams.*—A dark brown to very dark brown, humic, weak crumbly, sandy loam merges between 2 and 10 in. into a dark greyish brown to grey, massive, sandy loam to loamy sand that passes into weathered coral.

They are neutral in the surface horizon and mildly to moderately alkaline below, and have a moderate permeability.

(10*b*) *Shallow Black Clays*.—About 3 in. of a black, humic, firm crumbly, sandy clay merges into a black, angular blocky clay which overlies weathered coral. They are moderately alkaline and have slow permeability.

(11) *Terra Rossa Soils*.—The soils have well-developed A and B horizons and merge into weathering coral at depths varying from approximately 1 to 6 ft. They are largely ash-derived since the preservation of the atoll form suggests that the down-grading is less than 10 ft, whereas according to Mohr and van Baren (1954) several hundred feet of rock would be required to produce the deeper soils from relatively pure coral. The presence of a more recent ash cover in dolines indicates that a thin ash mantle was present but has been largely removed by sheet wash caused by the slow permeability of the subsurface soil.

This soil group has been separated into three families based on depth and colour.

(11*a*) *Shallow Reddish Plastic Clays*.—A dark reddish brown, humic, firm crumbly, clay to clay loam merges at 4–8 in. into a reddish brown, blocky, sticky, plastic clay. Weathered coral is normally between 12 and 24 in. from the surface. These soils are neutral at the surface, becoming mildly alkaline with depth, and have a slow permeability. They are associated with coral outcrops and occur on ridges and steep slopes.

(11*b*) *Reddish Plastic Clays*.—A dark reddish brown to dark brown, humic, firm crumbly, clay to clay loam, 6–12 in. deep, merges into a dark reddish brown to reddish brown blocky, sticky, plastic clay to about 30 in. This in turn merges into a yellow-red, angular blocky, sticky, plastic clay with faint, strong brown mottling to a depth of over 5 ft. They are slightly acid to neutral, becoming mildly alkaline with depth, have slow permeability, and occur on plains.

(11*c*) *Brown Plastic Clays*.—A dark brown, humic, firm crumbly, clay to clay loam merges between 3 and 6 in. into a brown to dark yellowish brown, blocky, sticky, plastic clay which merges at about 18 in. into a strong brown, sticky, plastic clay with yellow-red mottling to a depth of over 5 ft. They are slightly acid, have slow permeability, and occur in depressions and near stream channels where poor drainage conditions prevail.

V. Soil Distribution

The air-photo patterns give a direct indication of the extent of soils and non-soils only when the vegetation cover is absent or very sparse. Where there is no direct indication, the distribution of soils may be based on a correlation with either land form or vegetation, or both. In the survey area the very recent ashes round active volcanoes, sands on point bars and beaches, boulders on flood-out plains, and exposed rock on cliff and landslide faces could be recognized directly from aerial photographs. Correlation between soils and both vegetation and land form was found in areas where there were marked differences in drainage or flooding by either fresh or saline water. Correlation between soils and vegetation alone was found only where very recent ash soils occurred under vegetation in an early seral stage. Correlation between soils and land form alone was found on extremely dissected lands, well-drained plains, and low coral platforms. However, for a large part of the survey area, correlations between soil and vegetation and land form were not apparent and the estimation of soil distribution had to be based on field sampling, and owing to the reconnaissance nature of the survey, precise locations of the soil boundaries were mainly arbitrarily adjusted to land system boundaries.

Lack of correlation is caused by the recent volcanic ash mantle. Although the ash mantle is thick near the volcanic centres and becomes thinner with increasing distance from the source, it conforms with a previously developed landscape so that any modifications it has made to the land forms are not apparent on the small-scale air photos used. As previously stated, the distribution of vegetation types in these areas appears to be related mainly to climatic factors and gives no indication of the ash distribution.

Distribution of the soils in the area can be obtained from three sources in this report; each source, which is listed below, shows the distribution from a different aspect.

Table 13 shows the estimated area of each soil family occurring both in a land system and within the survey area. It illustrates the widespread occurrence of a recent ash mantle, which is present in varying amounts in all the land systems with the exception of Jaba, Soraken, Moila, and Silibai. Table 13 also indicates that some families are restricted to particular land systems.

The tabular land system descriptions in part show the detailed distribution of the soil families in relation to the land units within each land system.

In reconnaissance surveys, the most convenient method of showing soil distribution on a small-scale map is by delineating soil associations. "A soil association is a group of defined and named taxonomic soil units, regularly geographically associated in a defined proportional pattern" (United States Department of Agriculture 1951). In the context of this report, the soil unit is the family and generally the geographical area is the land system or systems, while the proportional pattern of soil units is controlled by the land unit. Thus, some of the soil associations shown on the soil map may differ because of different soil families making up the association, whilst others may have similar soil families but the proportions of these may differ.

As previously mentioned, the soil distribution has been based mainly on the land system boundaries. In Lonahan, Kohino, Deuro, and Saua land systems, however, an approximate boundary line based on field observations has been drawn, separating the ash-covered from non-ash-covered soils.

Approximately half of the survey area is covered by ash soils that are concentrated around volcanic centres in the central mountainous regions. In rugged and dissected terrain, such as is found in the Emperor Range, the ash soils are absent on the steeper slopes, having been stripped by erosion, leaving lithosols, bare rock faces or boulder debris. Around the active volcanoes of Balbi and Bagana very youthful ash soils occur on the gentler slopes. In the north and south of Bougainville Island, ash-derived brown loams cover most of the mountainous areas and where there are very gentle slopes an ash pan is present, while in the central portion of Bougainville

TABLE

DISTRIBUTION OF SOILS IN THE GEOMORPHIC

(Percentage area of

Soil Families	Geomorphic Categories													
	Raised Coral Reefs		Coasts		Swamps	Plains			Volcano–Alluvial Fans					
	Lonahan	Kohino	Jaba	Soraken	Moila	Saua	Silibai	Siwai	Buin	Rugen	Numa	Leikaia	Pauroka	
Swamp peats														
1(*a*) Submerged peats					15		1							
1(*b*) Surface peats					60									
Swamp soils														
2(*a*) Neutral peaty sands			48											
2(*b*) Neutral peaty clays					5									
Mangrove soils														
3(*a*) Shallow alkaline peaty sands				20										
3(*b*) Alkaline sands				9										
Alluvial soils														
4(*a*) Shallow grey mottled sands					1	1	1							
4(*b*) Brown mottled sands				8	5	50	94	2	4	1	1		1	
4(*c*) Stratified mottled loams and clays				2										
5 Lithosols									2					
Littoral soils														
6(*a*) White sands			5	1										
6(*b*) Brown sands			47											
Ash soils														
7(*a*) Grey fine sands						40								
7(*b*) Brown loams with an ash pan									88				10	
7(*c*) Brown loams									5	5	5	20	88	
7(*d*) Brown loams with lapillitic horizons											92	79		
Ash-covered soils														
8(*a*) Brown loams over sands								97						
8(*b*) Brown loams over brown friable clays														
8(*c*) Brown loams over reddish friable clays										87				
8(*d*) Black loams over reddish plastic clays	25	23												
Acid clay soils														
9(*a*) Brown friable clays														
9(*b*) Red friable clays										5				
Rendzinas														
10(*a*) Shallow greyish brown loams				59										
10(*b*) Shallow black clays				1										
Terra rossa soils														
11(*a*) Shallow reddish plastic clays	7	4												
11(*b*) Reddish plastic clays	66	51												
11(*c*) Brown plastic clays		21												
Non-soils*	2	1			14	9	4	1	1	2	2	1	1	

* Including rock outcrop, gravel and boulder beds, and open water.

13

CATEGORIES AND LAND SYSTEMS

each land system)

and Land Systems

Volcanic Landscapes																		Basin Floor	Erosional Mountains							Karst Plateau	Area of Soil Family (sq miles)
Balbi	Takuan	Erava	Sisivi	Puto	Umum	Dios	Ibu	Tumuri	Mafahia	Teopasino	Deuro	Bagana	Doiabi	Boira	Mainoki	Pomaua	Osirei	Torombei	Melilup	Chambers	Emperor	Karato	Pirurari	Nasioi	Kieta	Keriaka	
																											40
																											150
																											30
																											10
																											15
																											7
1																											5
							4	2						3	3			9									290
						9																					3
	5			7		30					7				12			1	88		78				8		220
																											4
																											30
38												98															35
	6	5																80									280
	84	93		18	40		10	95	44						83	98		8	9	44	19	9	98	98			800
			98				82		54				98	95						53		89				95	510
																											345
					58	60					35														3		55
				58						98							97										150
																											50
											57														67		100
				15													1										10
																											50
																											1
																											10
																											115
																											30
61	5	2	2	2	2	1	4	3	2	2	1	2	2	2	2	2	2	2	3	3	3	2	2	2	22	2	130
																										Total	3475

Island lapillitic ash soils are dominant. On the periphery of the ash soils are found ash-covered soils; the underlying buried soils include alluvial sand, red and brown friable clays, and reddish plastic clays. Within this peripheral zone, which includes Buka and the adjacent islands, there are areas where volcanic ash is absent as a result of moderate erosion or recent deposition of alluvial materials. In areas of moderate erosion the acid clay and terra rossa soils occur, while recent depositional soils include the swamp, littoral, mangrove, and alluvial soils. Rendzinas and swamp peats also occur within this zone.

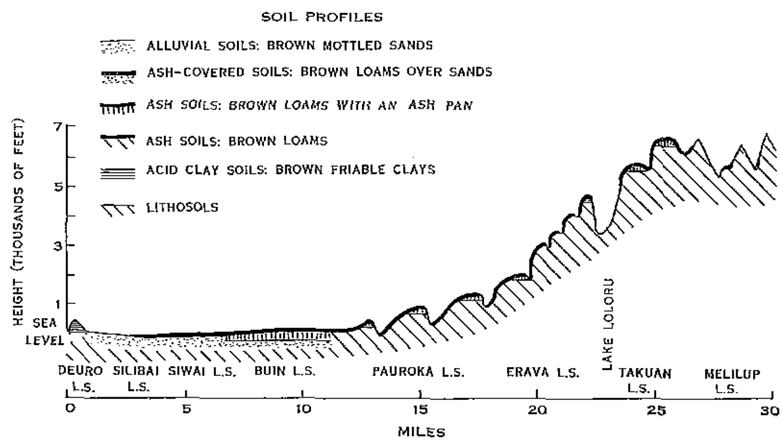

Fig. 13.—Transect through Kanggu Hill and Lake Loloru. Vertical scale of soil profiles greatly exaggerated.

This sequence of dominantly ash soils radiating from volcanic centres, with lithosols on the steep slopes, passing into the ash-covered and non-ash soils on the periphery, is diagrammatically illustrated in Figure 13. The section has been drawn through Kanggu hill and Lake Loloru; on the lower slopes the ash cover becomes thinner with increasing distance from the volcanic centres near Mt. Taroka.

VI. Soil Engineering

Soils have also been classified from the point of view of engineering. The engineering soil classification employed (Appendix I) is the American Association of State Highway Officials' (AASHO) system, based on the performance of soils beneath highways. The classification separates soils of about the same general load-carrying capacity and service into seven basic groups that are designated A1 through A7. The best soils for road subgrades are classified as A1 and the poorest soils as A7. The significance of the classification can be obtained by reference to the P.C.A. Soil Primer (Portland Cement Association 1962).

The classification normally depends on sieve analysis and laboratory tests of liquid limit and plasticity index, but in view of the sparse sampling network it was not considered worth while to collect the large samples required for the latter tests.

TABLE 14

AREAS OF AASHO SOIL CATEGORIES

Soil	Area (sq miles)
A3 soils (sands)	
A3 alone	46
A3 with cobble gravel	35
A3 with boulders	290
Total	371
A4 soils (loams)	
A4 or A6 alone	3
A4 over A1 over A4	510
A4 over R_S	1130
A4 over A3	345
A4 over A6	205
A4 over A7	50
Total	2243
A6 soils (friable clays)	
A6 alone	10
A6 over R_S	100
Total	110
A7 soils (plastic clays)	
A7 alone	145
A7 over R_S	1
A7 over R_H	10
Total	156
A8 soils (peats)	
A8 alone	200
A8 over R_S	15
A8 over A3	30
Total	245
No soil (rock and stones)	
R_S	220
R_H or B or C	130
Total	350
Total	3475

Instead, the probable category of each soil was assessed by comparison with descriptions in the P.C.A. Soil Primer. Sieve sizes could not be exactly matched with those specified by the American Association of State Highway Officials, but material passing BS 18 and retained on BS 30 was designated "coarse sand" and material passing BS 30 and retained on BS 200 was designated "fine sand".

The proportions of various soil categories present in the area are indicated in Table 14. Considering the soils in the upper 1 or 2 ft of the profiles it is clear that the loamy category A4 soils are predominant. These soils are fine sandy or silty loams rather deficient in both clay and coarse particles. Next in importance come the granular, but poorly graded, A3 soils comprising the sands of river beds, flood-plains, beaches, and recent volcanic ash; and after them are the areas of hard and soft rock, boulders, and cobble gravel. Swamp soils are classified as A8, but may not be completely intractable as the peat content is not always very high and sand is often present. Two types of clay soils occur: the friable clays developed on weathered volcanic and sedimentary rocks, classified as A6, and the more plastic clays developed over limestone, classified as A7.

For many purposes the soil characteristics at greater depth are important. Considering layers at depths of 3 or 4 ft, the category R_S, comprising weathered rock and unconsolidated volcanic debris, is predominant. A3 soils are more abundant than in the surface layers, and A4 soils, though much less abundant than in the surface layers, are next in importance to A3 soils.

The distribution of the engineering soil classes can be obtained from the tabular land system descriptions in Part III. The columns headed "land form" and "land class" in these descriptions are also of direct interest to the engineer.

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PART IX. VEGETATION AND ECOLOGY OF BOUGAINVILLE AND BUKA ISLANDS

By P. C. HEYLIGERS*

I. INTRODUCTION

(a) *Historical*

The botanical exploration of Bougainville started in 1905, when Rechinger and Rechinger (1908) visited several places on the east and south coasts. Kajewski (1946) collected for six months in 1930, mainly in the southern part and up into the mountains as far as Lake Loloru. In 1960, Corner (1963) visited Bougainville for a few days and found a very rich *Ficus* flora.

Plants connected with indigenous usage and folklore received attention from several persons during the 1930s and have been listed by Blackwood (1935), Record (1945), and Kajewski (1946).

In 1945 the Department of Forests carried out an aerial photographic interpretation of the vegetation cover of the whole district, recognizing only very broad types but mapping out the distribution of *Terminalia brassii*. An exploration of the forests of the Tonolei area in the south-eastern corner of Bougainville Island was made by this Department in 1962, and the Boku area was explored in 1964 just after the present survey.

The botanical knowledge on the adjacent Solomon Islands, with which Bougainville Island forms a geographical entity, is just as scanty, although collecting began earlier. In 1884, Guppy (1887) collected on the Shortland Islands. Kajewski also visited several of the islands and in 1945 Walker assessed the timber resources of the protectorate (Walker 1962; White 1946, 1950).

(b) *Methods*

With this scanty information in mind the preliminary mapping of vegetation types from aerial photographs was carried out. This also contributed to the establishment of the preliminary land system mapping types, which were based primarily on land forms.

The use of a helicopter during the field work greatly facilitated the examination of the distribution of those vegetation types readily recognizable from the air, e.g. vegetation types rich in bamboo, or forest dominated by *Terminalia brassii*.

Observations were made and final mapping was done in close cooperation with the forest botanist. Herbarium material has been deposited at the Herbarium Australiense, Canberra, where identifications have been carried out by the staff.

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TABLE

DISTRIBUTION OF VEGETATION TYPES

	Vegetation Type	Habitat	Geomorphic Categories												
			Raised Coral Reef		Coasts		Swamps	Plains			Volcano–Alluvial Fans				
			Lonahan	Kohino	Jaba	Soraken	Moila	Saua	Silibai	Siwai	Buin	Rugen	Numa	Leikaia	Pauroka
Primary Vegetation Types	Mixed herbaceous vegetation														
	Spinifex–Canavalia	Beach			m	m									
	Nymphaea–Azolla	Open water			m		m								
	Leersia–Hanguana	Swamps			S		D								
	Paspalum–Cassia	River bars					m	S	m	m				m	
	Lycopodium–Gleichenia	Volcano-seral					m	S						m	
	Mountain	Mountain tops													
	Tall grassland														
	Phragmites–Saccharum	Swamps					S	S							
	Saccharum robustum	River banks					m	m	m	m					
	Woodland and savannah														
	Casuarina woodland	Riverine						m							
	Savannah						m								
	Palm and pandan vegetation														
	Nypa vegetation	Tidal			m	m									
	Pandanus vegetation	Swamps					m		m						
	Gulubia–Pandanus vegetation	> 4000 ft a.s.l.													
	Scrub														
	Rhizophora	Beach			m	m									
	Hibiscus–Pandanus	Beach ridge			S	m									
	Trema	Boulder bars						m						m	
	Ficus arbuscula	Boulder bars								m					
	Cyathea–Trema	Precipitous slopes									m			m	m
	Cyathea–Bambusa	Ridge slopes						S							
	Mountain	Mountain tops													
	Low forest														
	Phyllanthus	Limestone outcrop													
	Mountain	> 3500 ft a.s.l.													
	Mid-height forest														
	Rhizophora–Bruguiera	Mangrove				S									
	Cerbera–Calophyllum	Beach ridge			S										
	Garcinia–Elaeocarpus	2500–4000 ft									m				m

15

IN RELATION TO LAND SYSTEMS*

and Land Systems

Volcanic Landscapes						Erosional Hills													Erosional Mountains							Karst Plateau	Approx. Total Area (sq miles)
Balbi	Takuan	Erava	Sisivi	Puto	Umum	Dios	Ibu	Tumuri	Mafahia	Teopasino	Deuro	Bagana	Doiabi	Boira	Mainoki	Pomaua	Osirei	Torombei	Mellilup	Chambers	Emperor	Karato	Pirurari	Nasioi	Kieta	Keriaka	
																											2
																											5
																											100
							m																				17
S												S															18
S																											5
																											65
							m																				26
																											2
m																											5
																											2
																											3
m	D	D																	m	m	S	m	m		m		65
																											1
																											4
																											1
																											1
																											6
m	S	m										D	D						S		D				S	D	150
m	m																		m		m						27
																										m	5
m	m	m																	m		m		m				27
																											22
																											4
	S	m	m											m					S	D		S	S	S	S		100

Table 15

	Vegetation Type	Habitat	Geomorphic Categories: Raised Coral Reef — Lonahan	Raised Coral Reef — Kohino	Coasts — Jaba	Coasts — Soraken	Swamps — Moila	Plains — Saua	Plains — Silibai	Plains — Siwai	Volcano–Alluvial Fans — Buin	Volcano–Alluvial Fans — Rugen	Volcano–Alluvial Fans — Numa	Volcano–Alluvial Fans — Leikaia	Volcano–Alluvial Fans — Pauroka
Primary	Tall forest														
	Vitex–Pometia	Lowlands	S	m	S				m	D	D	S	D	S	D
	Vitex–Octomeles	Lowlands		D					D	m		m	m		
	Euodia–Pometia	Riverine					m		S						
	Terminalia brassii	Riverine							m	m	m	m	m	m	m
	Terminalia brassii–Campnosperma	Swamps					S		S						
	Neonauclea–Sloanea	1500–2500 ft									m				m
Anthropogenous Vegetation Types	Gardens and plantations														
	Indigenous gardens	< 3500 ft a.s.l.	+	+		+				+	+	+	+	+	+
	Plantations	< 1300 ft a.s.l.	D	S		D				+	+	+	+	+	+
	Mid-height grassland														
	Imperata–Themeda	Lowland	m	m								m			
	Herbaceous regrowth†														
	Polytoca–Gleichenia	< 3500 ft a.s.l.													+
	Musa–Heliconia	Damp	+	S					+		+				
	Scrubby regrowth†														
	Macaranga–Alphitonia	< 3500 ft a.s.l.	+	+		+				+	+	+		+	
	Secondary scrub†														
	Macaranga–Bambusa	Rock outcrops													
	Saurauja conferta	Enclosed flats									+				
	Young secondary forest†														
	Macaranga–Alphitonia	< 3500 ft a.s.l.									+				
	Kleinhovia–Hibiscus	Lowland											+		
	Althoffia–Alphitonia	Lowland									+				+
	Secondary forest†														
	Artocarpus–Bambusa	< 3500 ft a.s.l.													
	Artocarpus–Albizia										S	D	S	D	S

* D, dominant, area occupied > 50% of land system; S, subdominant, area occupied 15–50%; m, minor, area occupied < 15%; +, areal extent undetermined.

(*Continued*)

and Land Systems

Volcanic Landscapes						Erosional Hills													Erosional Mountains							Karst Plateau	Approx. Total Area (sq miles)
Balbi	Takuan	Erava	Sisivi	Puto	Umum	Dios	Ibu	Tumuri	Mafahia	Teopasino	Deuro	Bagana	Doiabi	Boira	Mainoki	Pomaua	Osirei	Torombei	Mellilup	Chambers	Emperor	Karato	Pirurari	Nasioi	Kieta	Keriaka	
				D	D	S	S	D	D		D			S	S	S		D					m		m	m	865
																											178
																											28
							m	m	m	m	m			m	m	m	m	m				m	m	m	m		31
																											95
	m	m	D				m	S	S		m		S	S	m	S	m	S	S	S		S	S	S	S		340
	+		+	+	+	+	+	+		+	+			+	+	+	+	+	+	+		+	+	+	+	+	45
			+	+	+	D	+	+		+	+				+	+	+	+				+	+			+	91
					m																						6
															+				+					+			615
																							+				
			+		+						+											+			+		
					+						+											+	+				
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	+		+											+												+	
										+													+				
									+						+								+				
							+		+		+		+			+	+			+			+			+	30
			S	S	S		D	m	m	D	m		m	S	D	S	D	m	m	m		S	S	S	S	m	490

† Records for secondary vegetation types, except *Artocarpus–Albizia* secondary forest, are incomplete as they could not be supplemented by air-photo interpretation.

Species documented in this way are given their collection number between brackets when they are mentioned in Section IV of this Part for the first time. Specimens supported by wood samples only are referred to in Part X. All other species and generic names used are based on field identification only. Trees and palms not satisfactorily identified are quoted with the name given by our tree-spotters, who were not indigenous to Bougainville, but from Madang. Their names in Amele language do not necessarily refer to the same taxa as in their own district.

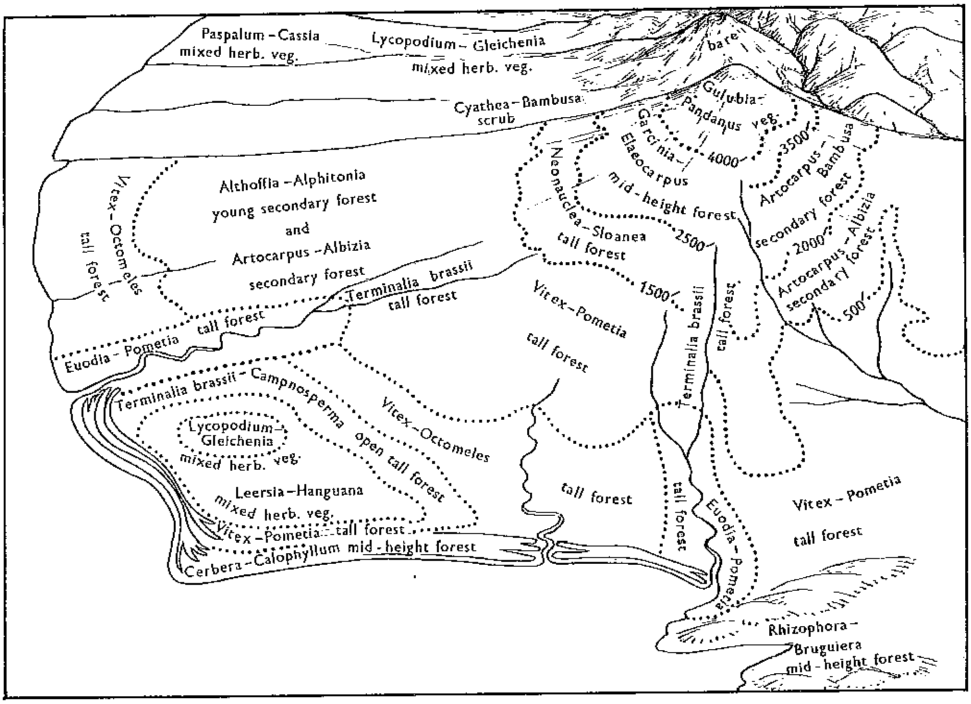

Fig. 14.—Diagrammatic presentation of the principal vegetation types in their environmental setting.

This Part is arranged so that the principles of vegetation classification are discussed first, followed by definitions and examples of the major groups of vegetation. This is followed by the detailed descriptions of the primary vegetation types, including seral vegetation due to volcanism, and of the anthropogenous vegetation types. Table 15 relates these types to the land systems and gives the approximate total area in square miles covered by each type. Figure 14 gives a generalized landscape setting of the more important types. A section on ecology concludes the Part and can be understood without reading the detailed description. It is accompanied by a separate map.

II. Classification

For classification of the vegetation the same principles are followed as in the Port Moresby–Kairuku area (Heyligers 1965). Major groups are distinguished on dominant life forms and include mixed herbaceous vegetation, grassland, woodland and savannah, palm and pandan vegetation, scrub, and forest. Grassland and forest have been separated into low, mid-height, and tall. Because the vegetation is evergreen the distinction between evergreen versus deciduous, on which some major groups in the Port Moresby–Kairuku area were subdivided, was irrelevant here and for the sake of brevity evergreen is omitted from the names.

The major groups have been subdivided into vegetation types which are characterized partly by structural features and partly by floristics. Vegetation types are generally named after two characteristic or abundant genera, and only in some cases after a dominant species. These vegetation types are not meant to be equivalent to associations, as defined by several phytosociological schools; they have in fact a much wider variation in composition than one would allow for an association.

Affinities between vegetation types are expressed by the use of the same genus or species name in the name of two or more types.

Some vegetation types for which data from aerial observations only were available have been given a general, habitat-indicating name.

The influence of the indigenous and European population on the vegetation has been considerable, especially at lower altitudes, and over large areas no primary vegetation is left. It was felt that the classification would gain in clarity if the types of an obviously secondary nature were brought together instead of treating them under the appropriate major group. Moreover, an addition in nomenclature has been adopted: the rather chaotic younger seral stages have been called "regrowth", viz. mixed herbaceous regrowth and scrubby regrowth; and for the already more balanced, older stages "secondary" has been tagged to the group name, viz. secondary scrub and secondary forest.

III. Definition and Discussion of the Major Groups

(a) *Mixed Herbaceous Vegetation*

Non-graminoid herbs distinguish this group, although grass-like plants are generally not absent and some woody plants are occasionally present. They are often pioneer or early successional types, e.g. the *Spinifex–Canavalia* vegetation of beach shores, the *Paspalum–Cassia* vegetation on sand bars in river-beds, and the *Polytoca–Gleichenia* regrowth that occurs on frequently cleared sites around villages and gardens. Another mixed herbaceous regrowth vegetation is dominated by giant wild bananas and gingers. On the other hand, the *Leersia–Hanguana* swamp vegetation and the herbaceous vegetation of mountain tops also belong to this major group.

(b) *Grasslands*

Grasslands are vegetation types dominated by grasses (excluding bamboos) and 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 trees or shrubs sometimes occur, especially near forest borders.

Low grassland does not seem to occur in the Bougainville area. The mid-height grasslands are classified into a single type: *Imperata–Themeda* grassland, which is clearly induced and maintained by man through regular burning. Two types of tall grassland occur: *Saccharum robustum* vegetation along river courses and *Phragmites–Saccharum* grassland, indicative of damp or swampy environment.

(c) *Woodland and Savannah*

Woodland and savannah are both open tree communities of which woodland comprises the denser stands with often more or less gregarious occurrence of the trees. They are only of minor importance in the Bougainville area.

The only example of woodland was found on the banks of braiding streams, where *Casuarina* formed open stands in tall grassland.

A savannah-like vegetation consisting of a dense herbaceous ground cover with scattered trees and bushes occurs on the slopes near Lake Billy Mitchell. Other representatives of savannah are the areas with scattered trees in *Leersia–Hanguana* vegetation, which forms the ecotone between herbaceous swamp vegetation and forest.

(d) *Palm and Pandan Vegetation*

In the vegetation types of this group either palms or pandans or both together occur in physiognomy-determining quantities.

Except for coconut plantations and planted *Metroxylon salomonense* groves, scattered stands of *Nypa* in swales behind the first beach ridge form the only palm vegetation type. Pandan vegetation is characterized by an open canopy formed by *Pandanus*. It was seen only from the air because its occurrence is limited to some swamps with tall grass vegetation.

A spectacular example of combined palm and pandan dominance is formed by the *Gulubia–Pandanus* vegetation which covers the part of the mountains that is shrouded in clouds daily.

(e) *Scrub*

Scrub comprises closed communities dominated by shrubs, low gnarled trees, or trailing bamboo. Emergent trees are often present and climbers abound, especially in the secondary types, e.g. in *Macaranga–Alphitonia* scrubby regrowth and *Macaranga–Bambusa* secondary scrub. Other examples of scrub can be found along shores (*Rhizophora* scrub, *Hibiscus–Pandanus* scrub), as seral vegetation in river beds (*Trema* scrub, *Ficus arbuscula* scrub), and on mountains, e.g. *Cyathea–Bambusa* scrub which is particularly common on mid-altitude ridges, and montane scrub formed by very low, bushy shrubs as was seen near the top of Mt. Balbi.

(f) *Forest*

Forest is a closed vegetation of trees and has been subdivided into low, mid-height, and tall, determined by the average height of the canopy: up to 50 ft for low, between 50 ft and 100 ft for mid-height, and over 100 ft for tall forest. Complexity in structure generally increases with increasing height.

To low forest belong several young secondary forest types, e.g. *Macaranga–Alphitonia* and *Kleinhovia–Hibiscus* young secondary forest, and some forest types occurring at higher altitudes.

Rhizophora–Bruguiera forest, a type of mangrove, and *Cerbera–Calophyllum* forest, usually called "*Barringtonia* formation", are typical examples of mid-height forests. In this category fall also *Garcinia–Elaeocarpus* forest of mid altitudes and the *Artocarpus–Bambusa* secondary forest.

Tall forest comprises what is usually called "tropical rain forest". *Vitex–Pometia* forest and *Neonauclea–Sloanea* forest occur on better-drained soils, *Vitex–Octomeles* forest and *Euodia–Pometia* forest on more poorly drained soils, and *Terminalia brassii* forest and *Terminalia brassii–Campnosperma* forest in swampy situations.

IV. Description of the Natural Vegetation Types

(*a*) *Mixed Herbaceous Vegetation*

(i) Spinifex–Canavalia *Mixed Herbaceous Vegetation.*—This vegetation, often called "*pes-caprae* formation" (van Steenis 1958), is dominated by sand-binding creepers, e.g. *Ipomoea pes-caprae*, *Canavalia maritima*, *Spinifex littoreus*, *Thuarea involuta*, and *Cyperus pedunculatus*. It occurs on beaches above the high-water mark. *Ipomoea pes-caprae* often dominates over large stretches, probably favoured by the short, steeply sloping beaches with much-moved sand.

(ii) Nymphaea–Azolla *Mixed Herbaceous Vegetation.*—Submerged *Ceratophyllum* and *Nymphaea* and floating *Nymphoides*, *Nymphaea*, *Azolla*, *Lemna*, and *Spirodela* form this community, which occurs in standing or slowly running fresh water. This habitat is of limited occurrence because of lack of open water at lower altitudes; it is found in some swales of Jaba land system and locally in Moila land system.

(iii) Leersia–Hanguana *Mixed Herbaceous Vegetation.*—This type, up to 6 ft high, consists of grasses (e.g. *Leersia hexandra*, *Hymenachne acutigluma*, and *Echinochloa*), coarse sedges (e.g. *Thoracostachyum sumatranum* and *Scleria*), herbs (e.g. *Hanguana malayana*, *Ludwigia*, and *Polygonum*), and ferns (e.g. *Cyclosorus*, *Blechnum*, and the climbing *Lygodium*). It occurs in swamps as a floating mat or rooted in organic mud.

Often special facies develop in which one or some of the species become dominant. From the air this was observed in the swamp south-west of the Deuro Range (Plate 10, Fig. 1). The centre of the swamp was dominated by a sedge–fern facies, while *Hanguana malayana* or *Thoracostachyum sumatranum* dominated large, more marginal tracts. *Pandanus* and broad-leaved trees, e.g. *Campnosperma*, overgrown with herbaceous climbers occurred in the *Thoracostachyum* facies near the forest border, which gives this facies a savannah-like appearance. The *Hanguana* facies is also found in inundated swales and along watercourses in Jaba land system (Plate 11, Fig. 1), whereas a *Thoracostachyum–Hanguana* facies with some *Hibiscus* and *Pandanus* occurs in old swales and channels in forest.

(iv) Paspalum–Cassia *Mixed Herbaceous Vegetation.*—This type is an open vegetation, colonizing sand-bars and boulder bars of meandering and braiding rivers

(Plate 9, Fig. 1). It consists of low tussock and creeping grasses (*Paspalum*, *Ischaemum muticum* (no. 1073)), weedy herbs (*Stachytarpheta*, *Polygala*, *Ludwigia*, Rubiaceae, and Compositae), weedy low shrubs (*Cassia alata*, *Mimosa pudica*), and herbaceous creepers (*Passiflora foetida*, Convolvulaceae, *Wedelia biflora*, and *Micania cordata*), usually with some ferns, especially in braiding rivers. Sometimes tussocks of *Saccharum robustum* line very neatly the margins of older sand-bars, together with *Melochia umbellata* (no. 1074) shrubs. Very scattered higher shrubs and young trees occur, e.g. *Trema*, *Albizia*, *Ficus arbuscula*, *Casuarina*, and *Macaranga aleuritoides*.

Soils are sandy or gravelly and liable to have a very variable ground-water regime, with wetter phases dominating, and frequent flooding.

(v) Lycopodium–Gleichenia *Mixed Herbaceous Vegetation*.—This type is characterized by the dominance of club mosses and ferns, and occurs on slopes of bouldery volcanic material and higher flats of the upper part of braiding streams (Plate 9, Fig. 2). Its cover varies from almost nil on steep slopes and exposed flats to 100% on crests and sheltered flats. *Lycopodium cernuum* is constantly common; *Gleichenia* is often common, sometimes strongly dominant, but is not found in frequently inundated localities. Other ferns (e.g. *Davallia solida* (no. 1047), *Pityogramma calomelanos* (no. 1048), *Blechnum orientale* (no. 1049), and *Nephrolepis cordifolia* (no. 1050)) generally occur and seem to be more common where the numbers of *Gleichenia* decline. Mosses and/or lichens are common in not too open vegetation. Herbs are generally absent but some *Spathoglossis* orchids occur on terraces. Scattered tussocks, up to 6 ft high, probably of *Saccharum spontaneum* and *Imperata*, give the vertical accent to this vegetation which is otherwise lower than 2 ft. *Saccharum* is particularly common on the ridges. *Imperata* forms open single-species stands in the lower, dampest parts of the volcanic flats of Mt. Bagana. Shrubs are rare but in the braiding-river beds *Melastoma malabatricum* (no. 1053) occurs sparsely.

Extreme hydrological conditions are characteristic of the habitats, not only in the fluctuation of the moisture content but also in locally high content of volcano-derived sulphur and other minerals that may inhibit plant growth.

In some of the largest herbaceous swamps of Moila land system the central area is occupied by dense stands of *Lycopodium–Gleichenia* vegetation, both taxa mentioned in this name being particularly common. Very small specimens of *Hanguana malayana* and of a sedge (?*Fuirena*) are indicators of the swamp conditions. The vegetation appears to occur on a dense floating mat of roots and organic debris, with water at about 8 in. Occurrence of this type in such a different situation may possibly be explained by physiologically extreme conditions, for instance swamp water with low nutrient status due to stagnancy.

(vi) *Herbaceous Vegetation Types of Mountain Tops*.—From the air, herbaceous vegetation types have been seen on Mt. Balbi, on the rim of Billy Mitchell crater lake, and in a minor area in the Lake Loloru crater, which all belong to Balbi land system. Unfortunately, no ground observations could be made on these types.

On Mt. Balbi large areas are covered with a vegetation in which a large tussock-forming species gives a characteristic physiognomy.

Also on Mt. Balbi and near Lake Loloru, high-altitude bogs situated in old craters were observed.

(*b*) *Tall Grassland*

(i) Phragmites–Saccharum *Tall Grassland*.—This is 8–15 ft high and is dominated by *Phragmites karka*, often mixed with *Saccharum robustum*, with a scanty undergrowth of ferns, scattered herbaceous climbers, and some individuals of *Kleinhovia hospita*, *Hibiscus*, *Trema*, or *Pandanus*. Habitats range from permanent swamps to periodically flooded areas. *Phragmites–Saccharum* grassland occurs, for instance, in mosaic with several facies of the *Leersia–Hanguana* vegetation, but sometimes dominates the whole swamp. It covers large areas of the bar plains in Saua land system, where it is at least partly successional, replacing died-off *Terminalia brassii–Campnosperma* forest.

(ii) Saccharum robustum *Tall Grass Vegetation*.—Stands of *Saccharum robustum*, up to 14 ft high, occur on lowest river terraces, on bars, and in old river channels (Plate 9, Fig. 1). Forbs and ferns are absent or scarce but climbers (e.g. *Micania cordata*, *Ipomoea*, and *Tetrastigma*) are sometimes abundant. Scattered shrubs of *Hibiscus*, *Kleinhovia hospita*, and *Macaranga aleuritoides* occur, and in local groups with *Melochia umbellata* and *Albizia* form a transitional stage to forest.

(*c*) *Woodland and Savannah*

(i) Casuarina *Woodland*.—*Casuarina* vs. *cunninghamiana*, pioneering on higher sand-bars in the *Paspalum–Cassia* vegetation, forms gregarious stands on the higher banks of braiding streams in Saua land system. Trees are on the average 35 ft tall, the tallest are 55 ft. The stands have a slight admixture of *Macaranga aleuritoides*, *Alphitonia*, and *Melochia umbellata*. Dense, 2-ft-high grass forms the ground cover in the more shaded areas and 12-ft-tall *Saccharum robustum* in the lighter spots. Abundant herbaceous climbers (e.g. *Micania cordata*, *Passiflora foetida*, and *Stenochlaena*) scramble over trunks and branches and through the ground cover.

(ii) *Savannah*.—Savannah is of very limited occurrence and was seen only from the air. One type was observed on the lower slopes of Lake Billy Mitchell; another seen near the border of herbaceous swamps was formed by *Pandanus* and trees over an understorey of *Thoracostachyum sumatranum* or other plants of the *Leersia–Hanguana* vegetation (Plate 10, Fig. 1).

(*d*) *Palm and Pandan Vegetation*

(i) Nypa *Palm Vegetation*.—This is a dense vegetation formed by the 12- to 30-ft-high fronds of *Nypa fruticans*. It is confined to some of the first swales in Jaba land system and the lower reaches of creeks and tidal plains in Soraken land system.

(ii) Pandanus *Vegetation*.—This vegetation type consists of a rather dense layer of *Pandanus* trees with herbaceous creepers often covering the trunks and branches and with an undergrowth of coarse sedges and *Hanguana malayana*. It occurs in some swamps and as enclosures in *Terminalia brassii–Campnosperma* forest.

(iii) Gulubia–Pandanus *Vegetation*.—This is a vegetation about 65 ft high, which could well be classified as a mid-height forest were it not that, owing to an abundance of palms in the canopy and pandans in the lower storeys, it is more properly placed in the major group of palm and pandan vegetation. *Gulubia* and other palms form an important and often predominating constituent of the irregular, rather open canopy (Plate 2, Fig. 2). A number of them are often more or less emergent, giving this vegetation a very characteristic silhouette from the air, especially where it occurs on ridge crests. Trees in the canopy, e.g. *Garcinia, Timonius, Rapanea,* and *Ascarina,* are microphyll and notophyll. *Pandanus* is very common in the lower tree layer, but is largely replaced by a bamboo species with whorled leaves where this vegetation type occurs on very steep slopes. Tree-ferns are common in the scattered shrub layer. The herb layer covers about 50% of the ground and ferns are common. A layer of mosses covers about 70% of the ground, which is springy owing to a peaty topsoil layer. Climbers are present; they are mainly thin woody and include some bamboo. Epiphytes are abundant; small ferns and particularly mosses are predominant, orchids and *Freycinetia* are common.

The *Gulubia–Pandanus* vegetation covers peaks, crests, slopes, and saddles above 4000 ft altitude, habitats that are clouded during part of almost every day.

(*e*) *Scrub*

(i) Rhizophora *Scrub.*—Giant shrubs of *Rhizophora* up to 20 ft high, sometimes mixed with *Sonneratia,* line protected, tidally inundated sandy shores and shallow sandy mouths of creeks. Where the shore is not too steeply sloping, *Rhizophora* scrub is backed by *Avicennia, Bruguiera,* and *Rhizophora* trees, but where a low ridge exists behind the scrub line *Excoecaria agallocha* occurs.

(ii) Hibiscus–Pandanus *Scrub.*—This scrub, of a height between 12 and 35 ft, consists of shrubs and low trees: *Hibiscus tiliaceus, Pandanus odoratissimus* var. *novoguineensis, Scaevola sericea, Cerbera manghas, Calophyllum inophyllum, Barringtonia asiatica, Alstonia spectabilis,* and young *Cocos* palms. In the understorey gingers are present to common, and sometimes palms occur, particularly in areas where they are also found in the adjacent forest. The herb layer varies in richness with grasses, ferns, orchids, and various seedlings. *Crinum* forms one of its typical constituents. *Smilax, Wedelia,* and other mainly thin woody climbers are very common. Epiphytic ferns are present to common.

Hibiscus–Pandanus scrub occurs on the first beach ridge in Jaba and locally in Soraken land system. It forms a part of the so-called "*Barringtonia* formation" (van Steenis 1958).

Where the ridge is formed mainly of coral rubble, a variant less than 10 ft high is found dominated by *Messerschmidia argentea* and *Acanthus ?ilicifolia.* On low-lying inner ridges a depauperate variant occurs mainly consisting of *Hibiscus tiliaceus* and some *Cerbera manghas,* in which *Pandanus* is rare and *Flagellaria indica* abounds. *Thoracostachyum sumatranum* is indicative of the damp situation.

(iii) Trema *Scrub.*—This 14-ft-high scrub formed by pure stands of *Trema* has a rather open canopy. Grasses, e.g. *Imperata exaltata* (no. 1082) and *Pogonatherum paniceum* (no. 1083), and ferns, e.g. *Pityogramma calomelanos* and *Nephrolepis cordifolia,* dominate in the continuous, 2-ft-high ground cover. It occurs on higher boulder bars in braiding streams.

(iv) Ficus arbuscula *Scrub*.—A rather dense, 20-ft-high scrub of *Ficus arbuscula* is found on some higher bouldery bars in river-beds of Siwai land system. The herb layer has a negligible cover and consists of grasses and some *Elatostema* (no. 1102) tussocks. Mosses cover the boulders. The ant-harbouring epiphytes *Myrmecodia* and *Phymatodes sinuosa* are common.

(v) Cyathea–Trema *Scrub*.—On the precipitous, strongly dissected slopes of badlands in the volcano–alluvial fan land systems, irregular vegetation occurs dominated by *Cyathea* (no. 1043) and mixed with many shrubs and treelets, e.g. *Trema*, *Albizia*, and *Laportea*, with *Casuarina* at higher altitudes. The understorey consists of ferns, tree-ferns, gingers, pandans, *Saccharum spontaneum*, and young *Caryota rumphiana* palms. Perpendicular walls are covered by mosses and liverworts.

(vi) Cyathea–Bambusa *Scrub*.—This is a 10–14-ft-high, dense, continuous vegetation formed by climbing, scrubby bamboos, e.g. no. 1044 and *Bambusa* (no. 1055), sometimes mixed with *Saccharum spontaneum* (Plate 7, Fig. 1; Plate 9, Fig. 2). *Cyathea* (no. 1043), scattered to abundant, is emergent, up to 25 ft tall, together with some *Musa peekelii* (no. 1031), and with *Macaranga*, *Albizia*, *Casuarina*, or other trees in varying numbers. The ground is covered by a thick springy layer of old leaves and stems, and the herb layer of ferns and grasses is open and irregular.

Because of its inaccessibility *Cyathea–Bambusa* scrub has been sampled inadequately. It occurs in a variety of habitats from almost sea level up to altitudes of about 5000 ft, for which reason a number of subtypes are very likely to occur. Often it covers large areas in which it seems to be a rather stable vegetation. On the plain remnants in Saua land system, however, it is very likely to be a successional stage to forest.

(vii) *Mountain Scrub*.—On the upper slopes of Mounts Balbi, Takuan, and Taroka, scrub has been observed from the air, but no ground observations could be made (Plate 1).

(*f*) *Low Forest*

(i) Phyllanthus *Low Forest*.—On limestone outcrops in Keriaka land system a 25–30-ft-high microphyll forest vegetation is dominated by *Phyllanthus* (no. 1084) with some *Dysoxylum* and *Ficus*, whose roots embrace the rock outcrops. Gingers are present in the patchy open shrub layer and *Asplenium nidus* features in the herb layer.

(ii) *Mountain Low Forest*.—An example of this type was found on slopes of an entrenched valley in Takuan land system at an altitude of 3500 ft above sea level. The canopy was 45 ft high and had irregular gaps; trees were mainly notophyll and mesophyll. The shrub layer was evenly scattered and up to 20 ft high. *Cyathea* was very common in both layers. The herb layer covered about 70% and consisted of *Elatostema* spp., *Begonia*, and various ferns and seedlings. A thick layer of litter covered the ground. Climbers, mainly thin woody, were common. Epiphytes were abundant; mosses and small ferns, e.g. *Asplenium* cf. *sancti-christophori* (no. 1089), were particularly common.

Forests probably belonging to the low forest subgroup were observed from the air at altitudes above 6000 ft in more or less sheltered situations in Takuan, Erava, Melilup, and Emperor land systems.

(g) *Mid-height Forest*

(i) Rhizophora–Bruguiera *Mid-height Forest.*—This forest is 50 to 80 ft high, has a canopy with irregular gaps, and is dominated by *Rhizophora* and *Bruguiera.* It is subject to frequent tidal inundation. A ground cover, except for seedlings, is absent in the lower-lying parts; in the higher-lying areas, where *Bruguiera* is common, it is formed by *Acrostichum* ferns and scrambling *Clerodendrum inerme* shrubs. This forest type occurs in sheltered embayments of Soraken land system and belongs to the "mangrove" vegetation (van Steenis 1958).

(ii) Cerbera–Calophyllum *Mid-height Forest* (Plate 11, Fig. 1).—This forest, 65–80 ft high with a commonly rather open canopy, consists of species characteristic of the "*Barringtonia* formation" (van Steenis 1958): *Cerbera manghas, Calophyllum inophyllum, Terminalia catappa, Casuarina equisetifolia, Barringtonia asiatica, Pandanus odoratissimus* var. *novoguineensis*, and *Hibiscus tiliaceus*, with other genera such as *Syzygium, Xylocarpus, Vitex*, and *Kleinhovia.* The lower tree strata are open or rather dense, up to 50 ft high, with palms common, and a rather dense, 7–10-ft shrub layer with many gingers and saplings. The herb layer varies in cover; ferns occur, but no *Selaginella* or *Elatostema.* Climbers in a variety of forms are present to very common. Epiphytes are present, and are mainly ferns, aroids are rare.

Cerbera–Calophyllum forest occurs on the first and the second beach ridge, locally fringed by *Hibiscus–Pandanus* scrub at the shore side.

Locally, *Casuarina equisetifolia* 80 ft high forms an open canopy over a 50-ft-high lower stratum of the above-mentioned species and represents probably a successional stage to *Cerbera–Calophyllum* forest.

(iii) Garcinia–Elaeocarpus *Mid-height Forest* (Plate 3, Fig. 1; Plate 5, Figs. 1 and 2).—This type has a rather open, irregular canopy 80–100 ft high, but rather dense lower tree strata up to 50 ft high. *Elaeocarpus* and *Garcinia* are often the predominating genera, others are *Schizomeria, Dillenia, Syzygium, Casuarina, Alphitonia, Cryptocarya*, and *Bischofia.* The straight stems have small or moderate girths, and medium-height buttresses are common. Leaves are microphyll, notophyll, and mesophyll. The shrub layer, 10–15 ft high, is scattered. The 3-ft-high, open herb layer is formed by grasses, ferns, *Elatostema, Begonia, Tradescantia, Cyrtandra*, and others. Climbers are rare to common; rattan is absent, but the presence of *Rubus* is noteworthy. Epiphytes are common to abundant; among them are conspicuous numbers of ferns, also club mosses and mosses. Stilt-rooted palms ("hehek") may be common; other palms are rare or absent. Tree-ferns are common or very common in shrub and lower tree layers; pandans are rare or present. Bamboo, gingers, and bananas are generally absent. The layer of leaf litter is several inches thick and often springy.

Garcinia–Elaeocarpus forest occurs at altitudes ranging from 2500 to 4000 ft.

(*h*) *Tall Forest*

(i) Vitex–Pometia *Tall Forest.*—This forest belongs to van Steenis's (1958) category of "rain forest (sensu stricto)": "storeys generally two with emergents; generally exceedingly complex in composition and immensely rich in species in all storeys, with here and there subdominant species on special soil types, but always remaining very mixed. Conifers, tree ferns, bamboo, pandans, and palms present, the latter three categories often with many species; generally rich in epiphytes, lianas, saprophytes, and parasites, but percentages varied". This is only a part of his description, which is quoted here as an introduction to the description of the *Vitex–Pometia* tall forest because it seems exactly suited to this type, which is very widespread in the lowlands of the Bougainville area.

Vitex–Pometia tall forest has a canopy, usually 100–115 ft high, which is irregularly closed or continuous but light, with irregularly scattered emergents up to 130 ft tall. Lower storeys are open or rather dense and up to 50 ft high. All girth classes are represented; straight boles are predominant, but low strongly branching crowns are not rare (e.g. *Vitex*); buttresses of various heights are well represented. Leaf sizes fall mainly in the notophyll and mesophyll classes. Among the commonly represented genera are *Vitex, Pometia, Ficus, Alstonia, Celtis, Elaeocarpus, Canarium, Syzygium, Cryptocarya, Dysoxylum, Terminalia,* and *Sterculia.* Sometimes one or two species predominate, e.g. *Vitex cofassus* on flatter country, *Pometia pinnata* on slopes, and *Albizia ?salomonensis* in some valleys.

Many palms, e.g. *Licuala, Caryota, Areca,* "siliki", "welkabibi", "sibal", and "hehek", feature in the lower tree strata and are common to abundant in the shrub layer, which is usually dense or rather dense and 15–25 ft high. In this layer giant herbs such as gingers and bananas (mainly *Heliconia indica*) are also present, but rarely common. Bamboos as well as pandans are usually absent but may be rare or present in tree or shrub layers. Tree-ferns are absent in about one-third of the stands, rare or present in another one-third, and common in the rest; they are generally restricted to the shrub layer.

The herb layer provides only an irregular and patchy ground cover and is of very mixed composition, often with abundant *Selaginella.* Climbers, such as lianes and rattans, are not particularly common; epiphytes, however, are common to abundant and occur in a great variety of forms.

In the lowlands *Vitex–Pometia* forest is of a widespread occurrence on well-drained soils. It is the type that has suffered most from disturbance by man, who now has large areas under permanent or shifting cultivation.

(ii) Vitex–Octomeles *Tall Forest.*—Structurally very much the same as *Vitex–Pometia* forest, *Vitex–Octomeles* forest shows a definite floristic trend towards species indicative of a moister soil environment. For example, *Octomeles sumatrana, Euodia* sp., *Campnosperma ?brevipetiolata, Kleinhovia hospita,* and *Dillenia ingens* (no. 1115) are present or even common among the genera mentioned for *Vitex–Pometia* forest. Rattan predominates among the climbers.

Vitex–Octomeles forest occurs on wetter parts of the plains and the former lagoon floors. Depth of ground water is 1 to 20 ft, and occasional flooding is likely.

(iii) Euodia–Pometia *Tall Forest* (Plate 9, Fig. 1).—The structure of this type differs from *Vitex–Pometia* forest mainly in the canopy, of which the average height is about 20 ft lower and which is commonly more open, resulting in denser, lower tree strata. Low and medium-height buttresses are common. The floristic composition deviates more from *Vitex–Pometia* forest than that of *Vitex–Octomeles* forest does: *Vitex* is absent, *Pometia* is still present, but *Euodia* is often common. Among the others are noted *Kleinhovia hospita, Bischofia javanica, Cananga odorata, Terminalia brassii,* and *T. kaernbachii.* Pandans usually occur in the shrub layer, and Marantaceae are found in the herb layer.

A certain degree of human disturbance in some stands might be indicated by the presence of *Althoffia* and the commonness of gingers.

The *Dillenia ingens* variant is regarded as a seral stage. It is a mid-height forest type, 50 ft high, and has an open canopy in which *Kleinhovia hospita* and *Dillenia ingens* are predominant and *Pandanus* is present. Emergents up to 80 ft are *Euodia* and *Terminalia.* The characteristics of the lower storeys are much the same as in the mature *Euodia–Pometia* forest.

Both *Euodia–Pometia* forest and the *Dillenia* variant are found on flood-plains and swamp margins. Leaf litter was scattered on the forest floor, which possibly indicates rather frequent flooding.

(iv) Terminalia brassii *Tall Forest.*—*Terminalia brassii* trees up to 140 ft tall with large, spreading crowns, notophyll leaves, and straight boles of large girths dominate in this forest type and give the canopy a very characteristic "cauliflower" appearance from the air (Plate 6, Fig. 2). Other species are scarce; *Ficus* spp. (e.g. "bameso") and *Pometia tomentosa* are some of the more frequently found. Density of the lower tree strata varies, but the shrub layer is usually rather dense. The herb layer covers 30–80% and is formed by ferns, *Selaginella, Elatostema,* Marantaceae, and aroids. Climbers are present and are mainly thin and woody; rattan is absent. Epiphytes are common to abundant. Palms are absent or rare except in stands occurring on the land systems of the dissected plains, where species such as "kabibi" and "siliki" are common. Tree-ferns and pandans may be present, gingers are usually common, and *Heliconia indica* is rare or present.

Terminalia brassii forest occurs in valleys, where soils are bouldery and ground water is at shallow depth. Where the valleys are enclosed in mountain ridges, moss-covered stems and the numbers of tree-ferns present express the higher-than-average humidity of these habitats.

(v) Terminalia brassii–Campnosperma *Open Tall Forest* (Plate 10, Fig. 2).—This forest type is related to the *Terminalia brassii* forest by the fact that *T. brassii* often forms the main constituent. The canopy, however, is more open and can reach a stage where it is broken up to form a layer of emergents. Beside *T. brassii* occur *Campnosperma ?brevipetiolata, Octomeles sumatrana, Ficus* sp. ("bameso"), and *Semecarpus.* In the lower layers, which reach a height of about 80 ft, young specimens of these trees occur together with *Kleinhovia hospita, Euodia, Dillenia ingens, Cananga odorata, Nauclea,* and *Syzygium.* Characteristics of the lower layers are like those of *Euodia–Pometia* forest, except that tree-ferns are absent and gingers rarely occur. In stands permanently inundated by through-going floods palms seem to be absent and pandans more numerous.

From the air it was observed that in extensive areas of Moila land system west of Boku, *T. brassii* was dying. Comparison of the aerial photographs taken in 1962 with those of 1947 revealed a forest with a closed canopy on the old pictures, in contrast with the pole-like appearance of the same stands on the recent photographs. Similar air-photo patterns were seen in the swamps near the lower course of the Luluai River south-east of Mangona.

(vi) Neonauclea–Sloanea *Tall Forest* (Plate 2, Fig. 1; Plate 3, Fig. 1).—The irregularly closed canopy of this type is usually about 100 ft high, but emergents are commonly up to 130 ft tall. *Ficus* spp. often dominate, perhaps indicating that this type is partly an advanced secondary forest. On the other hand, Bougainville seems to be naturally rich in *Ficus* spp. (Corner 1963), so this hypothesis might be wrong. Other commonly occurring genera include *Neonauclea, Sloanea, Elaeocarpus, Cryptocarya, Palaquium, ?Terminalia* ("ebel'kunon"), and *Canarium*. Lower tree strata are rather dense or open. Boles of all size classes are represented. Leaves are mainly notophyll or mesophyll. The shrub layer is 10–20 ft high and is dominated by saplings; *Cordilyne angustifolia* is commonly seen. The herb layer is mostly continuous and gives a 90 or 100% cover. *Begonia, Selaginella, Elatostema,* aroids, ferns, and seedlings are constituents. Climbers are present, common, or very common; thin and thick woody vines occur as well as some rattan. Epiphytes are common or abundant, and ferns, aroids, and *Freycinetia* are common. Young rattans are often the only palms in the shrub layer. *Caryota rumphiana* or "hehek" may be present in the lower tree layer. Tree-ferns as well as gingers are present in the shrub layer; bamboo, pandans, and *Heliconia indica* are absent or rare. The layer of leaf litter is of normal thickness.

Neonauclea–Sloanea forest has its main distribution between approximately 1500 and 2500 ft above sea level.

V. Description of Anthropogenous Vegetation Types

(*a*) *Gardens and Plantations*

(i) *Indigenous Gardens* (Plate 3, Fig. 2; Plate 7, Fig. 2; Plate 8, Fig. 2).—Crops cultivated for subsistence are of a great variety, but sweet potato, manioc, taro (tuber), and banana seem to form the staple foods. Other crops include sugar-cane, papaw, corn, rice, yam, pineapple, taro (leaf), and cucumber; potato, tomato, and cabbage are cultivated at higher altitudes.

Among the useful trees are *Canarium* and *Barringtonia* for nuts, and *Artocarpus altilis, Mangifera,* and *Citrus* for fruit. Useful palms are coconut, betel nut, "limbon", whose stems are used for flooring, and *Metroxylon salomonense*, fronds of which are used for thatching throughout the islands.

Other aspects of the indigenous agriculture are treated in Part XI. A more complete account of indigenous crops can be found in the lists published by Blackwood (1935) and Kajewski (1946).

(ii) *Plantations* (Plate 11, Fig. 2).—Cash crops produced in European as well as in indigene-owned plantations are mainly copra, cacao, and coffee. Coconut plantations occupy especially large areas along the coast and are being extended inland at altitudes up to about 1300 ft.

Cacao is often interplanted under *Cocos* palms, with or without *Leucaena leucocephala* for additional shade in the early stage. *Erythrina* is seldom used as a shade tree; locally the forest canopy has been left during clearing to provide shade.

(*b*) *Grassland*

(i) Imperata–Themeda *Mid-height Grassland.*—This grassland, up to 4 ft high and forming a dense cover, is dominated by *Imperata*; a coarse *Themeda* species occurs sporadically. Taller grasses such as *Saccharum spontaneum* and *Polytoca macrophylla* are sometimes found along the forest border. Some scattered *Nephrolepis hirsutula* (no. 1032), herbs, and climbers are usually present. Shrubs are absent or occur as an odd individual or in small groups.

Only minor areas concentrated in the north-western part of Bougainville Island are occupied by this grassland, which, according to local information, is burnt annually for hunting purposes. Its development is probably promoted by the rather pronounced seasonality in this region.

(*c*) *Secondary Vegetation Types*

(i) Polytoca–Gleichenia *Mixed Herbaceous Regrowth.*—Herbaceous regrowth establishes in untended or abandoned gardens and unless it is regularly cut or weeded, as for instance along tracks, it will soon be superseded by scrubby regrowth. It is a dense vegetation of grasses, e.g. *Polytoca macrophylla*, *Setaria palmifolia*, *Paspalum*, *Pennisetum macrostachyum*, and/or *Imperata*, and ferns, e.g. *Gleichenia*, *Pteridium esculentum*, or *Nephrolepis hirsutula*, with abundant herbaceous creepers, especially *Ipomoea*, and sometimes with *Rubus*. Gingers, bananas, and tree-ferns and fast-growing woody plants such as some euphorbs are mostly present.

(ii) Musa–Heliconia *Tall Herbaceous Regrowth.*—A dense vegetation up to 25 ft high is formed by the wild bananas *Heliconia indica* and *Musa peekelii*; the latter often tends to occur in groups. The undergrowth is scanty and consists of large aroids, gingers, some tree-ferns, or *Caryota* palms. *Nephrolepis hirsutula* is thinning out in the herb layer. Usually some woody regrowth genera such as *Kleinhovia*, *Hibiscus*, *Macaranga*, and *Ficus* are present and sometimes form an open canopy 40 ft high over the banana storey. Trees up to 130 ft tall occur throughout this regrowth, especially when it covers large areas as in Kohino land system. They have been spared during the clearing of the forest and are often useful because of edible fruits or nuts, e.g. *Artocarpus altilis*, *Pangium edule*, and *Canarium* spp.

Smaller stands occur regularly in areas at low altitude with other regrowth vegetation. Although in some situations there might be an indication that this vegetation favours less well-drained sites, this cannot be the only explanation for the frequent occurrence of this type. The length of the rotation cycle is probably important as it is not unlikely that a number of short cycles will favour development of bananas.

A well-established banana regrowth seems to be capable of suppressing woody regrowth for longer periods.

(iii) Macaranga–Alphitonia *Scrubby Regrowth.*—Under this heading are grouped all stages between pioneering shrubs in herbaceous regrowth, and secondary scrub and young secondary forest. Height of the canopy varies from 10 to 30 or 40 ft. *Ipomoea* and other herbaceous creepers, and *Flagellaria indica* often make the canopy dense. Woody regrowth taxa (e.g. *Macaranga aleuritoides, M. tanarius, Alphitonia, Kleinhovia hospita, Hibiscus, Trema, Thespesia* (no. 1059), *Dysoxylum*, and *Leucaena leucoaphala*), juvenile trees of *Alstonia, Artocarpus altilis, Ficus, Albizia falcata*, and *Casuarina*, and palms, e.g. betel nut and "limbon", sometimes occur together; such stands, however, alternate with stands where one or another of the regrowth species has become predominant. These differences do not seem to correlate with soil or topography, and it is very likely that factors such as clearing cycles, intensity of burning, availability of seed, and regeneration from vegetative parts will exercise important influences.

In the undergrowth, species of the herbaceous regrowth may persist for some time, but gradually gingers, bananas, and *Elatostema* are becoming more numerous. Epiphytes are absent in the younger stages but aroids appear in older stages.

(iv) Macaranga–Bambusa *Secondary Scrub.*—The canopy of this scrub, 15–25 ft high, is formed partly by *Macaranga* and such taxa as mentioned for *Macaranga–Alphitonia* regrowth, and partly by bamboo, which occurs also in the shrub layer, often together with scattered or dense gingers and some *Heliconia indica*. The usually open herb layer is formed by ferns, *Selaginella, Elatostema*, and other herbs. Climbers are common, particularly herbaceous creepers in the canopy, but some rattan and climbing bamboo also occur. Epiphytes are rare. Tree-ferns are absent. Emergent trees up to 100 ft (e.g. *Canarium, Artocarpus altilis, Althoffia, Ficus*, and *Sterculia*) occur in stands transitional to *Artocarpus–Bambusa* secondary forest.

Macaranga–Bambusa scrub is found on tops of ridges and steep upper slopes, often associated with rock outcrops.

(v) Saurauja conferta *Secondary Scrub.*—This scrub, 15 ft high, is dominated by *Saurauja conferta* (no. 1101), the stems of which are covered with mosses, small and large ferns, aroids, and a Melastomacea (no. 1060). It is interspersed with bamboo, tree-ferns, and some gingers. The ground cover consists of grasses, ferns, *Elatostema*, and *Tradescantia*. This scrub occurs on flats, enclosed by high ridges, at medium altitudes.

(vi) Macaranga–Alphitonia *Young Secondary Forest.*—The open canopy up to 50 or 60 ft high, with irregular gaps, is formed by *Macaranga* spp. and other Euphorbiaceae, e.g. *Glochidium, Mallotus, Melanolepis multiglandulosa*, and by *Alphitonia, Ficus, Thespesia*, and some coconut and betel nut palms. Scattered emergents include *Albizia falcata, Ficus*, and *Casuarina*. The shrub layer is rather dense; tree-ferns, e.g. *Angiopteris erecta* (no. 1046), are common, bananas very common, and gingers present. The herb layer is continuous and *Elatostema* spp. often predominate. Climbers are common and are mainly herbaceous creepers, e.g. *Micania cordata* over the trunks. *Rubus* also occurs. Epiphytes, mainly ferns and aroids, are common.

Macaranga–Alphitonia forest occurs on crests and slopes up to 3500 ft altitude.

(vii) Kleinhovia–Hibiscus *Young Secondary Forest.*—The canopy, about 50 ft high, is formed by *Kleinhovia hospita*, pure or mixed with *Hibiscus ?tiliaceus*, *Macaranga*, and *Alstonia*. Among the very scattered emergents up to 120 ft tall are *Ficus*, *Albizia falcata*, *Alstonia*, *Artocarpus altilis*, *Canarium*, *Elaeocarpus*, and *Alphitonia*. The branchy stem form of *Kleinhovia hospita* is a very conspicuous structural feature of this forest type. Lower tree strata are absent and the shrub layer reaches a height of 25 ft. It is rather dense and is dominated by gingers and scattered bananas. Tree-ferns are absent and palms, pandans, and bamboo are absent or rare. Climbers are usually common; rattan is present and herbaceous creepers cover the canopy. Epiphytes are rare in the canopy, but present to common lower down.

This type occurs in coastal lowland areas on plains, slopes, and crests.

(viii) Althoffia–Alphitonia *Young Secondary Forest.*—The canopy is continuous but light, or has irregular gaps, and is 50–65 ft high. *Canarium* and *Artocarpus altilis* are sometimes emergent and up to about 100 ft tall. *Althoffia* dominates in the canopy and *Albizia falcata*, *Alstonia*, *Alphitonia*, *Mangifera*, and *Thespesia* are often present. *Macaranga*, *Ficus*, *Myristica*, etc. occur in the lower tree storey, which is up to 45 ft high and usually rather dense. Straight stems of small girths predominate, low buttresses are common, leaf sizes are represented from leptophyll (*Albizia*) to macrophyll (*Althoffia*).

The shrub layer, about 15 ft high, is continuous and rather dense. The herb layer, up to 5 ft high, varies in cover between 10 and 80%, and is very mixed. *Selaginella* or *Elatostema* are sometimes predominant, the mainly thin woody climbers are usually rare; epiphytes are present in the canopy, but more common lower down. Tree-ferns are present to very common in the lower tree layer as well as in the shrub layer, and gingers are present to common in the shrub layer. Palms usually occur, but bamboo, pandans, and bananas are mostly absent.

This type is found on plains and flat crests up to an altitude of 1800 ft.

(ix) Artocarpus–Bambusa *Secondary Forest.*—This is an open forest with a canopy with irregular gaps, usually 65–80 ft high, with emergents up to 110 ft. It is formed of a mixed and varied assortment of trees of secondary as well as primary forest, e.g. *Artocarpus altilis*, *Alphitonia*, *Albizia falcata*, *Althoffia*, *Alstonia*, *Burckella obovata* (no. 1045), *Ficus*, *Elaeocarpus*, *Neonauclea*, *Mangifera*, *Pometia*, *Canarium*, *Sterculia*, *Celtis*, *Palaquium*, and *Litsea*. Bamboo, usually of the giant-clump type, characterizes this type because it is common in the lower storey and sometimes occupies about half of it. This lower layer is up to 50 ft high and rather dense. The shrub layer, up to 15 ft high, is rather dense or scattered, and often patchy. The herb layer, up to 4 ft high, is mostly continuous and covers 50% or more of the ground. It is of mixed composition; ferns or *Selaginella* are often predominant.

Climbers are usually present, sometimes common, and some rattan can be present. Epiphytes are generally scarce. Tree-ferns are usually present or common in shrub and/or lower tree layer. Gingers are absent, present, or common. Bananas are usually present. Palms and pandans are absent or rare. A layer of leaf litter up to 1 in. thick covers the ground.

Artocarpus–Bambusa forest occurs on crests and slopes, even very steep slopes, up to approximately 3500 ft above sea level. A variant in which *Althoffia* is rather common is limited to lower altitudes, up to about 1500 ft.

(x) Artocarpus–Albizia *Secondary Forest*.—The canopy, which has irregular gaps, is up to 115 ft high, usually with scattered emergents up to 130 ft. Lower tree strata are rather dense or open and up to 65 ft high. Boles are straight and belong mainly in the small and moderate girth classes. Leaf classes represented are leptophyll, notophyll, and mesophyll. Species composition is very mixed and rather related to *Artocarpus–Bambusa* forest; however, there are more primary forest elements, e.g. *Vitex cofassus*, *Sloanea*, and *Cryptocarya*. *Althoffia* has not been recorded in this type. The structure of the shrub and herb layers resembles that of the *Artocarpus–Bambusa* forest. Climbers are common or very common and rattan is often present. Epiphytes are common or abundant. Palms, pandans, tree-ferns, bamboo, and bananas are absent or rare, sometimes present. Gingers are usually present or common. The layer of leaf litter is thin or thick.

This type is found on crests and slopes, even on very steep slopes, up to altitudes of about 2000 ft. It does not appear to occur on Siwai land system, where primary forest probably develops from *Kleinhovia–Hibiscus* or *Althoffia–Alphitonia* young secondary forest.

VI. Ecology

(*a*) *General*

In the vegetation no elements were seen indicating seasonal drought stress, as all the forest types are evergreen. It is therefore probable that monthly precipitation is nowhere less than about 5 in. and annual totals are in the range of at least 80 to 100 in. in the lowlands, which is confirmed by the data available (Part IV). In the mountains, rainfall figures will be higher and, presuming an increase of 4 in. for every 100 ft of ascent (Beckinsdale 1957), could be in the order of 200 to 300 in. Almost every day in the late morning clouds gather around peaks and envelop the mountains for the rest of the day, causing a high degree of humidity. Moreover, the vegetation will intercept a part of the cloud water, which may add something of the order of 30 in. per annum to the amount of precipitation (cf. Ekern 1964). Temperatures will follow the pattern associated with increasing altitude, but no observations are available. Localized patches of higher soil temperatures due to volcanism may be expected.

Four major environments are distinguished, of which the first two are mainly controlled by drainage conditions and the last two by climatic differences due to altitude. They are swamps and frequently flooded plains, better-drained lowlands, a lower mountain environment from about 2000 to 4000 ft above sea level, and an upper mountain environment above this altitude. They occupy about 9, 63, 24, and 4% of the Bougainville area, and are distinguished and mapped on the basis of characteristic vegetation types (see map of major environments). Because factors related to altitude largely caused the differences between three of the major environments, there is a good agreement between their boundaries and the altitude zones shown on the physical features map.

The following sections deal with each environment separately.

As volcanoes form such a conspicuous part of the landscape this Part concludes with a section on volcano seres.

(*b*) *Swamps and Frequently Flooded Plains*

All freshwater swamps are included in Moila land system (Plate 10, Figs. 1 and 2). Frequently flooded plains form parts of Silibai and Saua land systems (Plate 9, Fig. 1). More or less stagnant swamps are covered with *Leersia–Hanguana* mixed herbaceous vegetation or *Phragmites–Saccharum* tall grassland. Oligotrophic conditions perhaps prevail in the centre of larger swamps where *Lycopodium–Gleichenia* mixed herbaceous vegetation occurs on a thick floating mat of roots and organic debris. Areas under permanently flowing water or frequently flooded such as drainage intake zones, swamp margins, and low riverine tracts are covered by *Terminalia brassii–Campnosperma* open tall forest, the degree of openness presumably being largely determined by the flooding conditions. The decline in vigour of this forest type in the Boku and Mangona areas (cf. Section IV(*h*)(v)) is probably caused by local changes in the flooding regime. The ecotone between mixed herbaceous vegetation and grassland, and open tall forest is generally broad and comprises savannah-like aspects of mixed herbaceous vegetation, *Pandanus* vegetation, and seral stages of *Terminalia brassii–Campnosperma* forest.

Less swampy riverine tracts are characterized by *Euodia–Pometia* tall forest and its seral stages.

Tidally flooded areas, which form a part of Soraken land system, are covered by mangrove of the *Rhizophora–Bruguiera* mid-height forest type.

(*c*) *Better-drained Lowlands*

This environment comprises Lonahan and Siwai land systems, and the land systems of the volcano–alluvial fans and of the volcanic and erosional hills (Plate 8, Fig. 1). The altitudinal range is from sea level up to 2000 ft. Conditions for tropical rain forest are approaching their optimum, and *Vitex–Pometia* tall forest is regarded as the climax vegetation under these conditions. However, an abundance of one or another or some of the canopy tree species, e.g. of *Vitex*, *Pometia*, or *Ficus*, may indicate that some factor in the environment interferes with optimal conditions. Volcanic activity, for instance, could be this factor. Species respond perhaps differently to the impact of ash fall, or a certain species is more favoured by fresh nutrient supply than other species.

Within this tropical rain forest country some edaphoclimaxes are found. On the moderately drained soils, characteristic for the ecotonal transition to the swamp environment (Kohino and Silibai land systems), *Vitex–Octomeles* tall forest occurs. The sandy soils of the beach ridges (Jaba land system), especially of the first ridge, are vegetated with *Cerbera–Calophyllum* mid-height forest, or its seral stages *Spinifex–Canavalia* mixed herbaceous vegetation, *Hibiscus–Pandanus* scrub, or the *Casuarina equisetifolia* phase of *Cerbera–Calophyllum* forest. Bouldery waterlogged flood-plains, often found in incised valleys, bear *Terminalia brassii* tall forest.

About 90% of the population lives in the better-drained lowland environment (i.e. 24 people to the square mile). The impact of this on the natural vegetation has been and still is very severe in many regions. Vegetation types caused by anthropogenous factors, as well as the relationships between regrowth stages, have been described in Section V. *Artocarpus–Albizia* secondary forest is regarded as the ultimate type, which grades into primary forest. The map of forest resources on which *Vitex–Pometia* and *Artocarpus–Albizia* forests appear as a combined type, shows how little of the tall forest is left in some regions.

(*d*) *Lower Mountain Environment*

Between approximately 2000 and 4000 ft above sea level *Garcinia–Elaeocarpus* mid-height forest forms the climax vegetation, which is a form of lower montane forest. It is found on dormant volcanoes and debris slopes (Takuan and Erava land systems) and on erosional mountains (Plate 2, Fig. 1; Plate 3, Fig. 1). A floristic composition very different from the lowland forests, a less complicated structure, smaller average leaf sizes, commonness of tree-ferns, and an increased mossiness of the trunks are related to the change in climate to lower temperatures and especially to increased humidity and rainfall.

The ecotonal zone to the better-drained lowlands is rather broad and characterized by *Neonauclea–Sloanea* tall forest. The lower boundary of this forest has been used as the boundary of the lower mountain environment against the lowlands.

Human impact on the vegetation is only slight; 10% of the population, or eight people to the square mile, live in this environment. Regrowth succession leads to *Artocarpus–Bambusa* secondary forest.

Cyathea–Bambusa scrub occupies minor areas on ridge crests and steep slopes throughout this zone, but is more common in the northern part of Bougainville Island and is particularly extensive in Bagana, Keriaka, and Doiabi land systems. Its ecological status is not well understood. Minor occurrences are probably edaphoclimaxes, stoniness and shallowness of soil being prohibitive for forest growth. It is not unlikely that in the larger areas *Cyathea–Bambusa* scrub has been promoted by deposits of rather recent volcanic eruptions that would have destroyed the forest, giving fast-regenerating bamboos a chance for temporary dominance, which retards the succession to forest.

(*e*) *Upper Mountain Environment*

Above 4000 ft above sea level the only topographic features are volcanic peaks, mountain crests, and their associated upper slopes and basins (Balbi, Takuan, Erava, Melilup, Chambers, Karato, and Emperor land systems). Cloud banks envelop these habitats for shorter or longer periods every day and high humidity, high precipitation, lower temperatures, and strong, gusty winds prevail in this environment. Observations on the vegetation were made mainly from the helicopter and showed that *Gulubia–Pandanus* vegetation is the dominant type (Plate 2, Fig. 2) interspersed with bamboo thickets on steep slopes or low forest in more sheltered positions. *Cyathea–Bambusa* scrub covers basin floors of Emperor land system. Mountain scrub and herbaceous vegetation, including high-altitude bogs, occur only above approximately 6500 ft on some of the highest tops, mainly in Balbi and Takuan land systems.

(*f*) *Volcano Seres*

Balbi and Saua land systems contain the most obvious volcano seres, successions in vegetation due to volcanic activity. Terrestrial observations are limited to one at the foot of Mt. Bagana and two along the Saua River.

The upper part of the cone of Mt. Bagana emits steam through several solfatara fields and is bare of vegetation. The lower part, consisting of steep debris slopes, bears a sparse herbaceous vegetation of the *Lycopodium–Gleichenia* type. The gentlest debris slopes at the foot of the cone are practically bare except for the lowest parts, where finer washed-out material has been accumulated against the adjacent ridges and moisture conditions allow the growth of *Imperata* or a tall sedge species. On some of these flats water is ponded up against the ridges and an algal growth seems to occur in some of these pools. Where the ridges, mapped as Bagana land system, border the volcanic flats they bear denser stands of *Lycopodium–Gleichenia* vegetation with *Saccharum spontaneum* as a common constituent. Other parts have *Cyathea–Bambusa* scrub (and possibly also *Musa–Heliconia* tall herbaceous vegetation), which becomes more densely interspersed with trees as the distance from Mt. Bagana increases.

The slopes of Lake Billy Mitchell are covered with a dense herbaceous vegetation with an increasing number of trees and shrubs downslope.

Solfatara fields and bare young debris deposits also occur on the slopes of the active crater of the Mt. Balbi complex (Plate 1, Fig. 1). The vegetation on the adjacent inactive craters, domes, and slopes probably includes both seral types and types in equilibrium with the high-altitude climatic and soil conditions. Comparison with the vegetation on the highest parts of Mt. Takuan, the southern dominant volcano, does not rule out this latter postulate.

The high plain in Saua land system, probably formed during the 1950 eruption of Mt. Bagana, is covered with a *Cyathea* facies of *Cyathea–Bambusa* scrub, which is very rich in *Cyathea* (no. 1043) and in which emergent *Albizia* is indicative of succession towards forest (Plate 9, Fig. 2). Erosion of the plain is severe and the subsequently formed bar-plains are covered by *Phragmites–Saccharum* tall grassland. The flood-out areas have *Lycopodium–Gleichenia* mixed herbaceous vegetation on the tracts with very strongly fluctuating water-tables and *Paspalum–Cassia* mixed herbaceous vegetation in areas with a more normal river regime.

These observations, scattered and sketchy as they are, do not permit a detailed description of the successions from bare deposits to climax vegetation such as that given for volcanoes on mainland New Guinea (Taylor 1957) and on New Britain (van Royen 1963). They confirm the conclusion by these authors that edaphic conditions are more important than other environmental factors in determining the pattern of succession. Floristically, however, the volcano seres in Bougainville are different from those described by Taylor and van Royen.

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PART X. FOREST RESOURCES OF BOUGAINVILLE AND BUKA ISLANDS

By J. C. SAUNDERS*

I. INTRODUCTION

The aim of this Part and its associated map is to describe the forest resources of the area, indicating the location and extent of forests and assigning estimated stocking rates to each forest type. The land has also been classified into categories giving indices of accessibility.

Forest (as defined in Section V of this part) covers 42% of the area, occurring in a wide range of environments from sea level to approximately 4000 ft. Within this range the forest exhibits a discontinuous distribution pattern due largely to clearing prior to cropping, and in some parts to volcanism. The woody vegetation above 4000 ft has no yield† potential and in many cases should not be disturbed as it plays a valuable role in watershed protection.

Generally the higher-yield forest types occur on the well-drained plains and on volcano–alluvial fans and low-altitude uplands with gentle to moderate slopes. These forests encircle the central mountain ranges but occur predominantly at the south-eastern end of Bougainville Island. Scattered, sometimes large, stands of high-yield forest also occur in swamps with through-flowing drainage.

Approximately 45% of the forested areas is found on rugged terrain (slopes exceeding 30°) along the central mountain ranges. Another 8% occurs in permanent swamps along the coastal fringe. Thus on 53% of the forested area, exploitation is rendered difficult or even impossible.

Some milling operations take place in the area. At the time of writing, three private timber permits had been issued, covering the exploitation of 123,332 acres‡ on Bougainville Island.

Previous forest surveys of the area carried out by the Department of Forests, Territory of Papua–New Guinea, include a vegetation map of Bougainville (unpublished) compiled from air-photo interpretation by Carron in 1945, and a detailed survey of Tonolei Harbour, proposed timber permit area, in 1962. Immediately following the CSIRO resources survey, the Department of Forests carried out a detailed investigation of the proposed Empress Augusta Bay timber area.

The forest potential of each land system is described in terms of area, forest type, yield, and access category at the foot of each land system's tabular description.

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† For the purposes of this paper, yield is equivalent to estimated stocking rate.

‡ Territory of New Guinea. — Annual Report for 1963–64. Appendix XI, Table 3. pp. 232–3.

II. Survey Methods

Preliminary air-photo interpretation was carried out in close association with the other team members, particularly the plant ecologist. The photo patterns of forests within each preliminary land system were described and delineated, and field sampling was carried out following the procedure set out in Part I. Where possible, each unit of the preliminary land system visited was sampled by three circular plots, each $\frac{1}{5}$ ac in extent. Data recorded for all emergent and canopy layer trees whose girth exceeded 5 ft included girth at breast height (outside bark), merchantable length, total height, botanical name, and local name in Amele (Madang) language. Each tree was also classed on form and external symptoms of defect as suitable, or unsuitable, for milling. This information was augmented by visual observation when flying over forests at low altitude and by the observations of the plant ecologist.

From the quantitative information collected in each plot, combined with a visual photo appraisal of each plot's representative value, estimated stocking rates were assigned to each forest type. These figures give a very approximate indication of timber volume and must be used with caution as the total area of sample plots was only 250 ac approximately. Volumes quoted were based on a form factor of 0·5 and no allowance for internal defect was made.

Identifications of unknown trees were based on the comparison of wood samples with wood specimens supported by herbarium material largely collected by Messrs. R. Schodde and L. Craven.

III. Mapping

Final mapping of the forest types appears on the map of forest types at a scale of 1 : 600,000. To permit their inclusion, areas of *Terminalia brassii* and *Casuarina* forests have been grossly exaggerated on the map; however, the areas quoted in the text are more accurate. Where wartime photography was used no allowance was made for subsequent change in forest pattern.

A generalized access category map is shown in Figure 15.

IV. Access Categories

The area has been divided into three major categories (I, II, and III) on the basis of dominant slope. Lower-case letters (s, f, a) modify some of the major categories, giving seven categories in all.

Category Is includes all land with slopes less than 10° either permanently inundated or flooded for long periods. It includes both freshwater swamps and tidal flats and covers 9% of the area, mainly in the southern half of Bougainville Island, on the inland side of and often impounded by the beach ridges.

Category If includes all land with slopes less than 10° liable to flooding for short to moderate periods. It includes the wetter flood-plains, covering 7% of the area mainly in the southern half of Bougainville Island.

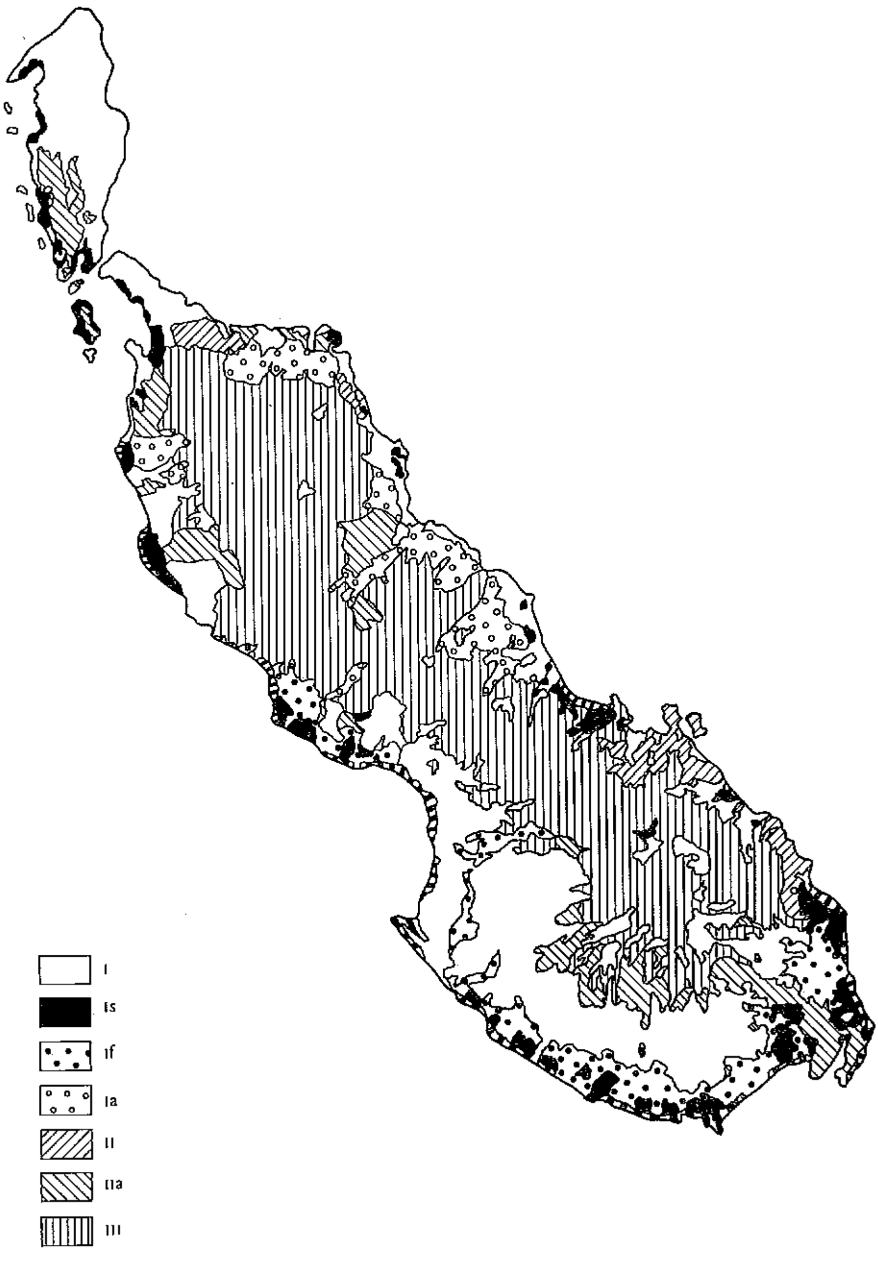

Fig. 15.—Access categories for forestry purposes: I, land with dominant slope <10°; Is, land with dominant slope <10° but permanently inundated; If, land with dominant slope <10° but subject to flooding; Ia, land with dominant slope <10° but up to 20% may exceed 10°; II, land with dominant slope 10–30°; IIa, land with dominant slope 10–30° but up to 20% may exceed 30°; III, land with dominant slope >30°.

Category I includes all well-drained land with slopes less than 10°. It includes the drier alluvial plains throughout the area and the volcano–alluvial fans of Buin land system, and covers 28% of the area.

Category Ia includes all land with dominant slopes less than 10° but with up to 20% of slopes exceeding this angle. This includes the gentle to low-moderate sloping volcano–alluvial fans found in the northern half of Bougainville Island, amounting to 5% of the area.

Category II includes land with a slope of 10–30°. This includes the high-moderate to steeply sloping erosional hills and volcanic landscapes. It covers 3% of the area along the north-eastern side of Bougainville Island.

Category IIa includes land with a dominant slope of 10–30° but with up to 20% of the slopes exceeding 30°. Its scattered occurrence amounts to 8% of the area.

Category III includes all land with a dominant slope angle greater than 30°. This covers 40% of the area mainly along the central mountain ranges of Bougainville Island.

The access categories were mapped using the land systems as a basis. Where subdivision was necessary, slope angles were checked using a Leitz (Hackman) stereo slope comparator. Table 16 includes areas of forest types in each access category within each land system.

The categories give an indication of accessibility both to and within forest types. In categories Is and III, access is difficult or even impossible because of swampy conditions in the former and very steep slopes in the latter. Category I land is readily accessible and this is generally also true for category If between floods and category Ia except in its steepest parts. Categories II and IIa may present moderate difficulty only, except for the latter in its steepest parts.

Access to and within the survey area as a whole, covering existing roads and port facilities, is discussed in Part I and shown on Figure 2.

V. Classification and Description of Forest Types

The area has been subdivided into "forest" and "other areas". For the purposes of this report, a forest is defined as containing at least 3000 super ft of standing timber per acre from trees over 5 ft in girth at breast height (or above buttresses). Stands of timber excluded by this definition have thus been included in "other areas". The only exception to the above definition is "mangrove", because of its possible value in the cutch industry.

The forests of the area fall into five broad types of habitat: coastal, swamp, riparian, plains, and upland. Upland includes all dissected country, fans, hills, and mountains, above sea level. Within each type of habitat the forest has been classified into forest types based on characteristics observed on aerial photographs, such as density, height, and recognizable species in the canopy or emergent layers. Forests in the coast, swamp, and riparian habitats were mapped on species recognition and, in the case of *Terminalia–Campnosperma*, on density. The plains and upland forest are of mixed species composition and were mapped on canopy characters.

TABLE 16

AREAS (SQ MILES) OF LAND SYSTEMS, ACCESS CATEGORIES AND FOREST TYPES, AND ESTIMATED STOCKING RATES (SUPER FT PER ACRE)

Land Systems	Forest Types and Access Categories																														Total Area
	Mangrove Forest	*Casuarina* Forest	Dense *Terminalia–Campnosperma* Forest	Open *Terminalia–Campnosperma* Forest		*Terminalia brassii* Forest				Irregular Tall Plains Forest		Tall Plains Forest	Low-altitude Upland Forest					Mid-altitude Upland Forest			High-altitude Upland Forest	Total Forest Area	Other Areas								
	Is	I/Is	Is	Is	If	If	I	Ia	III	If	I	I	I	Ia	II	IIa	III	I	II	III	III		I/Is	Is	If	I	Ia	II	IIa	III	
Lonahan												11										11				59					70
Kohino											42											42				98					140
Jaba		2																				2	58								60
Soraken	20										1											21		4		60					85
Moila			30	62																		92		158							250
Saua																									9	16					25
Silibai					1	2				116												119			121						240
Siwai							8				11	131										150				205					355
Buin							1						87					17				105				165					270
Rugen														41								41					34				75
Numa								3						37								40					75				115
Leikaia									1								35					36								24	60
Pauroka									1							42	42			2	2	89							53	53	195
Balbi																														30	30
Takuan																	1			8	25	34								41	75
Erava																				17	6	23								92	115
Sisivi																	2			4		6								4	10
Puto																3						3							32		35
Umum															6							6						14			20

Dios																1						1							9		10
Ibu																25						25							20		45
Tumuri									1								78			12		91								29	120
Mafahia																	6			19		25								25	50
Teopasino															5							5						5			10
Deuro																67						67							33		100
Bagana																														15	15
Doiabi																				2		2								13	15
Boira																	28			7		35								65	100
Mainoki									1								7			8		16								34	50
Pomaua																				6		6								4	10
Osirei															7				1			8						52			60
Torombei													4					3				7				8					15
Melilup																				98	9	107								83	190
Chambers																				16	19	35									35
Emperor																				2		2								18	20
Karato																	4			29	1	34								11	45
Pirurari									1								14			41	2	58								52	110
Nasioi									1								18			13	2	34								36	70
Kieta									1								6			25	13	45								15	60
Keriaka																	12			9		21								94	115
Total	20	2	30	62	1	2	9	3	7	116	54	142	91	78	18	138	253	20	1	318	79	1444	58	162	130	611	109	71	147	738	3470
Lake																															5
Total																															3475
Stocking rate	Nil	Nil	8000	3000		12,000				4750		8000	5750					6500			3000										

TABLE 17

TREES RECORDED AND THEIR FREQUENCY* OF OCCURRENCE

Botanical Name	Forest Type									
	Mangrove Forest	*Casuarina* Forest	Dense *Terminalia–Campnosperma* Forest	Open *Terminalia–Campnosperma* Forest	*Terminalia brassii* Forest	Irregular Tall Plains Forest	Tall Plains Forest	Low-altitude Upland Forest	Mid-altitude Upland Forest	High-altitude Upland Forest
Albizia falcata								O (D)	C	
Albizia ?salomonensis								R (D)		
Alphitonia						R		R	R	R
Alstonia scholaris							R	R	R	
Alstonia spectabilis							R	R		
Althoffia pleiostigma								R	R	
Antiaris toxicaria								R		
Artocarpus altilis								O	O	
Barringtonia asiatica		O								
Bischofia javanica						R		R		
Bischofia sp.										R
Bruguiera	D									
Buchanania								R		
Calophyllum inophyllum		O								
Campnosperma			C	C		R				
Cananga odorata						R	R			
Canarium spp.						R	O	O (D)	R	
Casuarina equisetifolia		D								
Casuarina										O (D)
Celtis latifolia								R	R	R
Celtis nymanii						R	R	R	R	
Celtis philippensis							R	R		
Cerbera manghas		R								
Cinnamomum								R		
Cryptocarya spp.						R		R	O	R
Dillenia ingens						R				
Dillenia										R
Dysoxylum spp.							R	R		R
Elaeocarpus spp.							R	R	R	VC
Euodia						R	R			
Ficus spp. (strangler)						O	R	O	C	O
Ficus spp.			R	R	R	O	R	C	C	O
Garcinia										R
Garuga floribunda									R	
Gynotroches axillaris								R		
Harpullia							R			
Hernandia ovigera								R		
Homonoia javensis								R	R	
Kingiodendron alternifolium							R			

* PD, predominant, >80%; D, dominant, 50–80%; SD, subdominant, 20–50%; VC, very common, 15–20%; C, common, 10–15%; O, occasional, 5–10%; R, rare, <5%; ( ), locally.

TABLE 17 (*Continued*)

Botanical Name	Forest Type									
	Mangrove Forest	*Casuarina* Forest	Dense *Terminalia–Campnosperma* Forest	Open *Terminalia–Campnosperma* Forest	*Terminalia brassii* Forest	Irregular Tall Plains Forest	Tall Plains Forest	Low-altitude Upland Forest	Mid-altitude Upland Forest	High-altitude Upland Forest
Litsea spp.								R	R	
Mangifera spp.								R		
Neonauclea						R		R	R	
Octomeles sumatrana			R	R	R	R	R	R		
Palaquium								R	R	O
Pangium edule								R		
Parinari							R			
Pimeleodendron amboinicum							R			
Planchonella									O	R
Pometia tomentosa					R	SD	SD	VC		
Pterocarpus indicus						R		R		
Pterocymbium									R	
Pygeum								R	R	
Rhizophora	D									
Schizomeria									R	VC
Semecarpus			R	R				R		
Sloanea spp.						R		R	O	R
Spiraeopsis								R	R	
Spondias dulcis								R		
Sterculia spp.								R	R	
Syzygium spp.		R				R	R	R	R	R
Terminalia brassii			PD	PD	PD	R		(R)		
Terminalia catappa		O								
Terminalia kaernbachii			R	R		R				
Terminalia spp.						R	R	R	R	
Toona							R			
Tristiropsis							R			
Vitex cofassus		O				SD	SD	C	R	
Xylocarpus		R								

Table 16 lists the forest types with their estimated stocking rates and areas in each access category within each land system. In the following descriptions of the forest types, only the common and more frequently occurring trees are quoted in the text. The remaining recorded trees, including their frequency of occurrence in the plots, are listed in Table 17.

(*a*) *Coastal*

Two forest types, based on habitat and species recognition, have been recognized.

(i) *Mangrove Forest* (20 sq miles).—Generally there is a moderately high forest in a narrow band bordering the dendritic pattern of stream channels. Away from the stream channels the height of the mangrove tapers rapidly to a low, often open, scrub.

No attempt has been made to map the individual communities. The moderately high forest (50–80 ft) has an even canopy composed of small crowns with irregular gaps. *Rhizophora* sp. and *Bruguiera* sp., with boles ranging between 20 and 50 ft and girths averaging 3 ft, are co-dominant.

Mangrove is subject to tidal inundation (access category Is) and is found in parts of Soraken land system mainly on the west and south coasts of Buka Island.

(ii) Casuarina *Forest* (2 sq miles).—This forest comprises an open layer of *Casuarina equisetifolia*, 80 ft high, over a layer of mixed littoral trees 50 ft high. The *C. equisetifolia* boles are straight but often low-branching and girths are generally small, mostly less than 5 ft. Trees in the lower layer often have short, pending, or twisted boles with occasionally large girths. No plots were measured in this type but a visual estimated stocking rate is 3000 super ft per ac.

It is found on the outer two beach ridges in some parts of Jaba land system (access categories I and Is), almost exclusively on the south-west coast of Bougainville Island.

(*b*) *Swamp*

Two forest types have been recognized based on density of the dominant species.

(i) *Dense* Terminalia–Campnosperma *Forest* (30 sq miles).—This forest has an even, slightly open canopy of light-coloured large crowns up to 140 ft high. *Terminalia brassii* is the predominant species with *Campnosperma* sp. as the common associate. Boles are clear and straight, ranging between 45 and 85 ft but frequently 60–65 ft. Girths are well spread over 5–11 ft. The estimated stocking rate is 8000 super ft per ac from 6 trees per ac.

It is found in swamps containing flowing water (access category Is) in Moila land system and occurs in scattered, sometimes large stands around Bougainville Island, but mainly in the Empress Augusta Bay and Luluai River areas.

(ii) *Open* Terminalia–Campnosperma *Forest* (63 sq miles).—This forest type is in all respects similar to the previous type but the canopy trees are scattered. The estimated stocking rate is 3000 super ft per ac from 2 trees per ac.

Its distribution is similar to that of the dense type, occurring on access category Is land in Moila land system.

(*c*) *Riparian*

(i) Terminalia brassii *Forest* (21 sq miles).—*T. brassii* forest is generally 110–140 ft high with large light-coloured crowns of even height. It consists of an almost pure stand of *T. brassii* with straight clear boles up to 85 ft long but usually 60–65 ft. Girths range from 5 to 11 ft and the estimated stocking rate is 12,000 super ft per ac from 8 trees per ac.

The forest is found on bouldery soils with a shallow water-table as discontinuous linear stands, often only two trees wide, along stream channels. It occurs throughout Bougainville Island on all land systems between the plains and 4000 ft altitude. Mapped areas have been exaggerated to indicate distribution of the type, but many stands are not mapped. The total area of the forest estimated from percentage occurrence on land units is 31 sq miles. Although unmappable, the access category is considered to be If.

(*d*) *Plains*

Two forest types have been recognized based on drainage status as reflected in the canopy appearance.

(i) *Irregular Tall Plains Forest* (170 sq miles).—This forest type has a rather open canopy 80–115 ft high with irregular gaps. Scattered emergents, particularly *Octomeles sumatrana*, reach a height of 130 ft. It is of mixed species composition. *Vitex cofassus* and *Pometia* spp. are subdominant although there is a greater proportion of *V. cofassus*. *Octomeles sumatrana* may be locally dominant. Boles are 10–70 ft long and are straight and clear except for *V. cofassus* and strangling figs. Most of the 38% of trees rejected as unfit for milling belonged to these last species. Girths range from 5 to 14 ft but are mostly 8–9 ft, *O. sumatrana* usually accounting for the large sizes. The estimated stocking rate is 4750 super ft per ac from 5 trees per ac but this is considerably increased in locally dominant stands of *O. sumatrana*.

It occurs on the wetter parts of alluvium subject to intermittent flooding, mainly on Silibai and Soraken land systems and on the imperfectly drained soils of raised coral reefs in Kohino land system.

The forest is concentrated mainly at the southern end of Bougainville Island on access category II land, with another large area in the north of Buka Island on access category I land. Small scattered stands occur throughout the plains.

(ii) *Tall Plains Forest* (142 sq miles).—The forest has an uneven usually closed canopy 100–115 ft high with scattered emergents rising to 130 ft. Crown sizes are variable but generally larger than the above type. Species composition is mixed. *Vitex cofassus* and *Pometia* spp. are both subdominant and occur in equal proportions. Bole sizes range from 5 to 85 ft with a modal length of 50 ft. All are straight and clear except *V. cofassus* and strangling figs, which together account for the 36% rejection of trees as unsuitable for milling. Girths are evenly spread in the 5–11-ft range and the estimated stocking rate is 8000 super ft per ac from 7 trees per ac.

The tall plains forest is found exclusively on access category I land scattered throughout the area on better-drained soils of Siwai, Lonahan, and Torombei land systems. However, the main occurrence is at the southern end of Bougainville Island. Large areas of the original forest have been cleared for cropping.

(*e*) *Upland*

Three forest types recognized on canopy appearance occur in altitudinal sequence.

(i) *Low-altitude Upland Forest* (578 sq miles).—At optimum development this forest is similar to the tall plains forest, having an uneven usually closed canopy 100–115 ft high with occasional emergents rising to 130 ft. Crown sizes are variable but tend to be moderate to large. *Pometia* spp. are very common with *Vitex cofassus* and *Ficus* spp. as commonly occurring associates. Boles are generally straight and clear, 5–80 ft long, but mainly in the 30–60-ft range. The lower rejection percentage (22%) is probably due to the lower proportion of *V. cofassus* present. Girths are well distributed over the 5–14-ft range.

The forest has been cleared extensively for cropping and the resulting secondary forests, often dominated by *Albizia falcata*, *Artocarpus altilis*, and *Canarium* spp., are also included in this forest type.

The stocking rate is extremely variable, depending mainly upon status (climax or secondary) and slope angle. Although the estimated stocking rate has been set at 5750 super ft per ac from 7 trees per ac for the overall forest type, stands on gentle to moderate slopes, particularly those on the volcano-alluvial fans, would have a stocking rate of approximately 8000 super ft per ac.

The forest occurs throughout the area in all access categories on upland land systems below approximately 1500 ft altitude. Large areas of the original forest have been cleared for cropping.

(ii) *Mid-altitude Upland Forest* (339 sq miles).—This forest type has a more or less closed canopy 100 ft high with occasional emergents to 130 ft. Crown size is generally moderate to small. *Ficus* spp. are common and in secondary forest *Albizia falcata* may be locally dominant. Boles are generally straight and clear and cover a good range up to 80 ft long. Girths are spread over the 5–12-ft range and the rejection percentage is 19%. The estimated stocking rate is 6500 super ft per ac from 8 trees per ac.

The forest is found on all land systems between approximately 1500 and 2500 ft altitude. It occurs mainly on access category III land, along the central mountain ranges of Bougainville Island.

(iii) *High-altitude Upland Forest* (79 sq miles).—This forest has a more or less open canopy 80–100 ft high composed of small crowns. *Elaeocarpus* spp. and *Schizomeria* spp. are very common, with *Ficus* spp. as the common associate species. *Casuarina* sp. is often locally very common on ridges. Boles fall into the 5–55-ft range, generally straight but sometimes low branching, and girths are generally small to moderate, 5–10 ft. The estimated stocking rate is low, 3000 super ft per ac from 9 trees per ac, the rejection percentage being 23%.

The forest is found on access category III land between 2500 and 4000 ft altitude. It occurs on several land systems in the Chambers Hill, Negrohead Mountain, Mt. Takuan, and Mt. Taroka areas.

PART XI. POPULATION AND LAND USE OF BOUGAINVILLE AND BUKA ISLANDS

By J. R. McAlpine*

I. Introduction

The population and land use of Bougainville and Buka Islands are discussed in this Part with emphasis on quantitative measures and relations with land forms rather than on description.

Descriptions of these aspects are covered by Blackwood (1935), Oliver (1949, 1955), and in numerous other papers quoted by Oliver (1949). Population and land use data are then related to the land systems described in Part III. The relationship between present land use and land use potential is stated in Part XII.

II. Population

Indigenous population data have been obtained from the quasi-annual censuses of Bougainville district. McArthur (1955) has dealt with the inconsistencies and qualified the reliability of these censuses, but the village population totals given are considered sufficiently reliable for the purposes of this Part.

The islands are inhabited by Melanesian people and the population is:

Indigenous†	59,250	1963–64
Non-indigenous‡	438	1961
Imported labour§	2,853	1963–64

The indigenous population of Bougainville District, which includes the distant atolls, is 64,080, by sex consisting of 33,764 males and 30,316 females, and by age 29,310 children and 34,770 adults.

Census figures indicate a rising population for the district in the post-war period. Pre-war population statistics were based partly on estimates but they indicated a population of 50,206 at the outbreak of war. The next census, in 1950, recorded 41,191 persons. Since then, the average annual increase in population appears to have

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† Source: 1963–64 quasi-annual census of villages listed in the "Village Directory, 1960", Department of Native Affairs, Port Moresby.

‡ Source: Territory of New Guinea Report for 1963–64, Commonwealth of Australia.

§ Source: Labour Information Bulletin No. 2, March 1965, Department of Labour, Territory of Papua and New Guinea.

Fig. 16.—Language distribution (after Allen and Hurd 1965).

been 2·9% per annum. As the annual totals show large variations they are listed in detail below:

1949–50	41,191	1956–57	51,608
1950–51	44,267	1957–58	51,764
1951–52	44,143	1958–59	53,130
1952–53	48,758	1959–60	54,627
1953–54	48,990	1960–61	56,330
1954–55	49,042	1961–62	59,619
1955–56	49,071	1962–63	62,372
1963–1964	64,080		

The indigenous population is engaged chiefly in subsistence cultivation except for 1968 persons employed for wages within the district and 587 employed outside Bougainville district. Another important source of cash income occurs in basket manufacture from a fern of the *Lygodium* genus in the Buin area. The non-indigenous population of 438 is employed in government, commercial (mainly plantation), and mission activity.

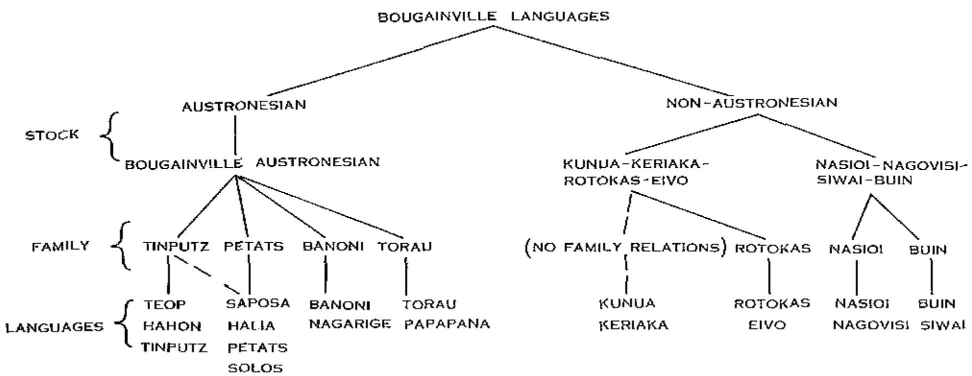

Fig. 17.—Diagrammatic presentation of the relationships of the languages in the area (after Allen and Hurd 1965).

Overall population density is 17 persons per sq mile and the population distribution is indicated on the accompanying map. This map was derived from a more precise village location map compiled in the field using the 1960 Village Directory, the previous 1945 Army Survey Corps map being out of date in this respect. The heaviest concentrations of population are found on the north-east coast of Buka Island where densities on village lands reach over 300 persons per sq mile. The Buin plain also possesses local areas of high density.

The population resides in village and hamlet settlements which can be generally classified in terms of the administrative subdistricts shown in Figure 1. The villages of Buka Passage subdistrict tend to be the largest in the area surveyed and are concentrated on the coast; those of Kieta subdistrict are smaller and more dispersed; those of Buin subdistrict are small, situated inland, and concentrated in groups.

Village settlements have changed in form and location since European contact. Generally, inhabitants of the original smaller and scattered hamlet settlements have grouped under government influence into "line villages" (Plate 3, Fig. 2). The process is described by Oliver (1955). In consequence, the size and possibly the importance of hamlets have diminished, particularly in recent years and after the period covered by Oliver. Village settlements do shift but only rarely and usually only over short distances within a tribal area.

In the absence of a full ethnographic survey of the area, the language distribution map (Fig. 16) and language relation diagram (Fig. 17) are included to indicate broad cultural groupings. Both figures have been adapted from Allen and Hurd (1965). Comparison of this map with the population distribution and land system maps indicates that except in areas of rugged relief each group tends to be concentrated in one relatively compact region. Generally, large tracts of unoccupied areas occur between each of these groups. This areal and social separation is diminishing due to various influences including economic development schemes, the widespread use of pidgin English (Neo-Melanesian) as a lingua franca, and the extension of adequate communications.

III. Land Use

Land use information in this Part and on the land use map has been compiled from an analysis of cultivation and regrowth patterns on the air photographs in conjunction with limited field observations and official statistics. The small scale and indifferent quality of the air photographs have necessitated an arbitrary grouping of land use categories on the map. These are:

(i) *Current Subsistence Cultivation.*—Areas currently used for subsistence agriculture have been mapped from visible activity. They include present cultivation and clearing together with the previous two years' garden regrowth.

(ii) *Current Subsistence Cultivation and Cash Cropping.*—These are areas of current subsistence cultivation that are also known to include the major areas of cash cropping by the indigenous population.

(iii) *Plantations.*—These are the areas of non-indigenously owned plantations.

(iv) *Other Anthropogenous Vegetation.*—These areas have been determined empirically by eliminating all areas showing no visible signs of current or previous use, i.e. all areas of primary and naturally occurring secondary vegetation. This mapping type indicates roughly the areas used for cultivation in the past 80–100 years. In populated areas it also indicates very broadly the maximum usable areas for subsistence cultivation. It occupies 1050 sq miles or 30% of the area surveyed.

Current cultivation and cash cropping occupy 163 sq miles or 5% of the area, and 49 sq miles or 1½% is used for non-indigenous plantations.

Three main types of agricultural land use occur in Bougainville district.

(a) *Subsistence Cultivation*

The system of subsistence cultivation can be described generally as bush fallowing or long fallow cultivation and not as true shifting cultivation (the general limitations of these terms are discussed by Brookfield and Brown (1963) and by

Barrau (1958)). While the gardens are shifted regularly, their rotation is restricted to a clearly defined area and, as will be seen below, particular social groups tend to confine their land use to certain land forms within this area. Plantings are non-seasonal and take place throughout the year.

From Table 18, 59,000 people have 76,000 acres in current use for subsistence cultivation after excluding an estimate for areas of cash crop. As the area in current use consists of three years of the garden rotation cycle, it appears that 0·4 ac is under garden per head per annum.

Subsistence cultivation is based mainly on root crops. Before World War II, taro was the chief staple but its dominance was reduced by the effects of the fungus, *Phytophora colocasiae* (Dumbleton 1954). At present, sweet potato, yam, and taro together form the chief crop plantings.

The main crops planted are listed below. Sweet potato (*Ipomoea batatas*), banana (*Musa sapientum*), taro (*Colocasia esculenta*), yam (*Dioscorea* sp.), sugar-cane (*Saccharum officinarum*), papaw (*Carica papaya*), edible pit-pit (*Setaria palmifolia*), bread-fruit (*Artocarpus* sp.), coconuts (*Cocos nucifera*), and cassava (*Manihot* sp.). Sago (*Metroxylon salomonense*) is collected and processed throughout Bougainville and is used together with other palms in house construction. European vegetables such as maize, tomatoes, pineapples, and beans are widespread and potatoes and cabbages are grown in those higher-altitude areas that are populated. Pigs and fowls are also raised domestically.

The types of land form used for subsistence agriculture are not uniform throughout the area, but may be grouped as follows into six regionally distinct associations of land use with land form indicated on Figure 18.

(1) Raised former reef flats on Buka Island.

(2) Ridge crest and upper hill slopes on northern Bougainville.

(3) Terraces in central Bougainville.

(4) Hill slopes of Kieta subdistrict.

(5) Plains or plateaux on the greater Buin plain.

(6) Low emerged coral platforms and beach ridges fringing Bougainville.

On Buka Island and the northern tip of Bougainville the use of raised former reef flats is characteristic of the association of land use with land form occurring on Lonahan land system (Plate 12, Fig. 2).

The seaward margin of the raised reef is fringed by a narrow discontinuous beach (Soraken land system) on which the village sites often occur. Beyond this, a coral reef flat provides the chief area for gathering seafood, a major part of the diet in this region. Inland from the top edge of the raised reef (Lonahan land system) lies a narrow coral ridge with remnant forest, behind which lies a belt of coconuts frequently interplanted with cacao. Village sites also occur in this area. Further inland on the plain lies the area used for subsistence agriculture divided into small strips running at right angles to the coast. This whole area is distinctive as it consists of only a narrow strip running parallel to the coastal escarpment. The recent large increase in cash cropping near the coast has caused the area under subsistence

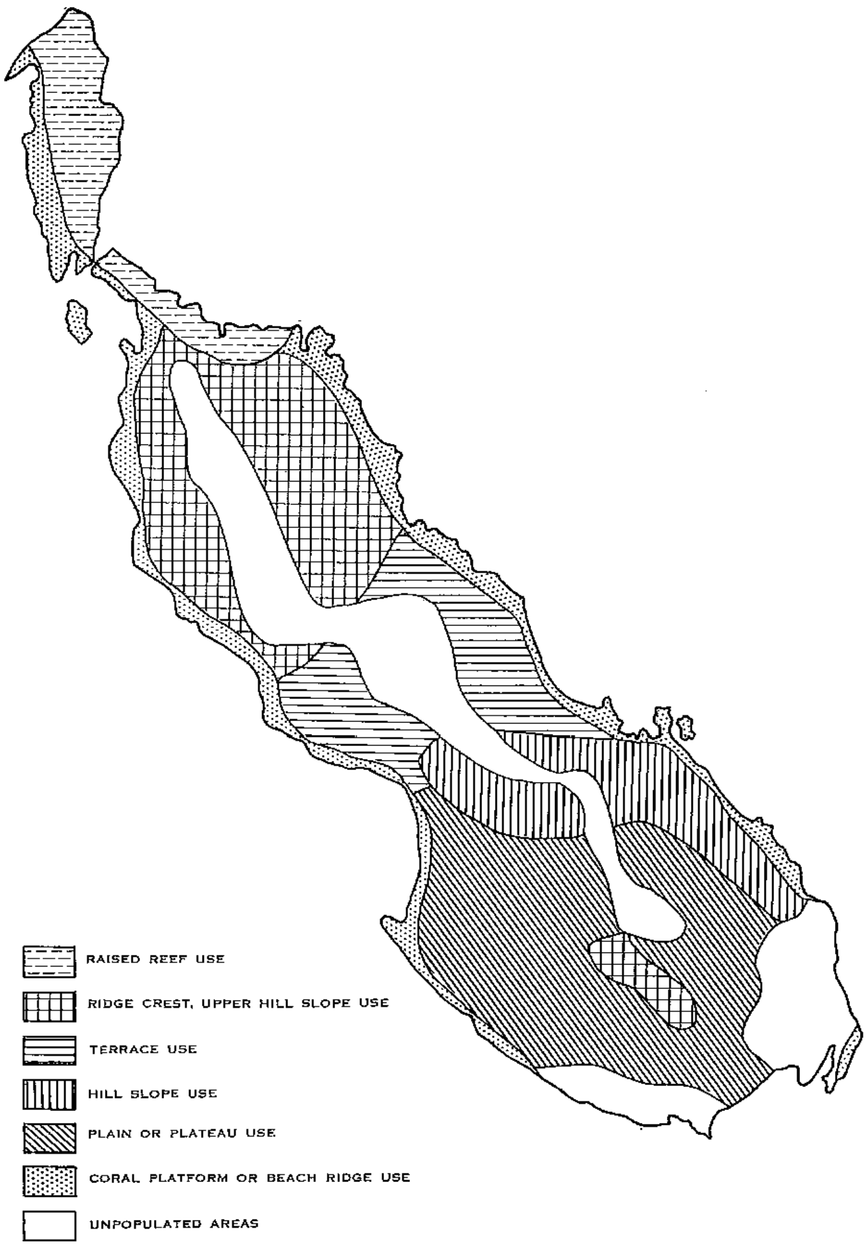

Fig. 18.—Regional associations of land use with land form.

agriculture to extend inland. Former small isolated patch reefs further inland have a similar intensive land-use pattern but the large areas of inland undulating plains are unused.

In northern Bougainville and particularly on Ibu, Pauroka, and Rugen land systems, the use of ridge crests and upper hill slopes for subsistence agriculture is typical. In these areas land use is generally restricted to the broader ridge crests and less severe upper hill slopes. Village sites and cash cropping are similarly restricted to the same land forms. Commonly this results in a fingering pattern of land use where groups of broader ridge crests are completely cleared down to the coastal lowlands, while the lower valleys between remain untouched. Where plains occur in this region they are only very lightly used.

The use of stream terraces in valleys and basins is typical of central Bougainville but also occurs to a minor degree throughout the area surveyed, usually in association with Siwai land system. This type of use is characteristic of Torombei land system and to a minor extent of Numa land system. Where terraces are used, cultivation is intensive but is limited chiefly to the higher terraces out of flood reach. Elsewhere in this region the use of plains, ridge crests, and hill slopes is only minimal.

Cultivation in southern and central Kieta subdistrict occurs typically on hill slopes and particularly on Pirurari and Osirei land systems. Land use in this area is distinguished by its disperse distribution over hill slopes. Ridge crests are sometimes used but this is not a distinctive feature in this association of land use with land form. Those plains and terraces that do occur are only lightly used.

The greater Buin plain is characterized by the use of inland plains and plateaux for cultivation, particularly on Buin and Siwai land systems. The most notable feature of this association of land use with land form is the tendency for land use to occur in separate compact regions possessing one language. The large and lower coastal plains and hills in the region are unused.

In the littoral region of Bougainville and Buka Islands the use of low emerged coral platforms and beach ridges is typical, particularly on the coral platforms of Soraken land system and the beach ridges of Jaba land system. Where the coral platforms consist of barrier reef islands they support higher population densities than where they are attached directly to the main islands. Intensive use is made of this land form for cultivation. By contrast the use of beach ridges for cultivation is light both in intensity and in occurrence. Subsistence from both of these land forms is largely supplemented by fishing and coconut cultivation.

(*b*) *Cash Cropping*

Cash cropping by the indigenous population is based almost wholly on tree crops, with some upland rice grown in the Buin area. Cash cropping is included as a separate land use type because it differs from subsistence cultivation both in the crops grown and in its more permanent use of land. Although it consists chiefly of plantation crops it is distinguished from the non-indigenously owned plantations by its disperse distribution, which results from its close areal association with subsistence agriculture and its considerably smaller plot sizes. Approximate production and areas* of the different crops in 1963–64 were:

Crop	Area (ac)	Production (tons)
Coconuts	24,000 ($\frac{2}{3}$ immature)	2991 (copra)
Cacao	5000 ($\frac{3}{4}$ immature)	168
Coffee (robusta)	300 ($\frac{2}{3}$ immature)	4·8
Rice	430	132

As can be seen from the areas of immature crops, cash cropping is at present undergoing a large expansion. Recently, arabica coffee has been introduced as a cash crop at higher altitudes and rubber trees are being test planted in the Buin area.

Although cash cropping is widespread, the chief areas of production are localized, as indicated on the land use map. Individual areas of cash crops are small and consist of scattered plots. Only where individual plots are contiguous, as on Buka Island, could they be mapped separately at the scale used. Generally, cash cropping does not occur in areas specifically separated and laid aside but takes place within the same general area used for subsistence cultivation. Thus the association of cash cropping with land forms is generally the same as with subsistence cultivation. The importance of adequate transport in the distribution of cash crops is obvious from the comparison of the land use map and Figure 2.

(c) *Plantations*

Non-indigenously owned plantations are based almost wholly on copra and cocoa production. Areas and production of individual crops† are:

Crop	Area (ac)	Production (tons)
Coconuts	32,777 ($\frac{1}{5}$ immature)	13,270 (1964)
Cacao	18,443 ($\frac{1}{3}$ immature)	3112 (1964)

Ninety-five per cent of the cacao grown is interplanted between coconuts and this accounts for most of the discrepancy between the areas of individual crops and the total of 49 sq miles for the total area of plantations derived from the land use map.

Of the larger copra- and cocoa-producing districts within the Territory of Papua and New Guinea, Bougainville district has the highest yields per acre, which must partly result from the lack of seasonality of the climate in this area. Areas of both crops are rising, cacao in particular increased 10% from the previous year while coconut areas increased 3%. Non-indigenous plantations are restricted almost solely to the north-east coast of Bougainville Island and the north-west coast of Buka Island, where the only suitable anchorages are found.

* Figures supplied by Department of Agriculture, Stock and Fisheries.

† Source: Rural Industries Production Bull. No. 6, Bureau of Statistics, Territory Papua–New *Guinea, March 1964.*

IV. Population and Land Use in Relation to Land Systems

Table 18 lists the population and areas of the types of agricultural land-use groupings for each land system. For the purposes of defining land system population figures the total population for each village occurring within the land system has been added. No allowance has been made for those few cases where the population may reside on one land system but carry out part of its gardening on another, but details of this are given in the land system descriptions. The data in Table 18 have been extended to give percentages of current use (including non-indigenous plantations) and of other anthropogenous vegetation for each land system. The detailed distribution of land use within the land systems is given in the land system descriptions in Part III. It must be emphasized that figures for subsistence cultivation in Table 18 refer to only three years of the rotation cycle. Actual total use will depend on the length of the rotation cycle and this in turn will vary with environmental factors and the adequacy of the tribal territories.

In Table 18 the land systems have been grouped according to the percentage of the area of current land use present on the area of each land system. Most apparent anomalies in these groupings are explained by three different factors.

(1) Land systems in which the degree of use is largely determined by the inclusion of non-indigenous plantations in their areas.

In Dios land system most of the currently used land is occupied by non-indigenous plantations. Population density on the remainder is 43 persons per sq mile. In Soraken land system one-third of the land is unusable mangrove swamp and another third is alienated. Thus, in effect, the percentage use of the remaining third is extremely high. Teopasino land system ranks in the moderately used group only through the inclusion of a non-indigenous plantation. It is not currently used for subsistence cultivation. Umum land system is used only for non-indigenous plantations and some cultivation by people living on adjacent areas of Lonahan and Soraken land systems.

(2) Land systems with few people but intensive land use.

Where Torombei land system occurs near the coast it is used intensively, while at higher altitudes it is little used. Most of the people who use it reside on adjoining land systems. Considerable use of the Kohino land system is made by the inhabitants of the adjoining Soraken land system. Deuro land system, similarly, is used by the inhabitants of Soraken land system. Numa land system contains large areas of land use associated with Wakunai patrol post and one individual indigenous plantation.

(3) Land systems with many people but little land use.

Soraken land system has been mentioned above. Fish forms a considerable part of the subsistence diet on Jaba land system. People on Kieta land system derive their subsistence mostly from the sea and adjoining land systems.

V. References

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TABLE 18

POPULATION AND LAND USE WITHIN LAND SYSTEMS

Land System	Area (sq miles)	Total Population	Land Use (sq miles)			% Use of Land System	
			Current		Anthropogenous Vegetation	Current	Anthropogenous Vegetation
			Subsistence and Cash Crops	Non-indigenous Plantations			
Intensively used							
Dios	10	250	0·6	4·3	4	49	40
Lonahan	70	11,000	25·8	2·7	35	41	50
Soraken	85	4400	7·9	16·4	10	29	12
Torombei	15	550	3·1	1·1	6	28	40
Moderately used							
Osirei	60	3050	7·0	1·8	45	15	75
Rungen	75	2250	8·9	2·2	30	15	40
Buin	270	10,800	30·0	—	140	11	52
Sisivi	10	450	1·1	—	2	11	20
Siwai	355	7150	22·4	8·5	170	9	48
Kohino	140	800	8·3	4·9	115	9	82
Teopasino	10	—	—	0·9	2	9	20
Ibu	45	1200	3·1	—	12	7	27
Lightly used							
Pauroka	195	5200	11·6	—	90	6	46
Numa	115	850	4·2	2·2	55	6	47
Pomaua	10	250	0·6	—	2	6	20
Puto	35	600	1·6	—	25	5	71
Pirurari	110	2600	5·0	0·4	45	5	40
Umum	20	—	0·2	0·9	15	5	75
Nasioi	70	1000	2·9	—	30	4	43
Jaba	60	1000	1·7	0·4	8	4	13
Boira	100	1250	3·4	0·7	55	4	55
Deuro	100	175	2·5	0·7	15	3	15
Little used							
Tumuri	120	850	2·2	—	20	2	17
Melilup	190	1050	3·8	—	10	2	5
Mainoki	50	500	1·0	—	30	2	60
Leikaia	60	700	1·0	—	15	2	25
Kieta	60	650	0·8	0·2	4	2	6
Emperor	20	125	0·2	—	1	1	5
Mafahia	50	—	0·6	—	5	1	10
Unused							
Silibai	240	200	0·8	0·4	15	1	6
Karato	45	125	0·2	—	5	1	11
Takuan	75	100	0·2	—	5	1	7
Keriaka	115	125	0·2	—	5	1	4
Saua	25	—	—	—	—	—	—
Moila	250	—	—	—	—	—	—
Erava	115	—	—	—	10	—	9
Doiabi	15	—	—	—	—	—	—
Chambers	35	—	—	—	—	—	—
Bagana	15	—	—	—	—	—	—
Balbi	30	—	—	—	—	—	—
Total	3470	59,250	162·9	48·7	1228	—	—

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PART XII. LAND USE CAPABILITY OF BOUGAINVILLE AND BUKA ISLANDS

By R. M. Scott*

I. Introduction

In Part XI it was indicated that the most widespread form of agriculture practised at present is that of bush fallow subsistence cropping. This type of agriculture is very different from modern European-type farming, since only a minimum of clearing and cultivation is undertaken and the use of machinery is not considered. Yield levels have very little meaning with subsistence cropping because there is no apparent land pressure and the marketing of produce does not arise. Thus, the site quality for subsistence cropping may greatly differ from that required for mechanized agriculture. For this reason the intensity of gardening in a particular area is not always an indication of the suitability of the land for other agricultural purposes.

The rapid introduction of cash cropping, which at present is largely confined to tree crops, will result in a more permanent form of agriculture in which the site quality will have to be assessed in relation to modern agricultural usage. The assessment of the land use capability of the area must be based on such methods rather than those of shifting cultivation.

II. Land Capability Classes

The method of classifying land devised by the United States Soil Conservation Service (Klingebiel and Montgomery 1961) and adapted by Haantjens (1963) to New Guinea conditions has been adopted in this report. Minor alterations have been made to suit local conditions in the area. The scheme is given in Appendix I (Table 26), in which there are eight classes indicating the degree of suitability of the land for different uses of agricultural production. 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 vary in potential land use for improved pastures and tree crops, while class VIII land is unsuitable for commercial production. Native pastures need not be considered as grasslands are practically non-existent in the Bougainville area. All classes are defined by limiting factors or hazards, which are based on varying degrees of erosion, drainage, flooding, surface stones, rockiness, fertility, workability, and alkalinity. The greatest hazard will decide the capability class of any land, e.g. land that has a number of limiting factors of class II and one of class VII will be placed in class VII lands. The additional hazard of soil moisture deficiency does not normally occur under the prevailing climate. In abnormally dry conditions, sandy-textured soils, shallow soils, or soils

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with sticky plastic clays will be most affected. On the other hand, although the climate provides for optimal vegetative growth throughout the year, the absence of a marked dry season may be a limiting factor for certain crops.

The land capability classification is based on dry-land farming and does not take into account wet-land crops such as rice or sago. It does not give a productivity rating nor does it aim at a productivity prediction for any specific crop. The limitations of this scheme have been discussed by Haantjens and Stewart (1964).

III. Distribution of Land Classes

During the survey, the limiting factors were noted and an assessment made of the land capability class of each land unit studied within a sample area. Information was also obtained from agricultural officers, planters, and indigenes of the area on some of the limiting factors that were difficult to assess in the field: in particular, the drainage and flooding conditions during wet periods. These assessments have been included in the tabular descriptions of land systems, which record not only the land capability class, but also the limiting factors from which the class is deduced. It is from the land system descriptions that the detailed distribution of the land classes within a land system can be obtained.

The distribution of the land classes as a percentage of the land system area together with the main limiting factor is shown in Table 19. The order in which the land systems are arranged in the table is according to whether the area of the highest significant capability class within a land system is predominant (>80%), dominant (50–80%), or subdominant (20–50%). These categories have been enclosed in boxes in the table. This gives only a general picture of the distribution of the land capability classes and the main limiting factor of that class, since many of these lands will have a number of limiting factors. It will be seen that the main limiting factor for the area is that of varying erosion hazards.

A comparison of Table 19 with Table 18 (Part XI) illustrates that the intensity of present land use is generally a good indication of the suitability of the land for modern agriculture. Discrepancies between the tables are mainly due to the fact that slopes are not a hazard in subsistence cultivation. An exception is in Numa land system in central Bougainville where suitable agricultural lands on the broad ridge crests and on the moderate hill slopes are only sparsely used for subsistence cropping.

The land use capability map is based on the boxed percentages of land classes shown in Table 19. The boundaries of the land use capability categories are based on land system boundaries, except in south Bougainville where a boundary has been drawn separating the more dissected from the less dissected parts of Pauroka land system.

IV. Land Use Capability

In the following discussion, areas are considered in square miles and not as a percentage area of the land system; therefore, the order of importance of the land systems differs from the order shown in Table 19 and in the map reference.

TABLE 19

PERCENTAGE AREA OF LAND CAPABILITY CLASSES AND MAIN LIMITING FACTOR WITHIN LAND SYSTEMS

(Boxes enclose highest significant land class in each land system)

Limiting factors: e, erosion; d, drainage; n, fertility; f, flooding; r, rockiness; st, stoniness; a, alkalinity

Land System	Area (sq miles)	Percentage Area of Capability Class						
		II	III	IV	V	VI	VII	VIII
Siwai	355	97 n	2 d			½ st		½ st
Kohino	140	97 d	1 e					2 f
Buin	270	85 d	3 e			2 f	1 e	5 e, 4 st
Lonahan	70	81 d	7 e, 8 f			1 e	1 e	1 e, 1 r
Torombei	15	45 d	42 e				1 e	2 e, 10 st
Jaba	60	47 n		5 e				48 d
Dios	10	30 e	9 d				30 e	30 e, 1 st
Numa	115	22 e	40 e			1 f	35 e	2 st
Rugen	75	22 e	40 e			1 f	35 e	2 st
Soraken	85		70 a	1 f				29 f
Ibu	45	14 e	38 e			10 e	5 e	25 e, 8 st
Sisivi	10	15 e	28 e					55 e, 2 st
Silibai	240			85 f		10 f		1 d, 4 st
Saua	25			40 e		50 f		10 st
Teopasino	10	3 e	3 e			48 e	44 e	2 st
Deuro	100		3 e			44 e	45 e	6 e, 1 r, 1 st
Pauroka (part)	100	5 e	5 e			38 e, 2 f	40 e	9 e, 1 st
Puto	35	9 e	5 e			29 e	45 e	10 e, 2 st
Umum	20	3 e			10 r		85 e	2 st
Osirei	60		3 e				95 e	2 st
Leikaia	60		15 e			4 e	40 e	40 e, 1 st
Keriaka	115		2 e			8 e	35 e	53 e, 2 r
Kieta	60					5 r	33 e	60 e, 2 st
Takuan	75	5 d	11 e			11 e	27 e	45 e, 1 st
Doiabi	15		5 e			5 e	30 e	58 e, 2 st
Pomaua	10		2 e			2 e	24 e	70 e, 2 st
Emperor	20					18 e	32 e	48 e, 2 st
Mainoki	50		2 e			3 e	20 e	70 e, 5 st
Boira	100		2 e			3 e	20 e	70 e, 5 st
Pauroka	95	5 e	5 e			9 e, 1 f	10 e	68 e, 2 st
Erava	115		7 e			16 e		75 e, 1 r, 1 st
Tumuri	120					10 e, 2 st		85 e, 3 st
Mafahia	50		5 e			5 e		88 e, 2 st
Karato	45		2 e			3 e	4 e	89 e, 2 st
Pirurari	110	1 e	2 e			2 e	4 e	89 e, 2 st
Nasioi	70		2 e			3 e	4 e	89 e, 2 st
Bagana	15					8 e		90 e, 2 st
Moila	250			5 f		1 f		94 d
Chambers	35		2 e			1 e	1 e	94 e, 2 st
Melilup	190		2 e			1 e	1 e	94 e, 2 st
Balbi	30			1 f				99 st

(a) Lands Suitable for Cultivation with No Limiting Factors (Class I Lands)

Lands of very high potential were not encountered during the survey. This class of land is unlikely to occur in the area since the physiography is such that where the terrain is favourable the soils have limitations, and vice versa.

(b) Lands Suitable for Cultivation with Minor Limiting Factors (Class II Lands)

Lands of high potential cover about 870 sq miles, and are suitable for the cultivation of crops adapted to the climatic conditions of the area. The main areas lie in Siwai, Buin, Kohino, and Lonahan land systems, which account for approximately 770 sq miles. This category of land mainly occurs on plains in the above land systems but the limiting factors vary. In Siwai land system the soils are sandy and, in spite of the recent ash cover with its high organic topsoils, available analyses of cation exchange capacity indicate that they have low fertility. The ash soils of Buin land system also have low fertility and, in addition, the ash-pan horizon may cause slight drainage problems and possibly restrict rooting. Similar lands also occur on the ridges and plateaux of this land system where the sloping nature of the terrain may introduce the additional hazard of erosion. In Lonahan and Kohino land systems the soils are fertile, but the sticky, plastic, impermeable clays may make cultivation difficult, introduce drainage problems, and even cause sheet erosion. On the southern mainland areas of these land systems there are about 13 sq miles of lands where an ash cover has eliminated the cultivation difficulty and erosion hazard, but the slow permeability of the underlying buried soil is still liable to introduce drainage problems. However, they are largely intermingled with dolines, which greatly reduce their worth.

Apart from small areas of Siwai land system on the west coast of Bougainville all these lands have easy access from the coast and, as they are mainly on plains, movement between them is simple, except in Buin land system where deep parallel valleys are liable to restrict easy movement to the interfluves.

Similar lands also occur in Torombei, Jaba, Numa, and Rugen land systems, but here they are only subdominant to other lands and cover approximately 75 sq miles. In Numa and Rugen land systems, class II lands are mainly confined to ridge crests where the gentle slopes give rise to slight erosion hazards; Numa land system, in addition, has youthful lapillitic ash soils that have low fertility. The lands in Torombei land system occur on terraces and have similar soils and slopes to those of Buin land system; therefore, drainage, low fertility, restricted rooting, and slight erosion hazards are possible. In Jaba land system they occur on beach ridges where the sandy soils have low fertility.

Access to this category of land in Rugen, the southern areas of Torombei, and most of Numa land systems is easy. However, in the northern areas of Torombei, the western and southern areas of Numa, and most of Jaba land systems, access is much more difficult: in Numa and Torombei the useful areas are encircled by hilly dissected terrain while in Jaba such lands are separated by inundated swales, with swamps on the inland margins and surf beaches on the coast. Easy movement within these land systems is restricted to the ridges and terraces.

Finally, there are very small areas of class II lands in Dios, Pauroka, Takuan, Sisivi, Umum, Puto, Ibu, and Pirurari land systems, amounting to about 25 sq miles, where access is difficult and easy movement restricted.

(c) Lands Suitable for Cultivation with Moderate Limiting Factors (Class III Lands)

Lands of moderately high potential cover approximately 245 sq miles of which the dominant area (approximately 60 sq miles) occurs on the coral platforms of Soraken land system. Here the main limiting factors are the shallowness and alkalinity of the soils, which will limit the choice of their use. Access onto and movement within these lands is generally easy.

Subdominant areas of class III lands, amounting to about 95 sq miles, occur on the hill slopes of Ibu, Rugen, and Numa land systems, where the presence of moderate slopes leads to erosion hazards. In addition, the soils of both Ibu and Numa land systems are low in fertility. These lands are suitable for most types of agricultural production provided that intensive measures are taken against erosion. At present, the lapillitic ash soils on the slopes of Ibu and Numa land systems appear stable but with intensive cropping this state may change. Access to these lands is generally easy, but easy movement tends to be restricted.

The remaining areas of this category of land are in small pockets where access is difficult and easy movement is very restricted. They occur mainly on moderate slopes or in low-lying situations where there are possible moderate erosion or drainage hazards.

(d) Marginal Lands for Cultivation with Major Limiting Factors (Class IV Lands)

Lands of moderate potential cover approximately 235 sq miles, of which 205 sq miles occur on the plains of Silibai land system. The plains are poorly drained and liable to be flooded for short periods at any time of the year. They are easily accessible where adjacent to the better lands of Siwai land system in southern Bougainville, but elsewhere access is more difficult. Movement within Silibai land system is not easy owing to the poor drainage conditions, flooding, water in drainage depressions, and the presence of many rivers. A further 15 sq miles of similar lands occur along rivers in Moila land system where access to these areas is very difficult. There are also another 10 sq miles of class IV marginal lands on the high plains of Saua land system. The very nature of the plains, and the extremely youthful ash soils of low fertility that occur upon them, give rise to a severe erosion hazard if these lands are cultivated. Both access to and movement on these lands is restricted. The remaining approximate 5 sq miles of class IV lands occur in narrow strips on the beach and foredunes of Jaba and Soraken land systems. Here the soils are very unstable, have low fertility, and are alkaline at depth. At present these lands have limited use owing to the nature of the hazards.

(e) Lands Suitable for Improved Pastures (Class V Lands)

These lands were encountered only on the ridge crests of Umum land system and only account for about 2 sq miles. The presence of rock outcrops restricts the use of this land to improved pastures. Access is difficult due to the steep slopes surrounding it.

(*f*) *Lands Suitable for Improved Pastures or Tree Crops, with Moderate Limiting Factors (Class VI Lands*)

The main areas of class VI lands are found in Deuro, Pauroka, Tumuri, Erava, and Silibai land systems where they occur either on slopes with moderate erosion hazards or on flood-plains and valley floors liable to irregular flooding. The above land systems account for about 150 sq miles out of an approximate 240 sq miles of class VI lands and access is generally easy to moderate, except to those occurring on Erava land system.

(*g*) *Lands Suitable for Tree Crops, with Severe Limiting Factors* (*Class VII Lands*)

Generally these lands occur on slopes where there are severe erosion hazards. The main areas are in Numa, Rugen, Umum, Osirei, Keriaka, Deuro, Takuan, Boira, Pauroka, Kieta, and Leikaia land systems, covering about 363 sq miles out of a total 425 sq miles of class VII lands. Access to the lands varies from easy to difficult.

(*h*) *Lands Unsuitable for any Commercial Land Use* (*Class VIII Lands*)

Class VIII lands, which cover approximately 1455 sq miles, occur mainly in swamps and river beds in the lowlands and on very steep slopes in the upland areas. Varying amounts of these lands are present in every land system, the greatest areas being in Moila and Melilup land systems.

V. Conclusion

In Bougainville and Buka Islands about 32% of the area has class II and III lands and nearly all of this is easily accessible. The most promising area previously surveyed by the Division of Land Research was the Safia–Pongani area, with approximately 22% of class I–III lands.

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APPENDIX I

Explanation of Land System Descriptions

By J. G. Speight*

I. Introduction

The following explanation of content, terms, and parameters of the tabular descriptions of land systems in Part III is arranged in the same order as the descriptions themselves. These descriptions comprise data from several scientific disciplines, contributed by members of the survey team, as follows: geomorphology, geology, terrain, and land form by Mr. J. G. Speight; soil and land class by Mr. R. M. Scott; vegetation by Dr. P. C. Heyligers; forest resources by Mr. J. C. Saunders; population and land use by Mr. J. R. McAlpine.

II. Heading and Summary Description

The heading consists of the sequence number of the land system, its formal name, and the area as estimated by a dot grid with 2·44 dots per sq mile. It is followed by a very brief summary of the diagnostic features of the land system.

III. Geomorphology

The geomorphic statement describes and attempts to explain the land forms of the land system, and specifies the areal arrangement, or pattern, of the land form elements described in the land unit tabulation, and the nature of the streams, as observed at the time of the survey.

IV. Terrain Parameters

Symbolic or numerical terrain parameters categorize the altitude, relief, slope, grain, and pattern of the land system as a whole.

(*a*) *Altitude*

Three altitudinal parameters are used:

Hypsometric index, the altitudinal zone expressed in terms of Table 20, containing the contour that divides the land system into two equal parts.

Generalized minimum altitude above mean sea level.

Generalized maximum altitude above mean sea level.

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(*b*) *Relief*

Relief, defined as the largest difference commonly occurring within a land system between the altitude of a major ridge crest or summit and that of the nearest adjacent major valley floor, is categorized as in Table 21.

TABLE 20

DEFINITION OF HYPSOMETRIC INDEX

Hypsometric Index (H.I.)	Altitude Range (ft)
I	0–50
II	50–300
III	300–1200
IV	1200–3000
V	3000–7000
VI	7000–15,000
VII	15,000–30,000

(*c*) *Slope*

Slope categories are set out in Table 22. The scale is rationalized in terms of equal increments of the logarithm of the slope tangent. The term "gradient" is employed for plains, the term "slope" being restricted to angles greater than half a degree. The characteristic slope is the slope category that is typical of the largest land unit.

TABLE 21

DEFINITION OF RELIEF CATEGORIES

Relief Category	Relief (ft)	Relief Category	Relief (ft)
Negligible	<30	Moderately high, Moderately deep	250–500
Ultra-low, Ultra-shallow	30–63	High, Deep	500–1000
Very low, Very shallow	63–125	Very high, Very deep	>1000
Low, Shallow	125–250		

(*d*) *Grain*

Grain (cf. Wood and Snell 1960) is defined here as the modal value of half the distance between major stream beds, as assessed by inspection of air photos. Categories are defined in Table 23.

(*e*) *Plan-profile*

The pattern of topographic highs and lows is categorized by use of the plan-profile index of van Lopik and Kolb (1959), as indicated in Figure 19. The minimum relief considered in the classification is 30 ft, but an exception has been made of low parallel beach ridges (category 5L//).

V. Block Diagrams and Map

Block diagrams illustrating the typical expression of each land system have been drawn by Mrs. N. Geier with the aid of vertical air photos. There is no vertical exaggeration except where it is indicated, but the scale varies considerably. An inset map shows the distribution of the land system.

Table 22

GRADIENT AND SLOPE CATEGORIES: LOGARITHMIC SLOPE TANGENT SCALE

Category	Angle	Tangent	%	Grade	Ft/Mile
	>90%	(Neg.)	(Neg.)	(Neg.)	
Cliffed slope					
	72°	3·00	300	1 : 0·33	
Precipitous slope					
	45°	1·00	100	1 : 1	
Very steep slope					
	30°	0·56	56	1 : 1·8	
Steep slope					
	17°	0·30	30	1 : 3·3	
High- moderate slope					
	10°	0·17	17	1 : 5·7	
Low- moderate slope					
	5°50′	0·10	10	1 : 10	530
Gentle slope (ultra-high gradient)					
	1°45′	0·03	3	1 : 33	160
Very high gradient (very gentle slope)					
	0°35′	0·01	1	1 : 100	53
High gradient					
	0°10′	0·003	0·3	1 : 330	16
Low gradient					
	0°04′	0·001	0·1	1 : 1000	5·3
Very low gradient					
	0°01′	0·0003	0·03	1 : 3300	1·6
Level					
	0°	0·0000	0	—	0

VI. Land Units

(a) Area

Area, expressed in square miles, is an estimate based on the apparent proportion of the land system taken up by the land unit. Such estimates may be reliable only within ±30%.

(*b*) *Land Form*

Five major categories of land form are distinguished in order to simplify their description in the standardized terms and parameters defined in Table 24.

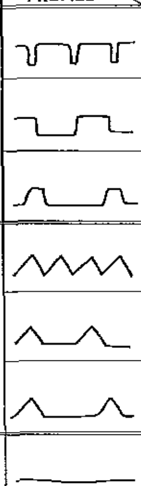
TABLE 23

DEFINITION OF CATEGORIES OF GRAIN

Grain Category	Grain (ft)
Ultra-fine	<250
Very fine	250–500
Fine	500–1000
Medium	1000–2000
Coarse	2000–4000
Very coarse	>4000

CHARACTERISTIC PLAN-PROFILE

HIGHS OCCUPY	HIGHS ARE → ↓	SCHEMATIC PLAN / SCHEMATIC PROFILE	NON-LINEAR AND RANDOM	LINEAR AND RANDOM	NON-LINEAR & PARALLEL	LINEAR AND PARALLEL
>60% OF AREA	FLAT-TOPPED		1	1L	1//	1L//
40–60% OF AREA	FLAT-TOPPED		2	2L	2//	2L//
<40% OF AREA	FLAT-TOPPED		3	3L	3//	3L//
>60% OF AREA	CRESTED OR PEAKED		4	4L	4//	4L//
40–60% OF AREA	CRESTED OR PEAKED		5	5L	5//	5L//
<40% OF AREA	CRESTED OR PEAKED		6	6L	6//	6L//
NO PRONOUNCED HIGHS OR LOWS.			7			



REPRESENTATIVE PLAN-PROFILES

Fig. 19.—Categories of plan-profile (after van Lopik and Kolb 1959).

TABLE 24

LAND FORM TERMS AND PARAMETERS

Land Form Category	Parameter	How Measured	Categories
Crest (e.g. *ridge crest*)	Width	Horizontal distance between limits of summit convexity	Knife-edged: 0–15 ft Very narrow: 15–50 ft Narrow: 50–150 ft Broad: 150–500 ft Very broad: 500–1500 ft
	Profile	Visual estimate	Even: small variation in crestal slope; reversals rare Uneven: moderate variation in crestal slope; some reversals Very uneven: great variation in crestal slope Stepped: few reversals Saw-tooth: reversals common
	Crestal slope	Along the ridge crest	Defined in Table 22
High-angle planes (e.g. scarp, hill slope, valley side slope, bench)	Length	Down line of greatest slope	Ultra-short: < 125 ft Very short: 125–250 ft Short: 250–500 ft Medium length: 500–1000 ft Long: 1000–2000 ft Very long: > 2000 ft
	Curvature	Visual estimate	Straight Concave Convex Irregular Undulating
	Slope	Down line of greatest slope	Defined in Table 22
	Spur characteristics	Visual estimate	Crestal slope: defined under land form category of crests Prominence: prominent inconspicuous absent
	Microrelief	Visual estimate	Slump alcoves Slump scars Debris slide tracks Gullies
Low-angle planes (e.g. plain, terrace, flood-plain, valley floor)	Gradient or slope	Parallel to the major drainage	Defined in Table 22
	Width	Perpendicular to the major drainage, across uninterrupted areas of the land unit	Not classified; expressed in ft or miles

TABLE 24 (*Continued*)

Land Form Category	Parameter	How Measured	Categories
Low-angle planes (e.g. plain, terrace, flood-plain, valley floor) (*continued*)	Microrelief	Visual estimate	Height: expressed in ft Type: undulating hummocky channelled terraced Local slope: defined in Table 22
Watercourses (e.g. river-bed)	Gradient	Along the channel	Defined in Table 22
	Width	Between bank tops, or between the bases of confining hill slopes	Not classified; expressed in ft
	Depth	From bank-top level to mean talweg level	Not classified; expressed in ft, unless the stream is incised, when no depth is stated
	Levee character	—	Continuous Discontinuous Absent
	Bank slope	Visual estimate	Defined in Table 22
	Bar characteristics	—	Channel bars Point bars Bars absent
Miscellaneous (e.g. lava flow, doline, beach, swamp)	Not specified; to be compatible with those defined for other land form categories		

(*c*) *Soil*

Soil description includes statement of soil group and family, sometimes preceded by reference to a particular part of the land unit. Soil classification is detailed in Part VIII, particularly in Table 12. Where particle size is mentioned the Wentworth

TABLE 25

WENTWORTH PARTICLE SIZE CLASSIFICATION

Category	Size Limits (mm)	Size Limits (in.)
Blocks, boulders	>256	>10
Cobble gravel	64–256	$2\frac{1}{2}$–10
Pebble gravel	4–64	$\frac{1}{6}$–$2\frac{1}{2}$
Granules	2–4	
Sand	0·062–2·0	
Silt	0·004–0·062	

TABLE 26

LAND CAPABILITY CLASSES*

Land Class	Limiting Factors							
	Erosion Hazard	Drainage	Flooding	Surface Stones	Rockiness	Fertility	Workability	Alkalinity
I Land suitable for cultivation; no limiting factors	e_1. Level or sloping at less than 1°45′; no erosion hazard	d_1. Well drained	f_1. Not subject to flooding	st_1. No stones on surface	r_1. No bed-rock exposures	n_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°45′–6°; minor erosion hazard when cultivated	d_2. Imperfectly drained		st_2. Surface stones cover 0·1–1% of land	r_2. Less than 2% bed-rock exposures	n_2. Appears to have low fertility, either inherently or through leaching	w_2. Not easily worked because of nature of the clay in the soil	
III Land suitable for cultivation; some limiting factors requiring intensive measures to maintain or reach optimum productivity	e_3. Slopes 6–10°; moderate erosion 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	r_3. 2–10% of bed-rock exposures			a_3. Mild to moderate alkalinity
IV Marginal lands for cultivation because of major limiting factors	e_4. Severe erosion hazard when cultivated because of erodability of soil		f_4. Subject to short irregular flooding in most years					a_4. Strongly to very strongly alkaline

V Lands unsuitable for cultivation but suitable for improved pastures or tree crops		d_5. Poorly drained, not easily improved		st_5. Surface stones cover 3–15% of land	r_5. 10–25% of bed-rock exposures			
VI Lands suitable for improved pastures or tree crops but with moderate limitations	e_6. Slopes 10–17°; erosion hazard moderate		f_6. Subject to frequent and irregular flooding or prolonged seasonal flooding	st_6. Surface stones cover 15–25% of land	r_6. 25–50% of bed-rock exposures			
VII Land with severe limitations restricting use to forest and tree crops	e_7. Slopes 17–30°; erosion hazard severe	d_7. Slightly swampy		st_7. Surface stones cover 25–90% of land	r_7. 50–90% of bed-rock exposures			
VIII Unsuitable for any commercial land use	e_8. Slopes $>30°$; erosion hazard very severe	d_8. Swampy	f_8. Frequent and devastating floods or tidal inundation	st_8. Surface stones cover $>90\%$ of land	r_8. 90% of bed-rock exposures			

* Prepared by R. M. Scott.

classification shown in Table 25 is implied. Water-table depth is cited on plains units. Shallow water-tables have been measured, but deeper ones have been estimated from stream channel depths.

(*d*) *Land Class*

The suitability of land for agricultural development is indicated by a Roman numeral, from I for first-class land to VIII for unusable land, followed by a subscript lower-case letter indicating the hazards that limit land usefulness, e.g. erosion, flooding, or rockiness. The greatest subscript value determines the land class. Table 26 defines the categories used.

(*e*) *AASHO Soil Classification*

For engineering purposes the soils have been categorized tentatively in terms of the classification of the American Association of State Highway Officials (Portland Cement Association 1962) as follows:

Granular materials

A1.—Well-graded (poorly sorted) mixtures from coarse to fine with a non-plastic or feebly plastic soil binder; also coarse materials without soil binder.

A2.—As A1 but with excessive fine material or higher plasticity.

A3.—Poorly graded (well-sorted) sands.

Silt–clay materials

A4.—Silty soils or loams, without much coarse material or colloidal clay.

A5.—As A4 but very poorly graded and tending to be elastic.

A6.—Predominantly clay.

A7.*—As A6 but very poorly graded and tending to be elastic.

A8.†—Peat or muck.

The following non-soil materials are also indicated when occurring at a depth of less than 4 ft: R_S, soft rock; R_H, hard rock; B, boulders; and C, cobbles.

Other symbols are: /, overlying at a depth of less than 4 ft; +, categories occurring together; "or", categories occurring at different places.

(*f*) *Vegetation*

Vegetation types, each named after two genera, are arranged into major groups, such as mixed herbaceous vegetation, mid-height and tall grassland, scrub, low, mid-height, and tall forest, on the basis of structural characteristics. The major group is mentioned first, and is followed by the name of the vegetation type, or types, between brackets. Plantations, gardening, and secondary vegetation are mentioned only when they cover a significant part of a land unit.

* Soils of Lonahan land system have been placed in A7 because of lime carbonate content.

† Swamp soils placed in A8 include peaty sands and peaty clays.

VII. Inclusions

The scale of mapping may prevent the delineation of small but significant areas of other land systems within the land system boundaries. These are mentioned here.

VIII. Population and Land Use

Population figures derived from district census data are stated, followed by assessments of the area under indigenous agriculture (with an estimate of the proportion of it under cash crops) and the chief land units on which it occurs. The assessment depends on interpretation of air photos taken in July 1962, and includes land under that part of the subsistence cultivation cycle that lies between forest clearing and two years of garden regrowth. Fishing is mentioned where it contributes to subsistence.

The population of a land system is given as the total of the populations of the villages that occur on it. Where the population of one land system uses land of an adjoining land system to any large degree, this is stated.

The area of non-indigenous plantation is also given.

IX. Forest Potential

The forest potential of the land system is described in terms of the area and yield rate of various forest types, and the land units on which they occur.

(*a*) *Yield*

Yield is specified in terms of stocking rate as follows:

Low yield	3000–5000 super ft/ac
Moderate yield	5000–8000 super ft/ac
High yield	>8000 super ft/ac

(*b*) *Forest Type*

The following forest types are distinguished:

Mangrove forest
Casuarina forest
Dense *Terminalia–Campnosperma* forest
Open *Terminalia–Campnosperma* forest
Terminalia brassii forest
Irregular tall mixed plains forest
Tall mixed plains forest
Low-altitude mixed upland forest
Mid-altitude mixed upland forest
High-altitude mixed upland forest

(*c*) *Access*

For forestry purposes ease of access is categorized primarily in terms of dominant slope:

Category I, $<10°$ Category II, 10–30° Category III, $>30°$.

Lower-case letters modify the major categories: s, swampy; f, flooded, i.e. seasonally inundated for short to moderate periods; a, up to 20% of slopes may exceed those specified by the major category.

X. Observations

The number of field observations made within the land system is stated, and any special concentration of observations on a particular land unit is mentioned.

XI. References

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INDEX TO LAND SYSTEMS

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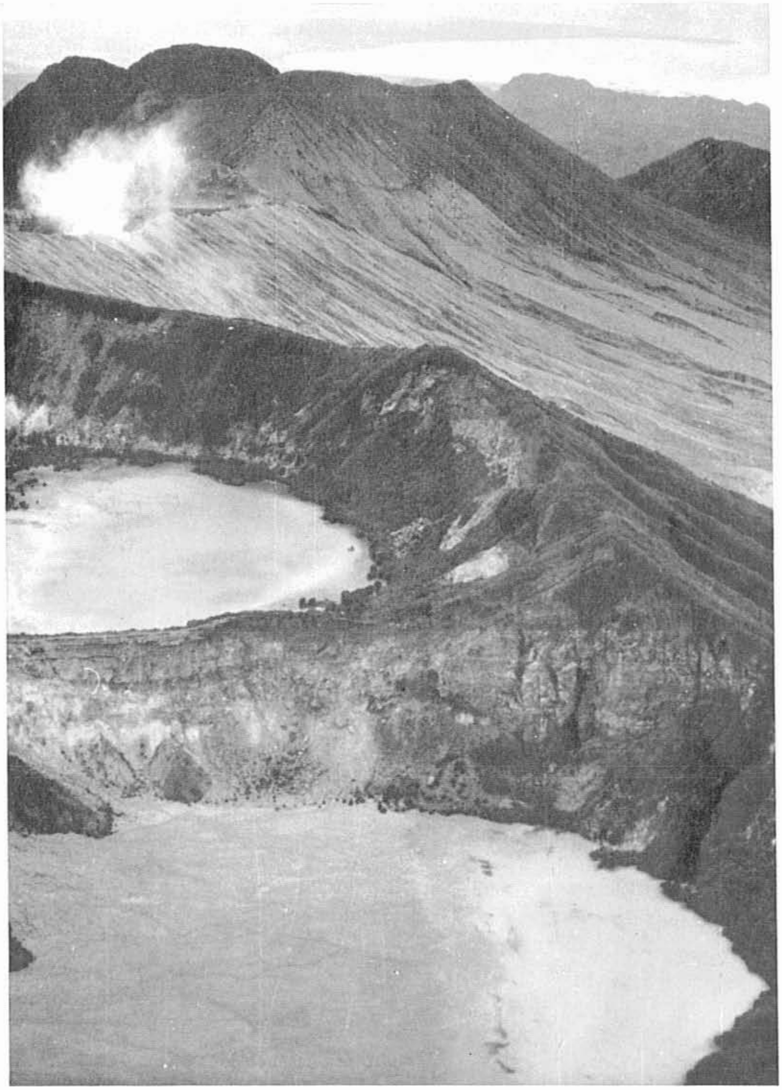

Volcanoes. Bougainville Island is dominated by volcanoes of varying age and form. Mt. Balbi (8700 ft), the highest mountain, is a strato-volcano. This view towards the south over part of the summit area (Balbi land system) shows recently active and inactive craters, and debris slopes. Two inactive craters in the foreground contain muddy lakes and have mountain scrub covering the walls and debris slopes. The recently active crater is emitting a cloud of steam.

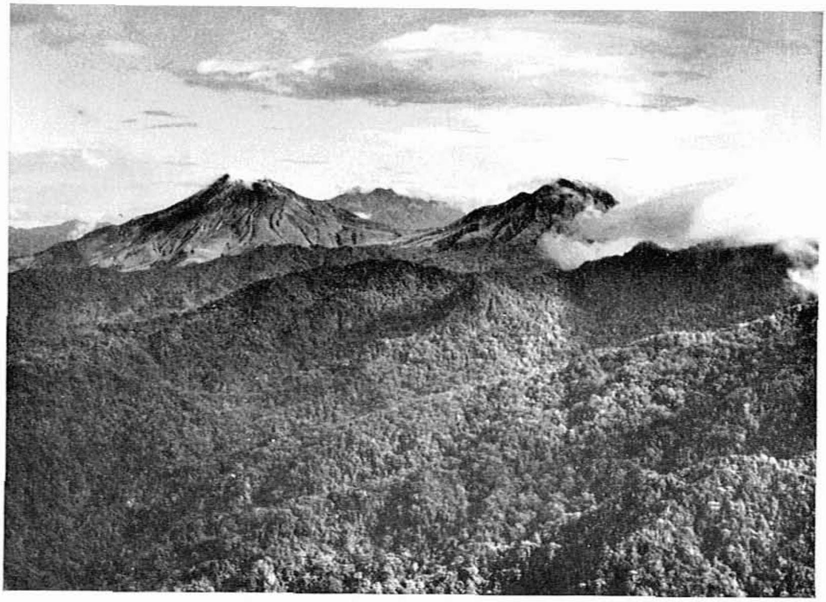

Fig. 1.—Volcanoes. This view north-westward along the mountain axis of Bougainville towards Mt. Balbi shows the active lava cone Mt. Bagana (5700 ft) on the left, emitting rather less steam than usual, and a similar, but inactive lava cone on the right. Both are classified in Balbi land system because of the very youthful ash soils and the absence of forest on their slopes. Erosional mountains of Karato land system with very steep slopes clothed in *Neonauclea–Sloanea* tall forest occupy the foreground.

Fig. 2.—Volcanoes. Much of the south of Bougainville Island is built up from the products of the older Mt. Taroka–Mt. Takuan volcanic complex. In the foreground is Lake Loloru (4700 ft), with debris slopes of Erava land system to the right. The rest of the landscape is in Takuan land system, comprising lava cones and domes; this whole area is covered by *Gulubia–Pandanus* vegetation, a type of cloud forest with characteristic emergent palms. Mt. Takuan (7400 ft) is the distant peak on the left.

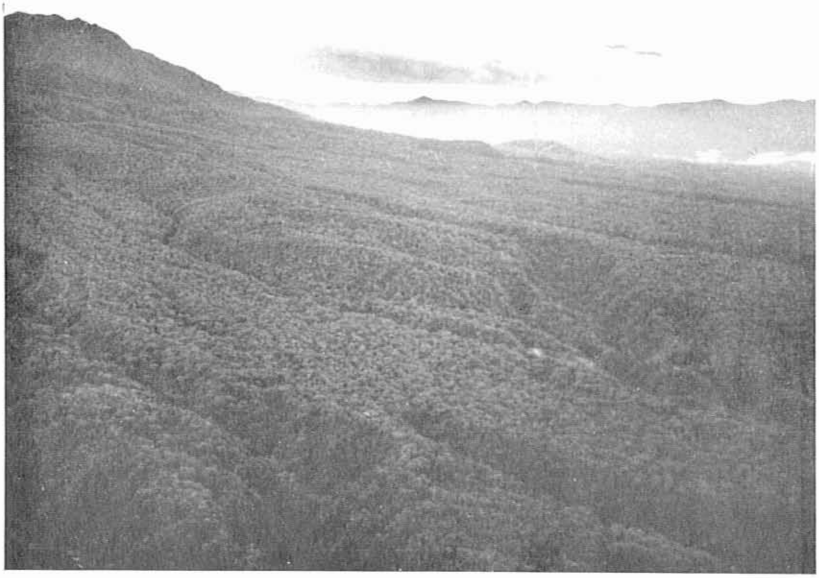

Fig. 1.—Volcano–alluvial fans. At the foot of each volcano is a great volcano–alluvial fan composed of volcanic mud flows and glowing avalanches, as well as fans of ordinary streams. Tall forest of high to moderate timber yield occurs below 2500 ft and mid-height forest of low timber yield above this altitude. The fan shown here, part of Buin land system below Lake Loloru, has a slope of 6° and is cut by valleys 400 ft deep. In the centre of the picture is a lava flow of Takuan land system. The vegetation is *Neonauclea–Sloanea* tall forest, grading into *Garcinia–Elaeocarpus* mid-height forest on the upper slopes.

Fig. 2.—Volcano–alluvial fans. Generally there is a high population density on these fans. Subsistence cropping is characteristically confined to the plateaux and plains, whilst the sloping land is left untouched. Ash-covered soils occur on the northern fans, lapillitic ash soils on the central fans, and ash soils with a pan on the southern fans. The view shows the "line village" of Lukauko, Kono Census Division, on a partly dissected volcano–alluvial fan at 1500 ft in Buin land system. The village is surrounded by gardens and secondary forest. Coconut palms are growing in front of the houses; some fruiting sago palms can be seen at the back.

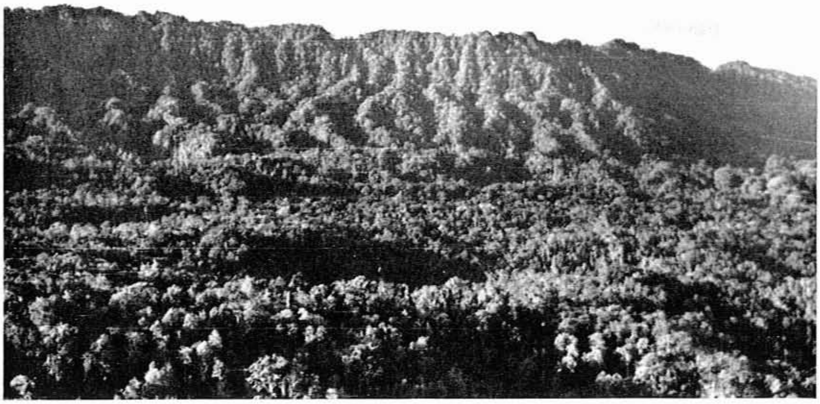

Fig. 1.—Karst. The Keriaka Plateau is a massif of Miocene limestone with a tilted planar upper surface and precipitous marginal scarps. The northern scarp, seen here, is less than 1000 ft high, but further east a height of 3000 ft is attained. Karst erosion has been somewhat modified by thick deposits of volcanic ash giving rise to lapillitic ash soils. This landscape is mainly covered by *Cyathea–Bambusa* scrub and is uninhabited. The erosional hills of Doiabi land system are seen in the foreground.

Fig. 2.—Erosional hills. This view shows Kieta Harbour, sheltered by Pukpuk Island and a barrier reef. The rugged topography of the island and peninsula (Kieta land system) is formed on a resistant agglomerate rock that gives rise to brown friable clay soils and lithosols. The widely spaced ridges with lesser slopes in the foreground (Osirei land system) are based on weaker, deeply weathered rocks overlain by ash-covered red friable clays. The latter land system has a large population practising hill-slope cultivation, as shown by the recent clearings and different stages of regrowth vegetation.

Fig. 1.—Erosional mountains. Landscapes of high relief, fashioned mainly by the action of running water, dominate the northern and south-eastern portions of Bougainville. The view is of the eroded volcanic mountains of northern Bougainville which occupy the foreground. The high ridges to the left and right are in Melilup land system, and the low ridges in the centre with *Garcinia–Elaeocarpus* mid-height forest are part of Erava land system. The distant hills on Buka and Taiof Islands are part of Deuro land system.

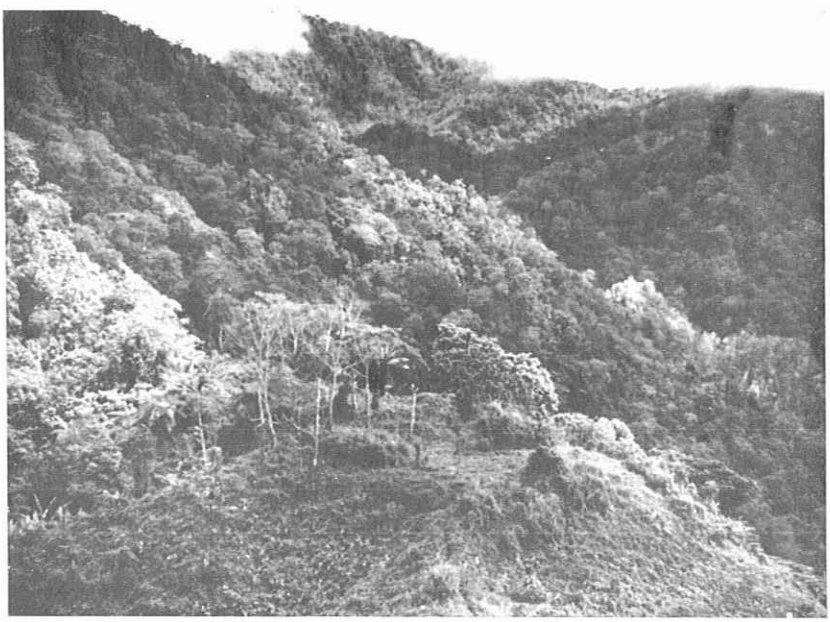

Fig. 2.—Erosional mountains. A view near Melilup at 3500 ft in northern Bougainville shows the typical high relief and straight hill slopes that are very steep or precipitous, giving rise to lithosols. The *Garcinia–Elaeocarpus* mid-height forest has some useful timber, though inaccessibility makes exploitation difficult. Access for the survey party was obtained by helicopter landings in village garden clearings such as that in the foreground.

Fig. 1.—Erosional mountains. Some of the highest peaks of the Crown Prince Range in south-eastern Bougainville are made rugged by a capping of agglomerate, which forms vertical faces, bare of vegetation or with *Cyathea–Bambusa* scrub (Kieta land system). The forest is dominated by *Albizia*.

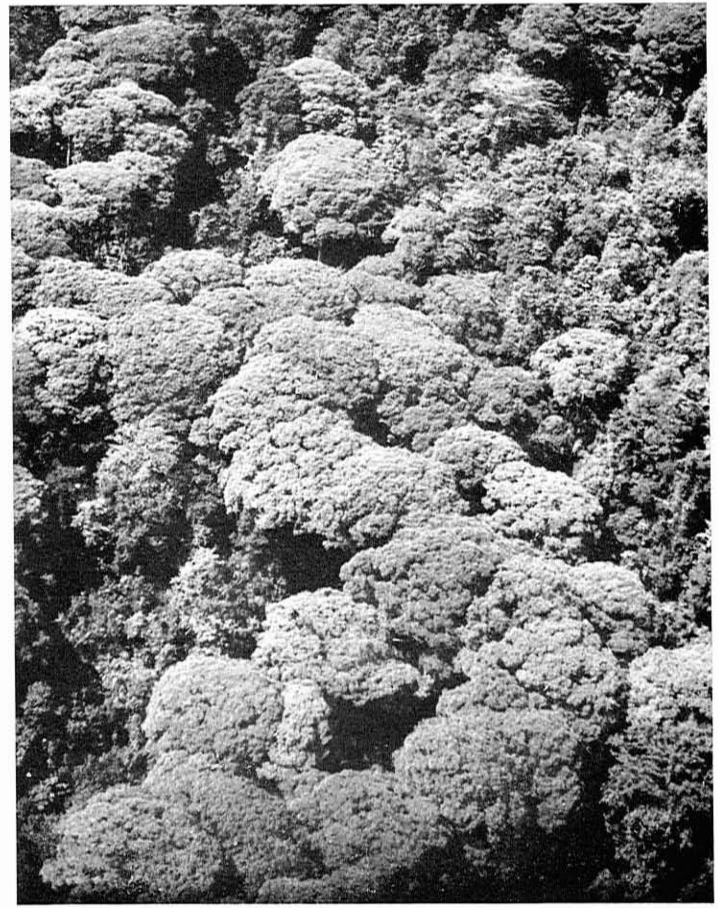

Fig. 2.—Upland valleys. Narrow bouldery valley floors in the mountains are characterized by *Terminalia brassii* with its distinctive cauliflower-shaped crowns. These high-yield timber areas are not always accessible.

Fig. 1.—Erosional mountains. *Cyathea–Bambusa* scrub covers large areas between 2000 and 4000 ft in northern Bougainville. It is dominated by dense trailing bamboo, with scattered tree-ferns emerging above it.

Fig. 2.—Erosional hills. Habitation is mainly confined to the lower altitudes of the mountains where gardening is carried out on very steep slopes, such as this one at 44° near Neblahiu, Teop Census Division. On lithosols, sweet potatoes (the staple diet), taro, sugar-cane, and bananas are grown.

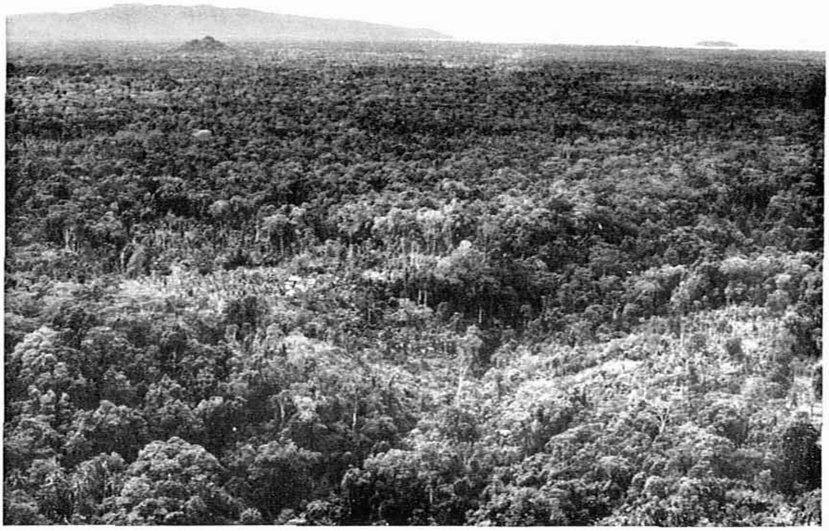

Fig. 1.—Plains. Alluvial plains are best developed in southern Bougainville. This view south-eastward from the vicinity of Buin airstrip, on a volcano-alluvial fan, illustrates the aspect of Siwai and Silibai land systems, alluvial plains formed by the reworking of volcanic material. Stream entrenchment diminishes towards the coasts and the general gradient decreases from 2° to a very low value. Hills of Deuro land system appear in the distance.

Fig. 2.—Plains. The stable plains of Siwai land system have high population concentrations and consequently most of the forest is secondary, with only isolated areas of high-yielding timber. Both subsistence and plantation crops are grown on the ash-covered alluvial sands, the main plantation crops being cacao and coconuts, which are largely interplanted. This view is at Rumba on the Daratui road (South Nasioi Census Division), where both forms of agriculture can be seen.

Fig. 1.—Plains. This view shows the Abia River flowing across the unstable alluvial plains of Silibai land system. Meander migration leaves point bars built of gravel at low levels and of sand at higher levels; the latter are colonized by *Paspalum–Cassia* mixed herbaceous vegetation which is succeeded by *Saccharum robustum* tall grass vegetation. Such streams are not entrenched, so large areas of the adjacent plain are subject to frequent flooding and high water-tables. The poorly drained, mottled alluvial sands carry *Euodia–Pometia* tall forest of moderate timber yield.

Fig. 2.—Plains. Saua land system comprises the plains formed of material erupted from Mt. Bagana. The continuing activity of the volcano results in broad bar plains of braided streams, colonized by *Lycopodium–Gleichenia* mixed herbaceous vegetation, cut slightly below ash plains with a vegetation of *Cyathea–Bambusa* scrub with emergent *Albizia* trees subject to recurrent devastation by eruptions.

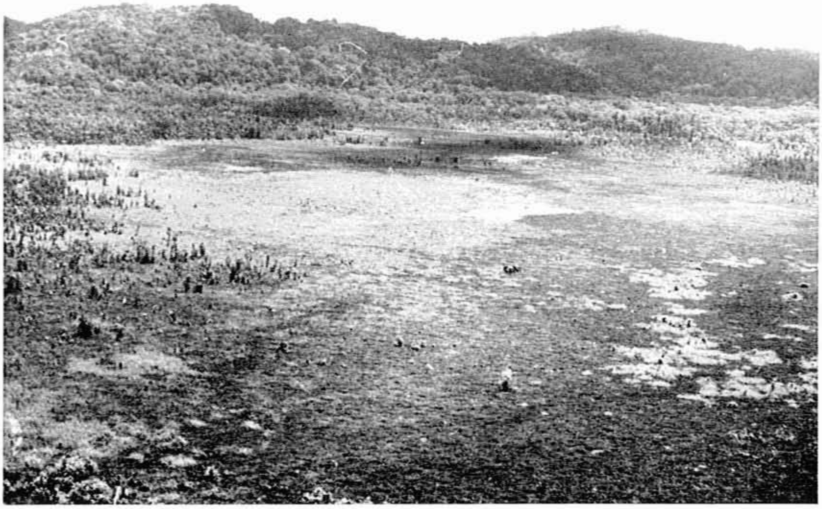

Fig. 1.—Swamps. Extensive swamps (Moila land system) are developed in many favourable localities, mainly adjacent to the coast. This one has been trapped against the Deuro Range by aggradation of the Samiei River. The stagnant water is covered by floating peats, which support *Leersia–Hanguana* mixed herbaceous vegetation, with scattered *Pandanus* draped with climbers towards the margins.

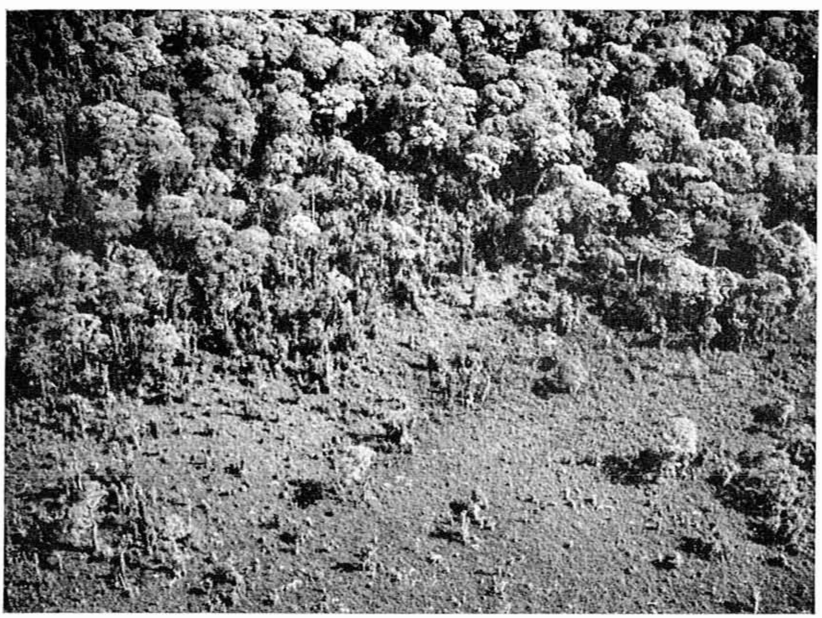

Fig. 2.—Swamps. Other swamps are a result of the impounding of water by beach ridges. Some are partly or wholly covered by *Terminalia brassii–Campnosperma* open tall forest. These forests are associated with flowing water with submerged peats, and have varying timber yields according to density but are difficult to exploit.

Fig. 1.—Coasts. Sandy coasts comprising Jaba land system are built mainly of dark volcanic sand. Dunes are not present, but successively constructed low beach ridges form barrier systems up to 1 mile across. The photo shows part of the barrier system at Moila Point with peaty sand swales with *Hanguana* and some *Nypa* palms between sandy beach ridges. The outer ridges support *Cerbera–Calophyllum* mid-height forest and the inner ridges *Vitex–Pometia* tall forest.

Fig. 2.—Coasts. The coasts of Soraken land system, characterized by the dominance of coral growth over beach building, provide better anchorages than those of Jaba land system and have influenced the siting of plantations, such as Numa Numa plantation shown here. These lands with their shallow rendzinas are almost entirely planted to coconuts and have a high population density.

Fig. 1.—Coasts. This view shows Buka Passage, a deep channel separating Bougainville and Buka Islands, with Sohano, the administrative centre for Bougainville District, at the far end of the passage.

Fig. 2.—Raised coral reef. Buka and the northern coast of Bougainville Island are very largely made up of an upwarped Pleistocene coral reef (Lonahan and Kohino land systems), approaching 300 ft above sea level at one point. This view westwards near Lonahan shows the characteristic dense cultural pattern of coconut plantations, gardens, and regrowth on the red sticky plastic clays of Lonahan land system. Further inland, *Vitex–Octomeles* tall forest of moderate to high timber yield occurs on Kohino land system. In the background are the low hills of Deuro land system.